

**DEPARTMENT OF WATER AND SANITATION**

**Chief Directorate: Water Ecosystems Management**

**DETERMINATION OF WATER RESOURCE  
CLASSES AND ASSOCIATED RESOURCE  
QUALITY OBJECTIVES IN THE UPPER  
ORANGE RIVER CATCHMENT**

**SCENARIOS AND CONSEQUENCES  
REPORT  
WP 11422**

**Study Report No.**

**RDM/WMA13/00/CON/CLA/0125**

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## TERMINOLOGY AND ABBREVIATIONS

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| <b>Acronym</b> | <b>Description</b>                             |
|----------------|------------------------------------------------|
| Al             | Aluminium                                      |
| BHN            | Basic Human Needs                              |
| CERA           | Comparative Ecological Risk Assessment         |
| CD: WEM        | Chief Directorate: Water Ecosystems Management |
| CRA            | Comparative Risk Assessment                    |
| CRR            | Critical Raik Rating                           |
| DWA            | Department of Water Affairs                    |
| DWAF           | Department of Water Affairs and Forestry       |
| DWS            | Department of Water and Sanitation             |
| EI             | Ecological Importance                          |
| ES             | Ecosystem Sensitivity                          |
| ESBC           | Ecologically Sustainable Base Configuration    |
| EWR            | Ecological Water Requirements                  |
| Fe             | Iron                                           |
| FIFHA          | Fish Invertebrate Flow Habitat Assessment      |
| FRAI           | Fish Response Assessment Index                 |
| FSL            | Full storage level                             |
| GD             | Green Drop                                     |
| GDP            | Gross Domestic Product                         |
| GVA            | Gross Value Added                              |
| ha             | hectare                                        |
| IUA            | Integrated Unit of Analysis                    |
| kL/a           | Kilolitres per annum                           |
| Kg/day         | Kilograms per day                              |
| MCC            | Millenium Challenge Corporation                |

|                    |                                                 |
|--------------------|-------------------------------------------------|
| LHWP2              | Lesotho Highlands Water Project Phase 2         |
| MAR                | Mean Annual Run-off                             |
| MIRAI              | Macroinvertebrate Response Assessment Index     |
| MM                 | Metropolitan Municipality                       |
| Mm <sup>3</sup>    | Million cubic metres                            |
| Mm <sup>3</sup> /a | Million cubic metres per annum                  |
| Mn                 | Manganese                                       |
| n.e.c              | Not elsewhere classified                        |
| NO <sub>3</sub> -N | Nitrate                                         |
| nMAR               | Natural Mean Annual Run-off                     |
| NVD                | Noordoewer/ Vioolsdrift Dam                     |
| ORASECOM           | Orange-Senqu River Commission                   |
| PES                | Present Ecological Sate                         |
| QSAM               | Quasi-Social Accounting Matrix                  |
| R/a                | Rand per annum                                  |
| REC                | Recommended Ecological Category                 |
| RQOs               | Resource Quality Objectives                     |
| RDM                | Resource Directed Measures                      |
| RSA                | Republic of South Africa                        |
| SRP                | Soluble Reactive Phosphate                      |
| TEC                | Target Ecological Category                      |
| TDS                | Total Dissolved Solids                          |
| TIN                | Total Inorganic Nitrogen                        |
| TSS                | Total Suspended Solids                          |
| WARMS              | Water Use Authorisation and Registration System |
| WC/ WDM            | Water Conservation/ Water Demand Management     |
| WMA                | Water Management Area                           |
| WQM                | Water Quality Model                             |

---

|      |                                      |
|------|--------------------------------------|
| WRCS | Water Resource Classification System |
| WRPM | Water Resource Planning Model        |
| WSA  | Water Service Authority              |
| WSP  | Water Service Provider               |
| WTW  | Water Treatment Works                |
| WWTW | Wastewater Treatment Works           |

## **EXECUTIVE SUMMARY**

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The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) is presently undertaking a study to determine Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River catchment which falls within the Vaal-Orange Water Management Area (WMA 04).

The main objective of this study is to coordinate the implementation of the determination of water resource classes and associated resource quality objectives for all significant water resources in the Upper Orange River catchment within the Vaal-Orange Water Management Area (WMA04) in accordance with the Water Resource Classification System (WRCS)(DWA, 2010) and determine the associated RQOs for the prioritised units. This is aimed at facilitating the management and regulation of water resources to ensure efficient and sustainable use, a balance between protection and use, while maintaining ecological integrity and specifically maintaining or improving the present ecological state (PES) of the water resources, in the Upper Orange River catchment.

Appropriate integration with water resource planning and management processes, as well as cooperation among stakeholders, will be key success factors in setting the water resource classes and RQOs. The outcomes of the process will result in the protection framework for the catchment that will guide actions, interventions, and needs, to ensure a sustainable water resource system that is able to balance water use and protection.

An integral component of the water resource classification process is the scenario configuration and evaluation. It is important to note that the Upper Orange River catchment cannot be evaluated individually but has to be evaluated with the Lower Orange River catchments. In this respect the scenarios developed relate to the overall Orange River catchment, and include relevant developments in Lesotho, the Vaal River inputs and the estuary.

The objective of this step is to evaluate scenarios configured. Scenario evaluation has been incorporated into the integrated water resource management process so that a subset of catchment scenarios can be recommended towards proposed water resource classes.

The following activities were undertaken as part of the water resource classification process and the outputs are detailed in this report:

- Inclusion of the following proposed scenarios:
  - Current scenario (2025) including the key current infrastructure developments in the Orange River System
  - Future development scenarios
    - A medium-term scenario (2040), and
    - A long-term scenario (2060).

- Water Resources Planning Model (WRPM) analysis and adjustment
- Reporting of ecological consequences and IUA- level ecological condition using the Fish Invertebrate Flow Habitat Assessment (FIFHA) model. It is important to note that the FIFHA model has limitations in that there is only one metric, while the Fish Response Assessment Index (FRAI) and Macroinvertebrate Response Assessment Index (MIRAI) consider all 3 metrics (habitat, water quality and flow), thus these limitations are viewed in Upper Orange.
- Assessment of water quality implications using load assessment and impacts.
- Description of the macro-economic implications, and
- Evaluation of the overall scenario implications for the Upper Orange River catchment in alignment with the Lower Orange River catchment, and
- Selection of a subset of recommended scenarios as described in Table ES-1.

**Table ES-1: Recommended Scenarios included**

| Scenario ID       | Scenario Name                               | Time slice / development level | Interventions included <sup>[1]</sup>                                                               | Operations                                                   |
|-------------------|---------------------------------------------|--------------------------------|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| 0                 | Natural                                     | N/A                            | none                                                                                                |                                                              |
| 1a                | Present day <u>without</u> EWRs             | 2020                           | As per present day (excl. LHWP2).                                                                   | Supply to users prioritised                                  |
| 1b                | Present day <u>with</u> EWRs                | 2020                           | As per present day (excl. LHWP2)                                                                    | EWR prioritised                                              |
| 1c <sup>[2]</sup> | Present day <u>with</u> adjusted EWRs       | 2020 - 2028                    | Preliminary EWRs to align with ORS yield impact for lower Orange. River management plan             | Short-term or phasing in option (until system is augmented). |
| 2a                | Medium term <u>without</u> EWRs             | 2040                           | LHWP2-Polihali, Violsdrift (size option 2 – 700 million m <sup>3</sup> ), Gariep to Bloem pipeline  | Supply to users prioritised                                  |
| 2b                | Medium term <u>with</u> EWRs                | 2040                           | LHWP2-Polihali, Violsdrift (size option 2 – 700 million m <sup>3</sup> ), Gariep to Bloem pipeline  | EWR prioritised                                              |
| 2.1a              | Medium term alternative <u>without</u> EWRs | 2040                           | LHWP2-Polihali, Violsdrift (size option 3 – 2800 million m <sup>3</sup> ), Gariep to Bloem pipeline | Supply to users prioritised                                  |
| 2.1b              | Medium term alternative <u>with</u> EWR     | 2040                           | LHWP2-Polihali, Violsdrift (size option 3 -2800 million m <sup>3</sup> ), Gariep to Bloem pipeline  | EWR prioritised                                              |
| 3a                | Long term <u>without</u> EWRs               | 2060                           | LHWP2-Polihali, Violsdrift (size option 2), Gariep to Bloem pipeline, with Verbeeldingskraal,       | Supply to users prioritised                                  |
| 3b                | Medium term <u>with</u> EWRs                | 2060                           | LHWP2-Polihali, Violsdrift (size option 2), Gariep to Bloem pipeline, with Verbeeldingskraal        | EWR prioritised                                              |

| Scenario ID         | Scenario Name                               | Time slice / development level | Interventions included <sup>[1]</sup>                                                                                        | Operations                  |
|---------------------|---------------------------------------------|--------------------------------|------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| 3.1a <sup>[3]</sup> | Long term alternative 1 <u>without</u> EWRs | 2060                           | LHWP2-Polihali, Violsdrift (Size option 2), Gariep to Bloem pipeline, Verbeeldingskraal and Makhaleng Dam                    | Supply to users prioritised |
| 3.1b <sup>[3]</sup> | Long term alternative 1 <u>with</u> EWRs    | 2060                           | LHWP2-Polihali, Violsdrift (Size option 2), Gariep to Bloem pipeline, Verbeeldingskraal and Makhaleng Dam                    | EWR prioritised             |
| 3.2a                | Long term alternative 1 <u>without</u> EWRs | 2060                           | LHWP2-Polihali, Violsdrift (Size option 1), Gariep to Bloem pipeline, Boskraai Dam and Makhaleng Dam                         | Supply to users prioritised |
| 3.2b                | Long term alternative 1 <u>with</u> EWRs    | 2060                           | LHWP2-Polihali, Violsdrift (Size option 1), Gariep to Bloem pipeline, Boskraai Dam and Makhaleng Dam                         | EWR prioritised             |
| 3.3a <sup>[4]</sup> | Long term alternative 3 <u>without</u> EWRs |                                | LHWP2-Polihali, Violsdrift (size option 4 – 1200 million m <sup>3</sup> ), Gariep to Bloem pipeline, with Verbeeldingskraal, | Supply to users prioritised |
| 3.3b <sup>[4]</sup> | Long term alternative 1 <u>with</u> EWRs    |                                | LHWP2-Polihali, Violsdrift (size option 4 – 1200 million m <sup>3</sup> ), Gariep to Bloem pipeline, with Verbeeldingskraal, | EWR prioritised             |

EWR: Ecological Water Requirements; LHWP2: Lesotho Highlands Water Project Phase 2; m<sup>3</sup> – cubic meters

**Notes:**

- 1) The intervention options align with the large dam development options (included in Table 4 of the main report).
- 2) Scenario 1c will be run and tested as a part of the implementation of the EWRs, once the trade-offs have been confirmed based on the longer-term realities and projections. This will be an interim scenario aimed at trying to mitigate possible short-term issues until the larger interventions are implemented and is thus an implementation focused matter.
- 3) This scenario includes additional consumptive water use through a transfer to Botswana and greater local water use for irrigation. It is thus not directly comparable with Scenario 3a, but still an important scenario to assess with the increased levels of catchment development and use.
- 4) A larger size of NVD was tested of 1 200 Mm<sup>3</sup> rather than the 2 800 Mm<sup>3</sup> as the feasibility study already raised concerns of the larger dam on the estuary, and the 2800 size has been included in Scenario 2.1.

Table ES-2 summarises the proposed ecological category against the Ecologically Sustainable Base Configuration (ESBC), which is the Recommended Ecological Category (REC), and the recommendations based on the scenario evaluations described in the report, that will be taken forward to inform the water resources class.

**Table ES-2 showing the recommended Target Ecological Category(TEC)**

| IUA |                     | EWR Site   | River          | Ecological Category |     | Overall Comments/ Recommendations                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----|---------------------|------------|----------------|---------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |                     |            |                | REC (ESBC)          | TEC |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 1   | Golden Gate         | UO_EWR01_R | Little Caledon | B/C                 | B/C | <ul style="list-style-type: none"> <li>No economic impact.</li> <li>Minor trade off on biota in drier months</li> <li>Maintain B/C as TEC.</li> </ul>                                                                                                                                                                                                                                                                                                                                           |
| 2   | Caledon/ Leeu River | UO_EWR01_I | Middle Caledon | D                   | D   | <ul style="list-style-type: none"> <li>No economic impact.</li> <li>Some trade-offs for biota in the drier months.</li> <li>Maintain PES of D - TEC as D</li> <li>Excessive sedimentation impacts from Lesotho; nutrients from Ficksburg.</li> <li><i>Note:</i> Lesotho future development - Lowlands (release from Muela Dam to Hlotsi to augment the supply for domestic use in Lesotho (12-14 million m<sup>3</sup> during extreme dry periods). May develop a dam on the Hlotsi.</li> </ul> |
| 3   | Caledon River       | UO_EWR04_I | Lower Caledon  | C/D                 | C/D | <ul style="list-style-type: none"> <li>Maintain REC as TEC (C/D category)</li> <li>Implement EWR - some implications for local users (irrigation and domestic).</li> <li>IUA will be impacted by development in Lesotho, however this is unknown at this stage.</li> <li>Excessive sedimentation impacts from Lesotho</li> </ul>                                                                                                                                                                |

| IUA |                    | EWR Site   | River       | Ecological Category |     | Overall Comments/ Recommendations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----|--------------------|------------|-------------|---------------------|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |                    |            |             | REC (ESBC)          | TEC |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 4   | Kraai River        | UO_EWR08_I | Lower Kraai | B/C                 | B/C | <ul style="list-style-type: none"> <li>• <b>Implement Scenario 1a</b></li> <li>• No economic impact</li> <li>• Some trade-offs for biota in dry season</li> <li>• System is in balance</li> <li>• Improve baseflow.</li> <li>• Water quality to be managed to prevent further deterioration, specifically from upstream irrigation.</li> <li>• Currently the only free flowing river in the system. Boskraai Dam (site close to Orange River confluence), (Scenario 3.2) will mean that it will no longer be a free-flowing river; loss of natural floods and freshets Trapping of sediments (natural); loss of coarse sediments (gravel). Loss of habitat; loss of armouring; fish migration and longitudinal connectivity (lower portion of reach) will be impacted</li> </ul> |
| 5   | Upper Orange River | UO_EWR02_I | Sterkspruit | C/D                 | D   | <ul style="list-style-type: none"> <li>• PES category - address with non-flow measures.</li> <li>• No trade off</li> <li>• No supply by system because of capacity constraints due to the pipeline from Johana's Hoek Dam to the town, so no releases to the river.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| IUA      | EWR Site               | River      | Ecological Category                              |          | Overall Comments/ Recommendations |                                                                                                                                                                                                                                                                                                          |
|----------|------------------------|------------|--------------------------------------------------|----------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |                        |            | REC (ESBC)                                       | TEC      |                                   |                                                                                                                                                                                                                                                                                                          |
|          |                        | UO_EWR03_I | Upper Orange                                     | <b>D</b> | <b>D present status (no EWR)</b>  | <ul style="list-style-type: none"> <li>• Trade -off - no EWR</li> <li>• Limited habitat availability - but representative of the reach</li> <li>• Improvement to C/D is linked to water quality drivers (sedimentation and other water quality issues from the extensive villages)</li> </ul>            |
| <b>6</b> | <b>Gariep Dam</b>      | UO_FMP     | Orange River between Gariep and Vanderkloof dams |          |                                   | <ul style="list-style-type: none"> <li>• No formal consequences</li> <li>• This reach relates to the FMP</li> </ul>                                                                                                                                                                                      |
| <b>7</b> | <b>Seekoei River</b>   | UO_EWR05_I | Seekoei                                          | <b>C</b> | <b>C</b>                          | <ul style="list-style-type: none"> <li>• No trade off</li> <li>• Minor economic impact</li> </ul>                                                                                                                                                                                                        |
| <b>8</b> | <b>Vanderkloof Dam</b> | UO_EWR10_I | Lower Orange Marksdrift                          | <b>C</b> | <b>C</b>                          | <ul style="list-style-type: none"> <li>• Ecological requirements achieved (note - limited habitat availability)</li> <li>• Exclusion of the larger floods as part of Reserve will have a significant impact on geomorphology and riparian veg (trade off)., and the REC will not be achieved.</li> </ul> |

| IUA |                    | EWR Site   | River        | Ecological Category |     | Overall Comments/ Recommendations                                                                                                                                                  |
|-----|--------------------|------------|--------------|---------------------|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |                    |            |              | REC (ESBC)          | TEC |                                                                                                                                                                                    |
| 9   | Upper Modder River | UO_EWR07_I | Upper Modder | C/D                 | C/D | <ul style="list-style-type: none"> <li>No trade off; (minor domestic trade off)</li> </ul>                                                                                         |
| 10  | Modder-Riet Rivers | UO_EWR06_I | Upper Riet   | C                   | C   | <ul style="list-style-type: none"> <li>Maintain a C</li> <li>Ecology and socio-economic trade-off (irrigation and domestic).</li> <li>Water quality improvements needed</li> </ul> |
|     |                    | UO_EWR09_I | Lower Riet   | B/C                 |     |                                                                                                                                                                                    |

EWR: Ecological Water Requirements; REC: Recommended Ecological Category; ESBC: Ecologically Sustainable Base Configuration; TEC: Target Ecological Category

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## APPENDICES

### APPENDIX A:

Notes from Planning meeting held on the 11<sup>th</sup> of February 2025

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## **1 INTRODUCTION**

The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) is presently undertaking a study to determine Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River catchment which falls within the Vaal-Orange Water Management Area (WMA 04) (Table 1).

Water Resource Classification, the Reserve and Resource Quality Objectives (RQOs) are protection-based measures that make up Resource Directed Measures (RDM), the protection principles contained in Chapter 3 of the National Water Act (Act No. 36 of 1998). Resource Directed Measures are intended to ensure comprehensive protection of all water resources. Protection relates to the quantity and quality (overall health) of the water resource. An important consideration in the determination of RDM is that they should be technically sound, scientifically credible, practical, and affordable. Once the water resource class and the Reserve have been established, RQOs are determined to give effect to those water resource classes and the Reserve. The DWS has progressively set water resource classes for all significant water resource systems in South Africa to ensure their protection and sustainable use and the Orange River System (ORS) is the last system that requires classification and setting of RQOs.

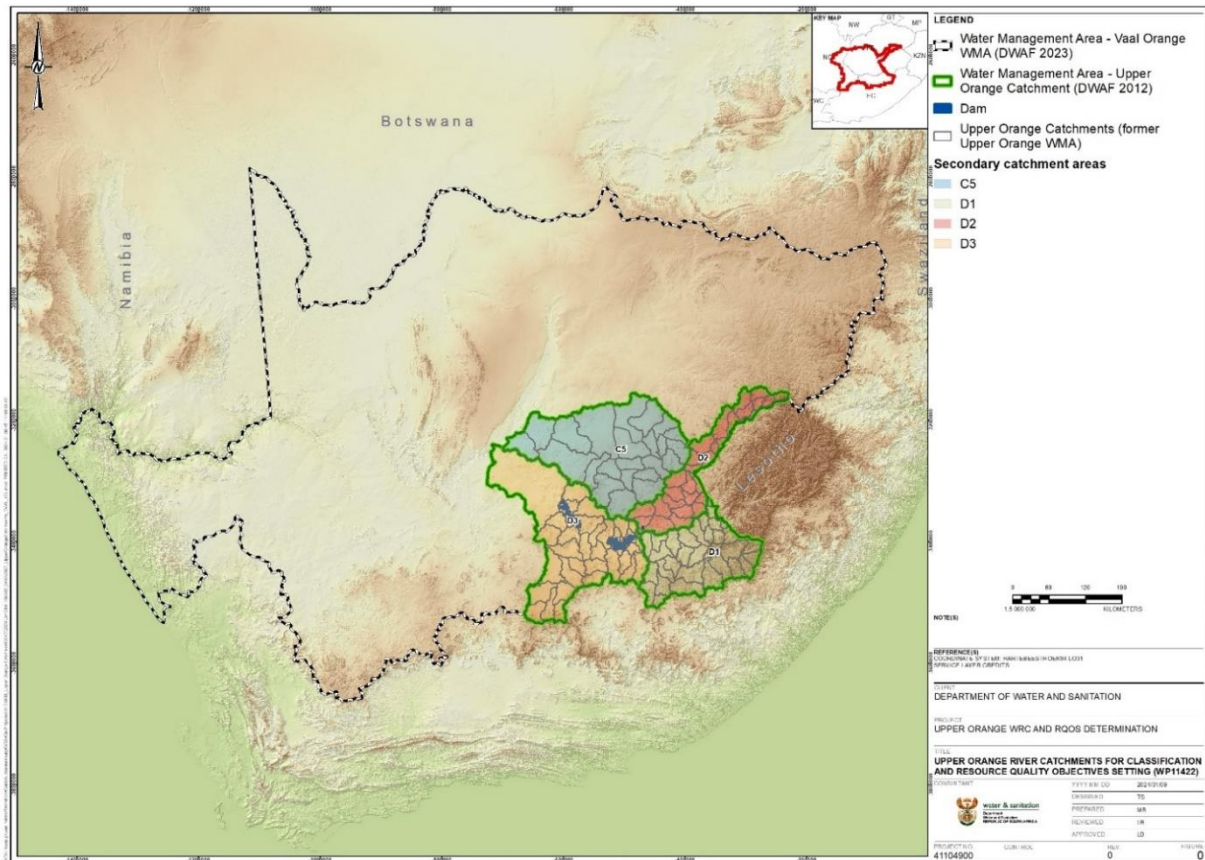
The Upper and Lower River catchment studies are being undertaken separately, however in parallel, with continuous liaison. This is particularly important for the outcomes of this component of the study where what happens in the upper catchment can have an impact on the lower catchment and vice versa.

### **1.1. Study Objective**

The main objective of this study is to coordinate the implementation of the determination of water resource classes and associated resource quality objectives for all significant water resources in the Upper Orange River catchment within the Vaal-Orange Water Management Area (WMA04) as described in the revised reconfiguration that was gazetted as part of the National Water Resources Strategy 3 (NWRS3) under Gazette Notice 49225, dated 1 September 2023, in accordance with the Water Resource Classification System (WRCS)(DWA, 2010), and determine the associated RQOs for the prioritised units.

This is aimed at facilitating the management and regulation of water resources to ensure efficient and sustainable use, a balance between protection and use, while maintaining ecological integrity and specifically maintaining or improving the present ecological state (PES) of the water resources, in the Upper Orange River catchment.

Appropriate integration with water resource planning and management processes, as well as cooperation among stakeholders, will be key success factors in setting the water resource classes and RQOs. The outcomes of the process will result in the protection framework for the catchment that will guide actions, interventions, and needs, to ensure a sustainable water resource system that is able to balance water use and protection.



**Figure 1: Upper Orange River catchment within Vaal-Orange Water Management Area (WMA04) in South Africa**

## 1.2. Purpose of this Report

The report describes the scenarios evaluated within the integrated water resource management process.

The purpose of this report is to describe the outcomes of the scenarios evaluated for surface water resources in the Upper Orange River catchments, considering the outcomes for the Lower Orange River catchment. Scenarios for groundwater and water quality are also described, and a subset of catchment scenarios are recommended towards proposed management classes.

## 1.3. Spatial Extent of the Study

The Upper Orange River catchment comprises four sub-catchments (Figure 2 and Table 1) stretching across the Northern Cape, Free State and Eastern Cape provinces and across three ecoregions, the Eastern Escarpment Mountains, Nama Karoo and Highveld:

- The Caledon River from its headwaters and its tributaries to the Gariep Dam (Secondary catchment D2)

- The Orange River from the Lesotho Border to the Gariep Dam, including the main tributaries namely Kornetspruit, Sterkspruit, Stormbergsspruit and Brandwaterspruit, and the Kraai River catchment (D1 secondary catchment), and
- The Orange River from the Gariep Dam, through Vanderkloof Dam to Marksdrift weir, just before the confluence with the Vaal River, including the Seekoei River in the south (D3 secondary catchment), and
- The Modder-Riet River (main tributaries of the Vaal River system) in the north (C5 secondary catchment). Although the Modder/Riet rivers are tributaries to the Vaal River, this catchment and related sub-systems are seen as part of the Orange River System due to transfers and support from the Orange to the Modder/Riet catchment.

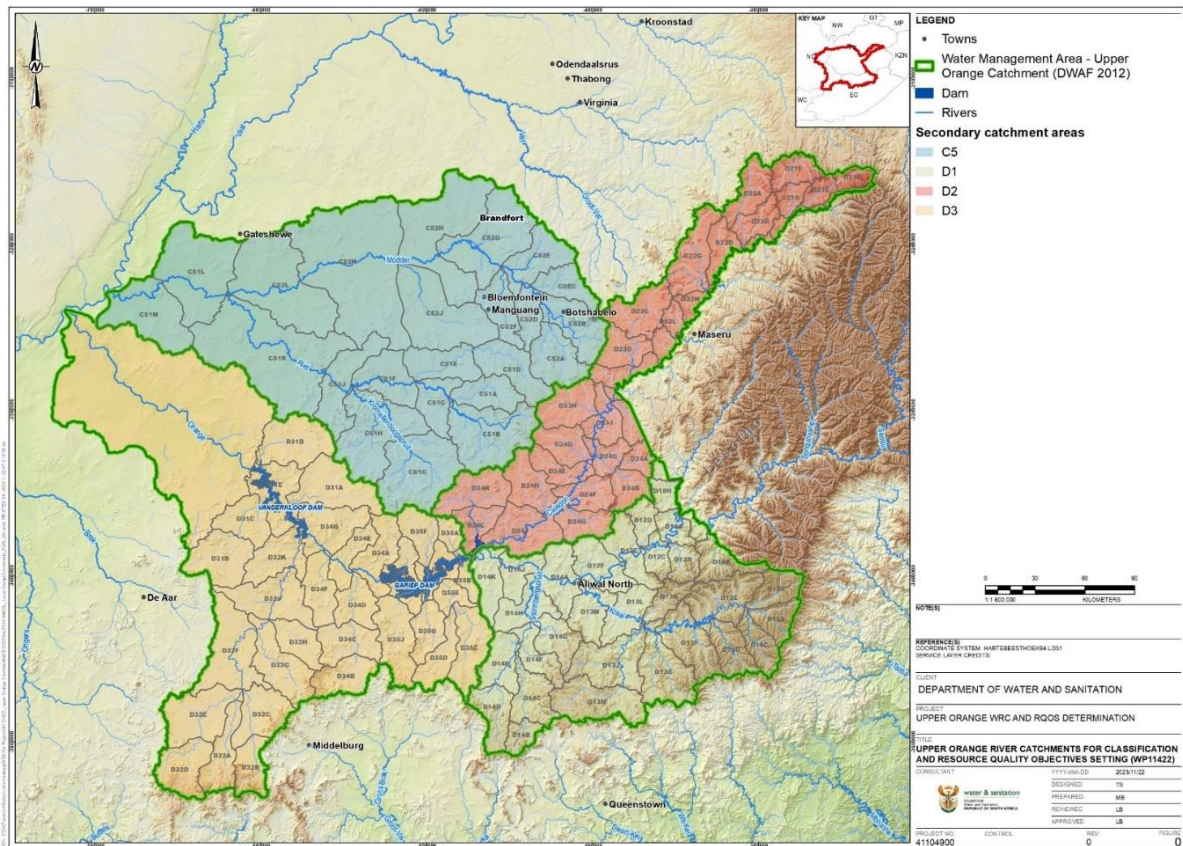


Figure 2: Upper Orange River sub-catchments

Table 1: Sub-catchment areas of the Upper Orange River catchment

| Secondary Catchment | Tertiary Catchment | Quaternary catchments | Main River/(s)                             | Catchment area <sup>(1)</sup> (km <sup>2</sup> ) |        |
|---------------------|--------------------|-----------------------|--------------------------------------------|--------------------------------------------------|--------|
|                     |                    |                       |                                            | Gross                                            | Net    |
| C5                  | C51                | C51A – H, C51J - M    | Fouriespruit, Ruisterspruit, Osportspruit, | 17 449                                           | 12 166 |

| Secondary Catchment | Tertiary Catchment | Quaternary catchments                                                  | Main River/(s)                                                                        | Catchment area <sup>(1)</sup> (km <sup>2</sup> ) |       |
|---------------------|--------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------|-------|
|                     |                    |                                                                        |                                                                                       | Gross                                            | Net   |
|                     |                    |                                                                        | Kromelleboogspruit, Rietspruit                                                        |                                                  |       |
|                     | C52                | C52A – H, C52J - L                                                     | Wildebeesspruit, Sepane, Osspruit, Modder River                                       | 17 366                                           | 8 572 |
| D1                  | D12                | D12A - F                                                               | Winnaarspruit, Kromspruit, Wilgespruit                                                | 2 967                                            | 2 967 |
|                     | D13                | D13A – H; D13J - M                                                     | Bell, Langkloofspruit, Dierspruit, Wasbankspruit, Holspruit, Skulpspruit, Kraai River | 9 354                                            | 9 354 |
|                     | D14                | D14A – H, D14J and K                                                   | Orange River                                                                          | 6 145                                            | 6 145 |
|                     | D15                | Portions of D15G and H                                                 | Makhaleng (lower reaches shared with Lesotho), Unnamed tributaries                    | 846                                              | 846   |
|                     | D18                | Portion of D18L and K                                                  | Tele (shared with Lesotho), Blikana                                                   | 1 545                                            | 1 545 |
| D2                  | D21                | D21D, D21E, D21F, D21G, portion of D21A and D21H                       | Caledon River<br>Little Caledon                                                       | 1 659                                            | 1 659 |
|                     | D22                | D22A, D22B, portions of D22C and D22D, D22G, portions of D22H and D22J | Meulspruit, Brandwater/ Groot, Rantsho; Mopeli                                        | 4 369                                            | 4 369 |
|                     | D23                | Portion of D23A, E, F and G; D23C, D23D, D23H, D23J                    | Montsoane, Maseng, Tsoaning<br>Leeurivier, Rietspruit                                 | 4 910                                            | 4 910 |
|                     | D24                | D24A – G, D24H, D24J - L                                               | Witspruit, Wilgeboomspruit, Grahamstadspuit, Slykspruit, Edon River, Skulpspruit      | 6 614                                            | 6 614 |
| D3                  | D31                | D31A - E                                                               | Bergrivier, Orange River,                                                             | 4 910                                            | 4 396 |
|                     | D32                | D32A – H, D32J and K                                                   | Seeikoeirivier                                                                        | 9 081                                            | 9 081 |
|                     | D33                | D33A – D33K                                                            | Orange River                                                                          | 9 598                                            | 3 404 |

| Secondary Catchment | Tertiary Catchment | Quaternary catchments | Main River/(s)                                                      | Catchment area <sup>(1)</sup> (km <sup>2</sup> ) |       |
|---------------------|--------------------|-----------------------|---------------------------------------------------------------------|--------------------------------------------------|-------|
|                     |                    |                       |                                                                     | Gross                                            | Net   |
|                     | D34                | D34A - G              | Orange River                                                        | 5 020                                            | 5 020 |
|                     | D35                | D35A – H, D35J and K  | Brandspruit, Brakspruit, Bossiespruit, Suurbergspruit, Orange River | 5 638                                            | 5 638 |

<sup>1</sup>WR2012 data

The Caledon River (also called the Mohokare River along the Lesotho/ South Africa border) forms the north-western boundary of Lesotho with South Africa and is the first major tributary of the Orange River with their confluence in the upper reaches of the Gariep Dam. Other large tributaries that contribute to the flow in the Upper Orange River catchment are the Makhalleng (although only the lower reaches within South Africa) and Kraai Rivers. Although the Seekoei River has a large catchment, the runoff is very low as it forms part of the drier Karoo area.

The Modder and Riet Rivers, tributaries of the Vaal River are also part of the study area due to the interconnectedness of these systems through water transfers.

The main storage dams in the Upper Orange River catchments are Gariep and Vanderkloof dams on the Orange River. Smaller dams in the study area are Welbedacht Dam in the Caledon River, Rustfontein, Mockes, and Krugersdrift Dams in the Modder River with the Tierpoort and Kalkfontein Dams in the Riet River. The Gariep Dam, Vanderkloof Dam, Orange-Fish Tunnel, Orange Vaal transfer canal and Orange-Riet Canal system are all part of the Orange River Project.

Groundwater occurrences in the Upper Orange River catchment occurs predominantly as shallow (<65 m thick) aquifer systems in the Karoo Supergroup sedimentary sequence (as primary rock formation). In most of the water management area, secondary Karoo Dolerite intrusions in the form of (i) sub-vertical dikes and (ii) semi-horizontal sills are present which enhances the yield potential of the primary aquifer system. In a few cases, specific aquifer yield potentials can be significantly enhanced by occasional flooding of local surface water drainages, especially where these drainages are mature, and alluvial sedimentation has developed overlying the Karoo rocks.

There are seven wetland types, often in wetland complexes: flats, floodplains, depression wetlands, unchanneled valley-bottom wetlands, seeps, and channelled valley bottom wetlands. There are several high-altitude wetland complexes that are characterised by unique vegetation assemblages.

## 2 THE EVALUATION OF SCENARIOS WITHIN THE INTEGRATED WATER RESOURCE MANAGEMENT PROCESS

An integral component of the water resource classification process is the scenario configuration and evaluation.

It is important to note that the Upper Orange River catchment cannot be evaluated individually but has to be evaluated with the Lower Orange River catchments. In this respect the scenarios developed relate to the overall Orange River catchment, and include relevant developments in Lesotho, the Vaal River inputs and the estuary.

This is an iterative process that assesses the resulting yields of alternate ecological protection categories; conservation targets and future use and development to determine what is most feasible for the Orange River System, including the upper and lower catchments, and the impacts from the Vaal River system, to support the recommended water resource management class options.

This task has been undertaken in compliance with the requirements of the study terms of reference that specifies that the classification process is required to build from existing and current initiatives within the framework of the integrated water resource management processes in the Upper Orange River catchment and is illustrated in Figure 3. The study process is now in the final stages of the water resources classification process that will inform the setting of Resource Quality Objectives.

The scenario evaluation has been finalised and recommended scenarios are proposed.

## **2.1 Objectives of the scenario's evaluation step**

The objective of this step is to evaluate scenarios configured. Scenario evaluation has been incorporated into the integrated water resource management process so that a subset of catchment scenarios can be recommended towards proposed water resource classes.

The following activities have been undertaken as part of the water resource classification process:

- Inclusion of the following proposed scenarios:
  - Current scenario (2025) including the key current infrastructure developments in the Orange River System
  - Future development scenarios
    - A medium-term scenario (2040), and
    - A long-term scenario (2060).
- Water Resources Planning Model (WRPM) analysis and adjustment
- Reporting of ecological consequences and IUA- level ecological condition
- Assessment of water quality implications
- Description of the macro-economic implications, and
- Evaluation of the overall scenario implications for the Upper Orange River catchment in alignment with the Lower Orange River catchment, and
- Selection of a subset of recommended scenarios.

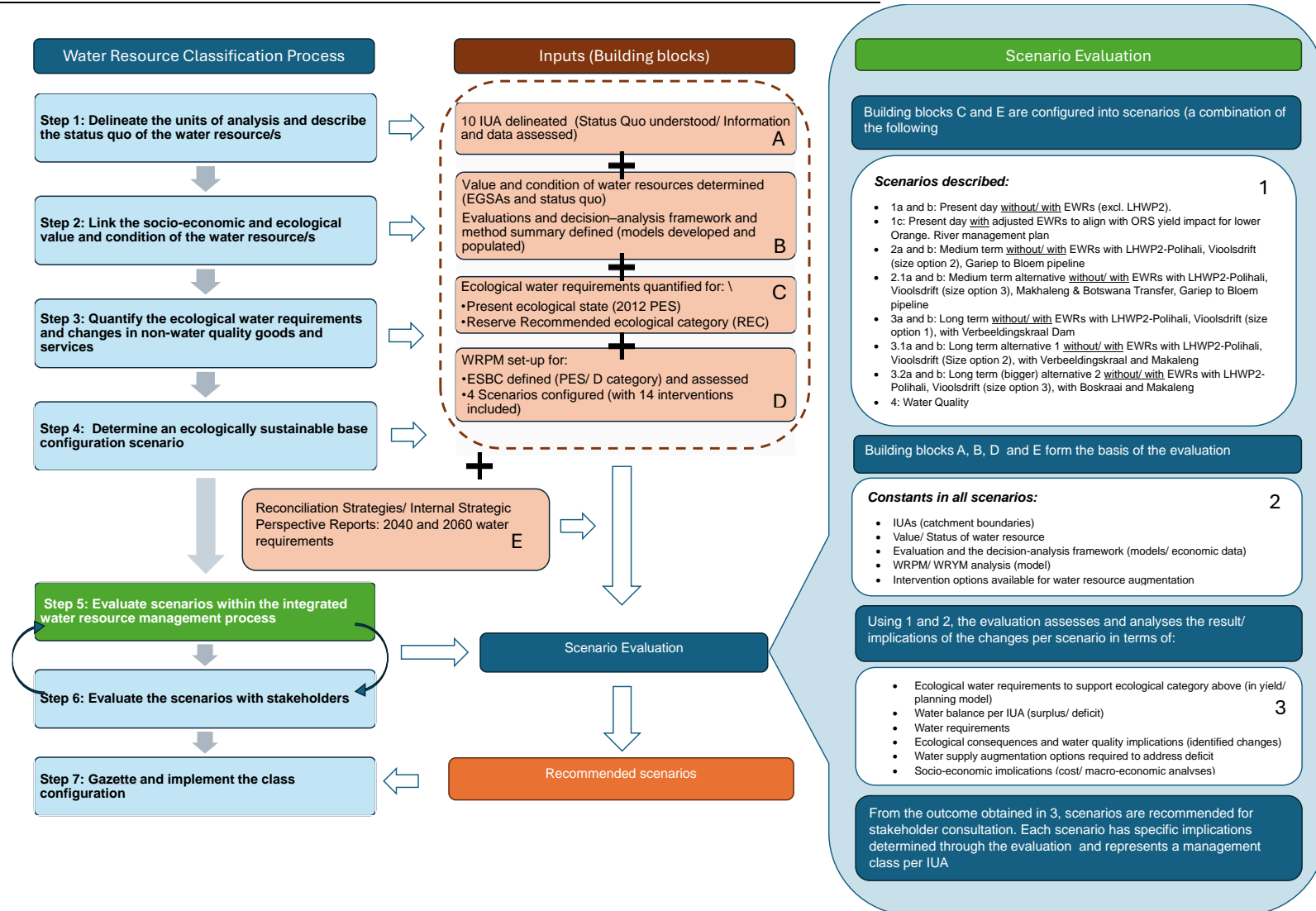


Figure 3: Scenarios evaluation within the integrated water resource management systems

## 2.2 Integrated Units of Analysis

The study area is the catchment of the Upper Orange River catchment, predominantly in the Free State and Eastern Cape Provinces, and a small portion of the Northern Cape Province, and is an integral part of the Vaal-Orange Water Management Area (WMA 04), and the Orange-Senqu River Basin.

To enable improved representation of the water resources and socio-economic situation in the catchment, and to facilitate the determination of water resource classes, Integrated Units of Analysis (IUA) were defined as Step 1 of the classification process and are listed in Table 2 and illustrated in Figure 4. The detailed descriptions and rationale for these IUAs are provided in RDM/WMA13/00/CON/CLA/0224, Status Quo and delineation of Integrated Units of Analysis and Resource Units Report.

**Table 2: IUAs delineated in the Upper Orange River Catchment**

| IUA | Description         | Quaternary                                                                                                                                                                                 |
|-----|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Golden Gate         | D21D and a portion of D21A along South Africa/ Lesotho border                                                                                                                              |
| 2   | Caledon/ Leeu River | D21E, D21F, D21G; portion of D21C; D22A, D22B; portions of D21H and D22C along the SA/ Lesotho border; Portions of D22D, D22G, D22H, D22L, Portion of D23A, D23C, D23D and portion of D23E |
| 3   | Caledon River       | D23F, D23G, D23H, D23J, D24A, D24B, D24C, D24D, D24E, D24F, D24G, D24H, D24J, D24K and D24L                                                                                                |
| 4   | Kraai River         | D13A – D13M                                                                                                                                                                                |
| 5   | Upper Orange River  | D12A – D12F, D14A – D14K, Portions of D15G, D15H, D18K and D18L                                                                                                                            |
| 6   | Gariiep Dam         | D34A, D34B, D34C, D34D, D34E, D34F, and D34G, D35A, D35B, D35C, D35D, D35E, D35F, D35J, D35G, D35H, D35K                                                                                   |
| 7   | Seeikoei River      | D32A, D32B, D32C, D32D, D32E, D32F, D32G, D32H, D32J, D32K                                                                                                                                 |
| 8   | Vanderkloof Dam     | D33A – D33K (along main stem Orange River); D31A – D31E                                                                                                                                    |
| 9   | Upper Modder River  | C52A, C52B, C52C, C52D, C52E, C52F and C52G                                                                                                                                                |
| 10  | Modder/ Riet River  | C51A, C51B, C51C, C51D, C51E, C51F, C51G, C51H, C51J, C51K, C51L, C51M, C52H, C52J, C52K and C52L                                                                                          |

## 2.3 Biophysical Nodes

Biophysical nodes represent flow requirements and ecological state relevant for the IUA and are established to account for interactions between ecosystems. Allocation nodes are

established to account for specific catchment issues or socio-economic aspects and to serve as modelling points for the scenario evaluation process in a catchment.

The nodes are used to assess the response of upstream water resources to changes in water quality, quantity, and timing (DWA, 2007). Biophysical nodes should be located at interactions between ecosystems and at the end points of eco-system reaches to account for interactions. Allocation nodes should be located at the downstream edge of a reach of interest, as required for modelling and to allow for meaningful trade-offs.

Biophysical nodes have been selected within the study components (river, wetland and groundwater) for analysis. These nodes represent the significant water resources that have a high ecological importance and/ or sensitivity that could be under threat due to its importance for water resource use and/ or where water use is high and/ or where water quality is impacted. The selected nodes are presented per water resource component.

Biophysical nodes have been selected for the significant water resources per IUA to quantify the Ecological Water Requirements (EWR) to inform the scenario analysis, the evaluation of ecological consequences and the determination of the water resource classes. These nodes are existing EWR sites (key biophysical nodes) where a high confidence Reserve determination was undertaken (DWS, 2023).

The biophysical hydronodes per IUA used for the scenario evaluation and their level of assessment are listed in Table 3 and shown in Figure 4. These sites were modelled and used to evaluate the ecological consequences and macroeconomic implications for the defined development scenarios.

**Table 3: Biophysical nodes per Integrated Units of Analysis in the Upper Orange River Catchment**

| IUA | Name                | River       | QC             | Level | Coordinates        |             |            |
|-----|---------------------|-------------|----------------|-------|--------------------|-------------|------------|
|     |                     |             |                |       | Latitude           | Longitude   |            |
| 1   | Golden Gate         | UO_EWR 01_R | Little Caledon | D21D  | Rapid              | -28.557796  | 28.405709  |
| 2   | Caledon/ Leeu River | UO_EWR 01_I | Middle Caledon | D22D  | Intermediate       | -28.9089    | 27.785     |
| 3   | Caledon River       | UO_EWR 04_I | Lower Caledon  | D24G  | Intermediate       | -30.436136  | 26.299258  |
| 4   | Kraai River         | UO_EWR 08_I | Kraai          | D13M  | Intermediate       | -30.69007   | 26.74157   |
| 5   | Upper Orange River  | UO_EWR 03_I | Upper Orange   | D12F  | Intermediate       | -30.652793  | 26.823213  |
|     |                     | UO_EWR 02_I | Sterkspruit    | D12B  | Intermediate       | -30.5178445 | 27.3690799 |
| 6   | Gariiep Dam         | UO_FMP      | Orange         | D34E  | Field verification | -30.503677  | 25.200574  |
| 7   | Seekoei River       | UO_EWR 05_I | Seekoei        | D32J  | Intermediate       | -30.534359  | 24.962895  |

| IUA |                    | Name       | River                      | QC   | Level        | Coordinates |           |
|-----|--------------------|------------|----------------------------|------|--------------|-------------|-----------|
|     |                    |            |                            |      |              | Latitude    | Longitude |
| 8   | Vanderkloof Dam    | UO_EWR10_I | Orange                     | D33K | Intermediate | -29.16202   | 23.695944 |
| 9   | Upper Modder River | UO_EWR07_I | Upper Modder               | C52B | Intermediate | -29.160017  | 26.572492 |
|     |                    | UO_EWR06_R | Middle Modder (Soetdoring) | C52H | Rapid III    | -28.807191  | 26.109695 |
| 10  | Modder-Riet Rivers | UO_EWR06_I | Upper Riet                 | C51F | Intermediate | -29.535065  | 25.52457  |
|     |                    | UO_EWR09_I | Lower Riet                 | C51L | Intermediate | -29.03842   | 24.50283  |

QC: Quaternary catchment; UO: Upper Orange; EWR: Ecological Water Requirements

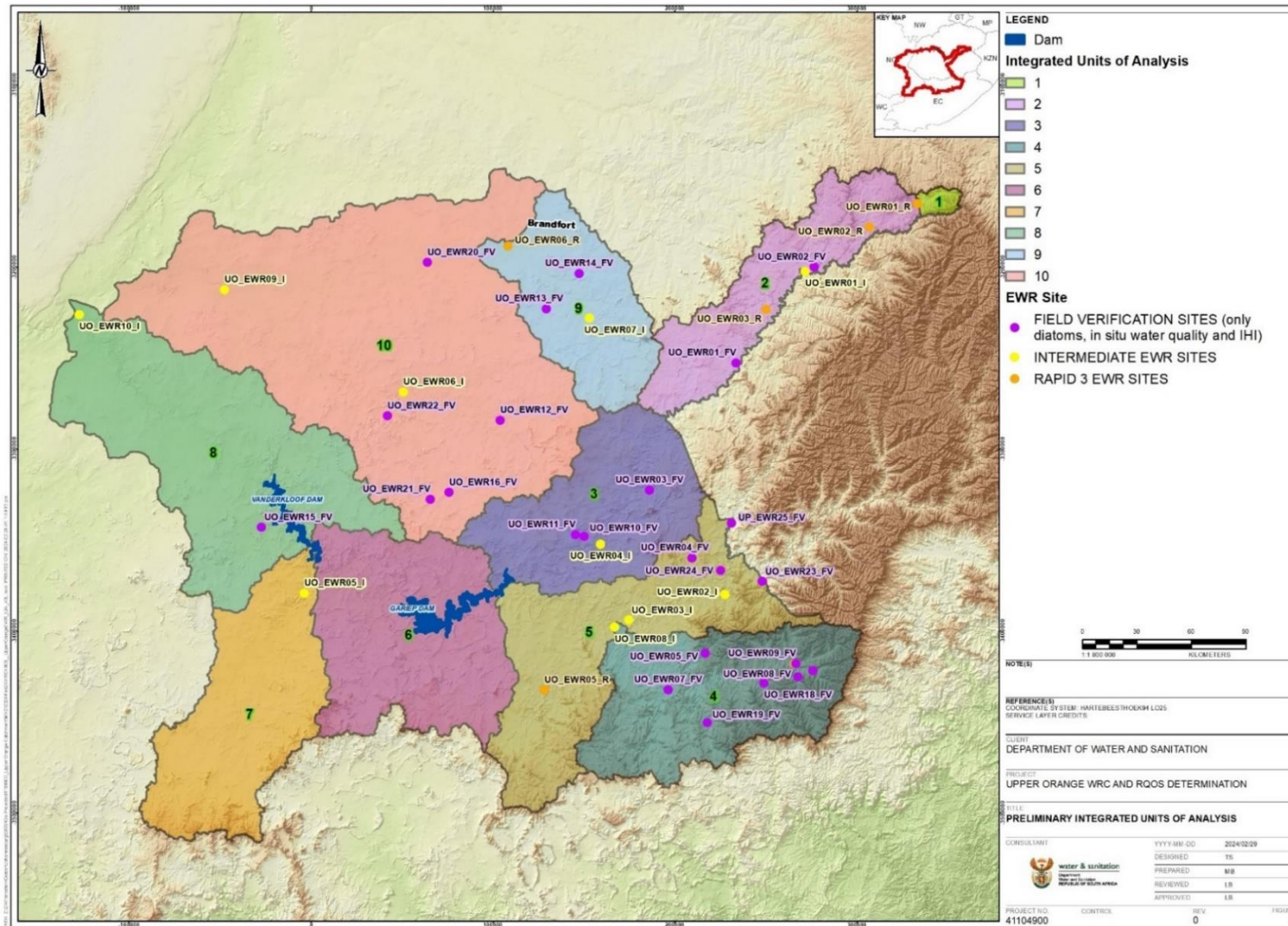


Figure 4: Upper Orange River EWR sites (biophysical hydronodes)

### 3 WATER RESOURCE PLANNING ANALYSIS

The various planning scenarios that were used to assess current and future development in the Orange River catchment needed to cover a suitable range of likely futures and consider the plans of the Department of Water and Sanitation (DWS), as well as other government water services authorities (WSA), water service providers (WSP) and the public.

The Orange-Senqu River basin is one of the largest river basins south of the Zambezi with a catchment area of approximately 1 million km<sup>2</sup>. Co-operation amongst the Orange River Basin countries is facilitated through the Orange-Senqu River Commission (ORASECOM), with membership by the basin countries. The Orange River is critical to South Africa in that it augments the Vaal River System through the Lesotho Highlands Water Project and supplies the economic heartland of South Africa, as well as supplying water to the Eastern Cape via the Gariep Dam to Great Fish transfer scheme. It also supplies thermal power stations on the Highveld, irrigation schemes covering large areas along the Vaal, middle and lower portions of the Orange River, as well as hydroelectric power generation at Gariep and Vanderkloof dams. An estimated 15 million people are dependent on secure water supplies from this basin. For this reason, the analyses were done for the full Orange River catchment as it is not logistically feasible to analyse scenarios for the Upper Orange River catchment, without considering the above-mentioned aspects.

The DWS, and the Study Team thought it prudent that a planning scenario definition document be prepared early in the classification process, to consolidate the various plans and information into a single source that can guide the development of, and thereafter assessment of, selected scenarios required to inform the classification process and setting of Resource Quality Objectives (RQO). This planning document has evolved and been integrated into this report as the scenario development and analyses have evolved and provided a sound platform from which the analyses could be done.

#### 3.1 Scenario variables

##### 3.1.1 Development levels/time slices

The following development level/ time slices were proposed. These time slices are aligned with the Upper Orange Reserve determination study scenarios (DWS, 2023a), and intend to capture a range of likely catchment development levels into the future.

- **Scenario 0:** Natural catchment state.
- **Scenario 1:** Present day catchment state, based on recent studies on the catchment conditions and development levels.
- **Scenario 2:** Medium term with water requirements projected for approximately the year 2040. Associated infrastructure developments will be required to increase water supply potential for the projected growing water requirements.
- **Scenario 3:** Long term with water requirements projected for approximately the year 2060. Additional interventions will be required to meet the water requirements for the longer-term projection horizon.

These time slices and associated interventions are summarised in Table 6, after discussing other variables considered as part of the scenarios. A note for Table 6 is that additional to the (a) and (b) letter for each scenario (i.e., denoting without and with EWRs respectively), alternative interventions (or combinations of such) may also be options for a given development level/time slice. This is of particular importance for the future scenarios, where the interventions may not yet be fully confirmed and committed to. In such case, there will be a decimal number added, e.g., 3.1 and 3.2 for such alternative scenarios within a given time-slice.

### 3.1.2 Ecological water requirements

For each development level (other than Scenario 0 – the natural), the following was included:

- a) No EWRs active and operationalised in the Orange, to show the impacts on ecological water flows and associated consequences, of prioritising and maximising consumptive water use for socio-economic supply and development.
- b) With EWRs switched on and active in a prioritised way, to show the consequence on the socio-economic sector of prioritising EWRs implementation. It is not necessarily the ultimate development possible in the catchment, but a practical level of development that can be foreseen into the future.

### 3.1.3 Intervention options

For the future development levels/time slices, additional interventions were projected to be required to meet the growing water requirements within the Orange and neighbouring Vaal catchments. These options include large dams to create more storage and yield, as well as operational and management interventions.

#### **Additional Storage options**

The large dam options are based on existing planning as part of the Reconciliation Strategy (DWS, 2015), and the ORASECOM Core Scenario Report (ORASECOM, 2020):

- Polihali Dam as part of the Lesotho Highlands Water Project (LHWP) Phase 2.
- Noordoewer/ Vioolsdrift Dam (NVD) on the Lower Orange River
- Verbeeldingskraal Dam on the Upper Orange River (above Gariep Dam)
- Boskraai Dam on the Kraai River, and
- The Raising of the Gariep Dam wall.

The attributes of these possible options are presented in Table 4, and the locations within the system presented schematically in Figure 5. While the Polihali Dam has been designed and is proceeding into implementation, options for other future infrastructure are still being finalised. As such, there are different sizes, or combinations of infrastructure options possible. These possible alternatives have been included in the scenarios with the goal to capture the ranging ecological and socio-economic impacts and consequences.

The interventions options included in the two future scenarios are:

- **Scenario 2: Medium term** - The Polihali Dam as part of the planned next phase of the Lesotho Highlands Water Project (LHWP-2), and the Noordoewer/ Vioolsdrift Dam (NVD) to augment the catchment and improve the operations of the Lower Orange River catchment. Multiple size options for the NVD have been considered (Table 4).
- **Scenario 3: Long-term** - Additional interventions include more storage at Verbeeldingskraal Dam to provide further yield in the Orange River. The addition of the Makhaleng dam in Lesotho and a transfer of water to Botswana was included as an alternative. The inclusion of Boskraai Dam instead of Verbeeldingskraal Dam was also considered as another alternative to this scenario.

Scenarios were discussed with the DWS: Strategic Water Resources Planning Directorate, to get inputs and confirmation on the alignment of the possible scenarios with current catchment plans. The notes from the meeting are contained in Appendix A.

A key observation from the meeting related to the size of the NVD, which due to its position close to the estuary, and purpose as a yield replacement and flow re-regulation dam, has a big impact on the ecology of the Lower Orange River. As the size of the dam was investigated but not finalised as part of the Feasibility Study for the proposed dam, size options to be considered by the classification are deemed important.

Size options for the NVD, as well as the other large dam options are summarised in Table 4.

**Table 4: Large Dam intervention options in the Orange River catchment**

| Dam options <sup>[1]</sup>                  | Dam size (option 1)         |                           | Dam size (option 2)      |                  | Dam size (option 3)         |                  | Comment                                                                                                                 |
|---------------------------------------------|-----------------------------|---------------------------|--------------------------|------------------|-----------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------|
|                                             | Capacity (Mm <sup>3</sup> ) | Height <sup>[2]</sup> (m) | Capacity Mm <sup>3</sup> | Height (m)       | Capacity (Mm <sup>3</sup> ) | Height (m)       |                                                                                                                         |
| LHWP2 - Polihali                            | 2 322                       | 160 m (2 075 fsl)         | N/A                      |                  |                             |                  | Size already fixed                                                                                                      |
| Makhaleng                                   | 1 216                       | 127m (1 637 fsl)          | N/A                      |                  |                             |                  | Pre-feasibility Study Phase II – N1a site                                                                               |
| Vioolsdrift <sup>[3]</sup>                  | 300                         | 35 m (203.3 fsl)          | 700                      | 46 m (213.5 fsl) | 2 800                       | 69 m (236.9 fsl) | Upper Orange reserve used a value of 2 216 capacity. Feasibility size from 300 (re-regulation) to 2 800 (yield focused) |
| Verbeeldingskraal                           | 1 363                       | 85 m (1 385 fsl)          | N/A                      |                  |                             |                  | As per Upper Orange Reserve WRPM.                                                                                       |
| Boskraai <sup>[5]</sup>                     | 880                         | TBC                       | N/A                      |                  |                             |                  | Size aligned with MAR of Kraai at site – generic curve used.                                                            |
| Raising existing Gariiep Dam <sup>[4]</sup> | N/A                         |                           |                          |                  |                             |                  | Not preferred - high evaporative losses                                                                                 |

Notes related to Table 4:

- 1) There may be more large dam developments proposed. These are the key options that have been identified and prioritised as part of the Reconciliation Strategy (DWS, 2015).
- 2) The dam heights are indicative estimates with a reasonable freeboard assumption to help visualise the extent of the structure proposed. These are not exact heights for construction or feasibility planning (there

are sometimes multiple dam alignments still possible). Consequences driven by capacities are included in the models.

- 3) There are still ultimately more size options being considered for NVD. A limited number were selected for the initial consequences and trade-off process. If additional runs are required for alternative dam sizes, these will be included with the final EWRs proposed and commentary provided on the possible consequences. The dead-storage volume of the size options is not the same due to differences in the dam trap efficiency. A smaller dam option 1 is projected to have a loss of storage to sediment of around 110 million cubic metres (Mm<sup>3</sup>), option 2 around 400 Mm<sup>3</sup>, and option 3 around 700 Mm<sup>3</sup>. These volumes are related to the 50-year sediment loads and have been included in the Water Resources Planning Model (WRPM) scenarios as reduced operational storage.
- 4) The raising of Gariep Dam was identified as a reconciliation option in previous studies. However, the large increase in surface area due to a flattening of the dam basin will result in significant increases in evaporation and overall loss of water from the system. Alternative dam sites upstream have since been earmarked as preferred alternatives to create more storage in the Orange River catchment. These include Boskraai and Verbeeldingskraal dams.
- 5) [The Boskraai Dam, like the raising of Gariep Dam was considered in previous Reconciliation Strategies. However, the Boskraai Dam option will impact one of the only free flowing un-regulated main tributaries of the Upper Orange River catchment and thus have significant ecological impacts as a barrier effect, disconnecting the Kraai River from the main stem. This will need to be viewed taking into consideration the negative or positive impacts the dam will have on the flow regime.

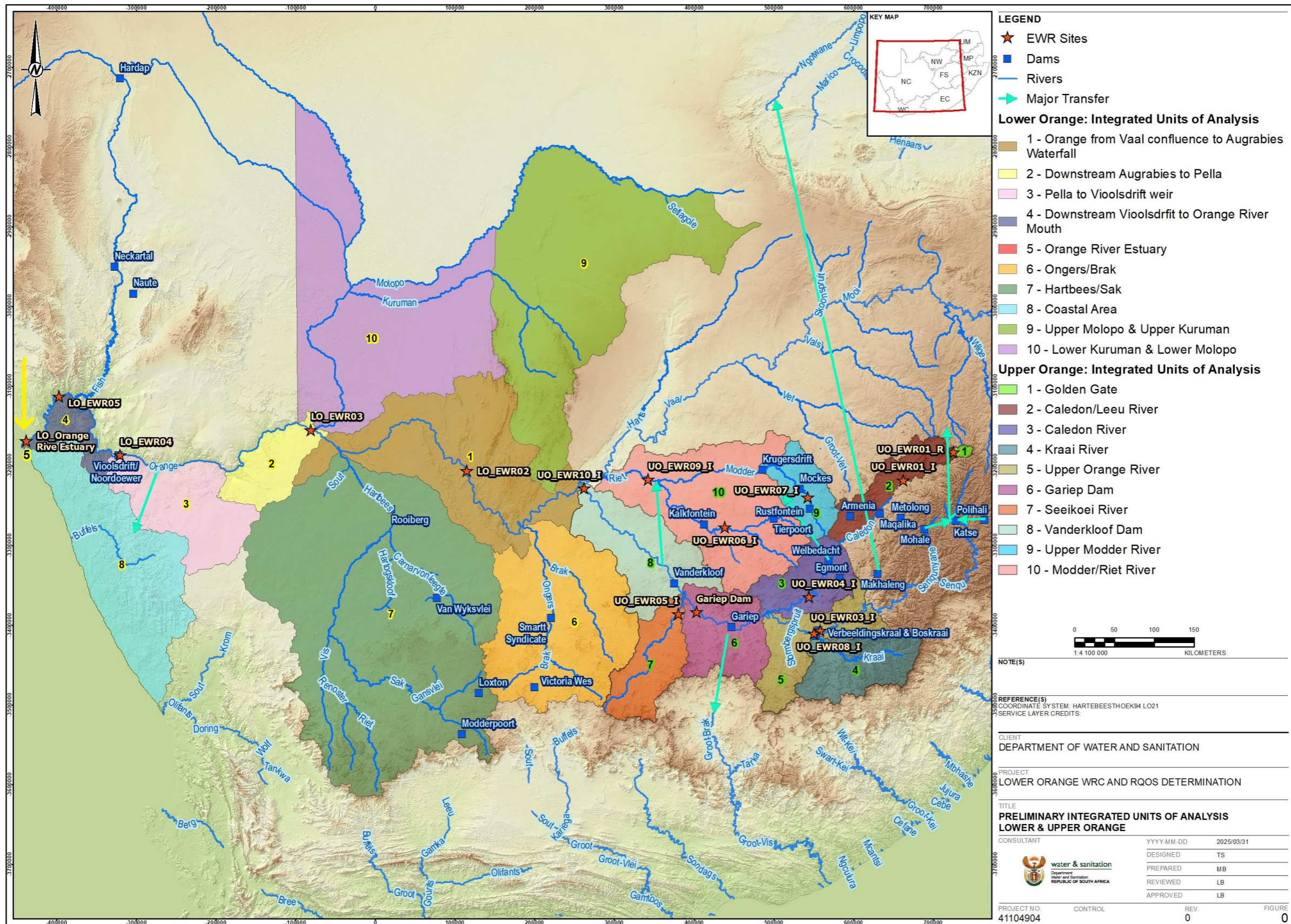


Figure 5: Map of Orange River System showing the IUAs for both the Upper and Lower Orange River catchments

Additional to the large dam development options, other intervention options considered to increase water availability in the catchment are:

- Water conservation and Water Demand Management (WC/WDM): The water requirements presented in the sub-section to follow are based on the Core Scenario of the ORESACOM Planning Work (2020). These include:
  - Integrated Vaal River System: assumes that WC/WDM is in place (ORASECOM, 2020). This reflects the potential savings that can be achieved by carrying out WC/WDM in the major urban centres.
  - Senqu/ Mohokare River Systems Lesotho: the latest urban/ industrial and mining demand growth as determined as part of ORASECOM, 2020, including reductions as a result of WCWDM initiatives were used.
  - Integrated Orange River System RSA: the latest urban/ industrial and mining demand growth as determined as part ORASECOM, 2020, including reductions as a result of WCWDM initiatives, were used.
  - In summary, WC/WDM was included in the projected water requirements as an intervention for the key catchments and water users.
- Real-time monitoring and operating rules development/ implementation: Water is released from the Vanderkloof Dam to the users on the Lower Orange River main stem. Currently the average annual losses due to operational complexities and the distance and travel times between Vanderkloof Dam and the end of the Lower Orange River, is around 180 Mm<sup>3</sup>/a (DWS, 2015). This excludes evaporative losses on the Lower Orange River which occur naturally. While the inclusion of the NVD will allow some of these losses to be reduced due to re-regulation by the NVD, the inclusion of a real-time monitoring operation system can reduce the losses by around 80 Mm<sup>3</sup>/a. This is not only advantageous for improving water availability but is likely necessary to implement the EWRs. While not in the Upper Orange Reserve scenarios, this intervention option was added to align with the Reconciliation Strategy options, and with the goal of reducing trade-off consequences.
- Vanderkloof low-level storage utilisation: The Vanderkloof Dams' current minimum operating level is linked to the hydropower scheme and the Orange-Riet Canal off-take level. There is still however considerable water in storage below this level that can be utilised if the minimum operating level were to be reduced. This would require some alterations to the outlet configuration at the dam, and pumping water from a lower outlet into the Orange-Riet Canal. Doing so would allow releases and supply to the irrigation canals linked to the Orange-Riet Canal and the Lower Orange River. This could maintain supply for critical irrigation purposes (e.g., keeping valuable orchards alive). No hydropower can be generated when the dam is below this level, so there is a negative economic impact that comes with this intervention. It is thus considered an emergency intervention to help manage critical larger droughts and should occur infrequently. Similar to the real-time

operations, this intervention was added to the scenarios to help address the projected stress and trade-offs in the catchment. The impacts on hydropower generation will be assessed, which will include the impacts of implementing the EWRs as well as the use of the low-level storage.

### 3.1.4 Water Requirements

The water requirements adopted for the scenarios development and assessment are based on the core scenario of the ORASECOM planning study (ORASECOM, 2020). These water requirements were adopted for the Upper Orange Reserve Determination Study (DWS, 2023) and used for this classification process. While a Reconciliation Strategy update was initiated by the DWS for the Central Region, results from that process were not yet available for consideration by the classification study team. The core scenario is thus the latest available information for the whole of the Integrated Orange-Vaal River Systems, for both present and future projections beyond 2030.

The water requirements per water use sector, per IUA are summarised in Table 5 for the Upper and Lower Orange River systems.

More detailed tables of the simulated water supply per scenario, per water user, are included in the Tables in Appendix B. Also included in Appendix B are the water requirements/ supply projected for the neighbouring and linked catchments of the Vaal, Inkomati, Thukela and Olifants catchments. Water requirements and water availability in these upstream and connected catchments impact the water available in the Orange River catchment. They have thus been included for completeness and record keeping purposes. These water requirements are also included in the WRPM, used to assess the scenarios and associated water availability and flow consequences for the Upper and Lower Orange River catchments.

The following large scale water transfers are also included in the WRPM and scenarios evaluated:

- Transfers from Gariep Dam to the Fish River (Eastern Cape) – abstraction and transfer from Gariep Dam includes 88 Mm<sup>3</sup>/a for domestic use and 612 Mm<sup>3</sup>/a for irrigation. The total of around 700 Mm<sup>3</sup>/a aligns with what was assumed in the Classification of Water Resources in the Keiskamma to Tsitsikamma WMAs (DWS, 2024).
- Gariep Dam to Bloemfontein pipeline was included in two future scenarios with growing water supply support of 45 Mm<sup>3</sup>/a in 2040, and 60 Mm<sup>3</sup>/a in 2060 future scenarios.
- LHWP Phase 2 was included with increased water supply from the addition of Polihali Dam. The transfer to the Vaal River increases from a maximum of 780 Mm<sup>3</sup>/a in the present day, to 1 217 Mm<sup>3</sup>/a in the future scenarios. There is no change beyond 2040 to 2060. Increased supply to meet growth in the Vaal River catchment is anticipated to come from other sources outside of the Senqu and Orange rivers.
- A dam on the Makhaleng River in Lesotho, and a transfer of water to Botswana. The information included in the Upper Orange Reserve study was updated due to new

information on the dam site, transfer volume (with some additional local use), and the EWR below the dam site. The latest information was sourced from the Feasibility Study Phase – Component IV of the Preparation of Climate Resilient Water Resources Investment Strategy & Plan and Lesotho-Botswana Water Transfer Multipurpose Transboundary Project, specifically the Makhaleng River Environmental Requirements Report (ORASECOM, 2023). A dam of 1 216 Mm<sup>3</sup> at the N1a site was included as the preferred site from the Prefeasibility Study Phase II. The total volume to be transferred and used by irrigation has increased for the latest reporting (ORASECOM report – feasibility phase – Makhaleng River Environmental Requirements Report received), over that used in the Upper Orange Reserve Study (DWS, 2023a). The revised volume is for a total of 270 Mm<sup>3</sup>/a to be abstracted above the EWR sites. The revised EWRs for the site as provided by the latest report were included below the Makhaleng Dam.

The following are planned water resource developments for increased consumptive water use outside of the south African water users in the Orange River IUAs:

- Lesotho Developments: development of weirs and abstractions on the Hlotse and the Caledon. This was included for additional irrigation being planned by the Government of Lesotho with support from the Millenium Challenge Corporation (MCC), and
- Namibian water requirement growth from 75 Mm<sup>3</sup>/a in present day, to 113 Mm<sup>3</sup>/a in 2040 and 130 Mm<sup>3</sup>/a in 2060.

The total water requirements per IUA are summarised in the tables included in Appendix B. The total water requirements within the Upper Orange River catchment are projected to be:

- Present Day – 1 171.29 Mm<sup>3</sup>
- Medium Term – 1 238.33 Mm<sup>3</sup>
- Long Term – 1 302.37 Mm<sup>3</sup>

The water requirements in the Lower Orange Catchment are projected to be:

- Present Day – 1 094.07 Mm<sup>3</sup>
- Medium Term – 1 159.85 Mm<sup>3</sup>
- Long Term – 1 162.07 Mm<sup>3</sup>

**Table 5: Projected average annual water requirements for Upper and Lower Orange (Mm<sup>3</sup>/a) per water use sector**

| Orange River       | IUA | User type  | Scenario 1 | Scenario 2 | Scenario 3 |
|--------------------|-----|------------|------------|------------|------------|
| Upper Orange River | 1   | Irrigation | 6.23       | 6.23       | 6.23       |
|                    |     | Domestic   | 0.60       | 0.60       | 0.60       |
|                    |     | Total      | 6.83       | 6.83       | 6.83       |
|                    | 2   | Irrigation | 28.92      | 28.92      | 28.92      |

| Orange River | IUA        | User type   | Scenario 1 | Scenario 2 | Scenario 3 |
|--------------|------------|-------------|------------|------------|------------|
|              |            | Domestic    | 41.30      | 58.42      | 72.22      |
|              |            | Total       | 70.22      | 87.33      | 101.14     |
|              | 3          | Irrigation  | 40.26      | 40.26      | 40.26      |
|              |            | Domestic    | 8.01       | 9.79       | 10.81      |
|              |            | Total       | 48.27      | 50.05      | 51.07      |
|              | 4          | Irrigation  | 47.06      | 40.28      | 47.06      |
|              |            | Domestic    | 1.20       | 1.20       | 1.20       |
|              |            | Total       | 48.26      | 41.48      | 48.26      |
|              | 5          | Irrigation  | 218.82     | 218.82     | 218.82     |
|              |            | Domestic    | 20.52      | 26.73      | 28.82      |
|              |            | Total       | 239.34     | 245.55     | 247.64     |
|              | 6          | Irrigation  | 33.82      | 33.82      | 33.82      |
|              |            | Domestic    | 5.19       | 5.80       | 6.73       |
|              |            | Hydro power | 70.00      | 70.00      | 70.00      |
|              |            | Total       | 109.01     | 109.62     | 110.55     |
|              | 7          | Irrigation  | 4.15       | 4.15       | 4.15       |
|              |            | Domestic    | 0.00       | 0.00       | 0.00       |
|              |            | Total       | 4.15       | 4.15       | 4.15       |
|              | 8          | Irrigation  | 255.25     | 255.25     | 255.25     |
|              |            | Domestic    | 2.42       | 3.26       | 4.38       |
| Hydro power  |            | 70.00       | 70.00      | 70.00      |            |
| Total        |            | 327.68      | 328.52     | 329.63     |            |
| 9            | Irrigation | 26.46       | 41.93      | 41.93      |            |
|              | Domestic   | 105.23      | 135.52     | 171.14     |            |
|              | Total      | 131.70      | 177.45     | 213.07     |            |
| 10           | Irrigation | 174.92      | 174.47     | 174.47     |            |
|              | Domestic   | 10.90       | 12.89      | 15.57      |            |

| Orange River       | IUA                 | User type                 | Scenario 1                | Scenario 2      | Scenario 3      |                 |
|--------------------|---------------------|---------------------------|---------------------------|-----------------|-----------------|-----------------|
|                    |                     | Total                     | 185.82                    | 187.36          | 190.03          |                 |
|                    |                     | <b>Upper Orange Total</b> | <b>1 171.29</b>           | <b>1 238.33</b> | <b>1 302.37</b> |                 |
| Lower Orange River | 1                   | Irrigation                | 582.79                    | 585.28          | 574.78          |                 |
|                    |                     | Domestic                  | 42.76                     | 50.94           | 50.94           |                 |
|                    |                     | Total                     | 625.55                    | 636.22          | 625.72          |                 |
|                    | 2                   | Irrigation                | 310.53                    | 331.32          | 343.44          |                 |
|                    |                     | Domestic and small mines  | 25.96                     | 27.77           | 27.77           |                 |
|                    |                     | Total                     | 336.49                    | 359.10          | 371.21          |                 |
|                    | 3                   | Irrigation                | 69.95                     | 104.15          | 103.98          |                 |
|                    |                     | Domestic                  | 0.00                      | 0.00            | 0.00            |                 |
|                    |                     | Total                     | 69.95                     | 104.15          | 103.98          |                 |
|                    | 4                   | Irrigation                | 10.05                     | 7.99            | 7.85            |                 |
|                    |                     | Domestic and small mines  | 16.65                     | 16.97           | 17.89           |                 |
|                    |                     | Total                     | 26.70                     | 24.97           | 25.74           |                 |
|                    | 6                   | Irrigation                | 17.83                     | 17.83           | 17.83           |                 |
|                    |                     | Domestic                  | 0.00                      | 0.00            | 0.00            |                 |
|                    |                     | Total                     | 17.83                     | 17.83           | 17.83           |                 |
|                    | 7                   | Irrigation                | 17.55                     | 17.59           | 17.59           |                 |
|                    |                     | Domestic                  | 0.00                      | 0.00            | 0.00            |                 |
|                    |                     | Total                     | 17.55                     | 17.59           | 17.59           |                 |
|                    |                     |                           | <b>Lower Orange Total</b> | <b>1 094.07</b> | <b>1 159.85</b> | <b>1 162.07</b> |
|                    | <b>System total</b> |                           |                           | <b>2 265.35</b> | <b>2 398.18</b> | <b>2 464.44</b> |

A summary of the proposed scenarios and associated development levels, interventions and operational considerations is included in Table 6.

**Table 6: Scenarios Summary**

| Scenario ID         | Scenario Name                               | Time slice / development level | Interventions included <sup>[1]</sup>                                                                      | Operations                                                   |
|---------------------|---------------------------------------------|--------------------------------|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| 0                   | Natural                                     | N/A                            | none                                                                                                       |                                                              |
| 1a                  | Present day <u>without</u> EWRs             | 2020                           | As per present day (excl. LHWP2).                                                                          | Supply to users prioritised                                  |
| 1b                  | Present day <u>with</u> EWRs                | 2020                           | As per present day (excl. LHWP2)                                                                           | EWR prioritised                                              |
| 1c <sup>[2]</sup>   | Present day <u>with</u> adjusted EWRs       | 2020 - 2028                    | Preliminary EWRs to align with ORS yield impact for lower Orange. River management plan                    | Short-term or phasing in option (until system is augmented). |
| 2a                  | Medium term without EWRs                    | 2040                           | LHWP2-Polihali, Vioolsdrift (size option 2 – 700 million m <sup>3</sup> ), Gariep to Bloem pipeline        | Supply to users prioritised                                  |
| 2b                  | Medium term with EWRs                       | 2040                           | LHWP2-Polihali, Vioolsdrift (size option 2 – 700 million m <sup>3</sup> ), Gariep to Bloem pipeline        | EWR prioritised                                              |
| 2.1a                | Medium term alternative <u>without</u> EWRs | 2040                           | LHWP2-Polihali, Vioolsdrift (size option 3 – 2800 million m <sup>3</sup> ), Gariep to Bloem pipeline       | Supply to users prioritised                                  |
| 2.1b                | Medium term alternative <u>with</u> EWR     | 2040                           | LHWP2-Polihali, Vioolsdrift (size option 3 -2800 million m <sup>3</sup> ), Gariep to Bloem pipeline        | EWR prioritised                                              |
| 3a                  | Long term without EWRs                      | 2060                           | LHWP2-Polihali, Vioolsdrift (size option 2), Gariep to Bloem pipeline, with Verbeeldingskraal,             | Supply to users prioritised                                  |
| 3b                  | Medium term with EWRs                       | 2060                           | LHWP2-Polihali, Vioolsdrift (size option 2), Gariep to Bloem pipeline, with Verbeeldingskraal              | EWR prioritised                                              |
| 3.1a <sup>[3]</sup> | Long term alternative 1 <u>without</u> EWRs | 2060                           | LHWP2-Polihali, Vioolsdrift (Size option 2), Gariep to Bloem pipeline, Verbeeldingskraal and Makhaleng Dam | Supply to users prioritised                                  |
| 3.1b <sup>[3]</sup> | Long term alternative 1 <u>with</u> EWRs    | 2060                           | LHWP2-Polihali, Vioolsdrift (Size option 2), Gariep to Bloem pipeline, Verbeeldingskraal and Makhaleng Dam | EWR prioritised                                              |
| 3.2a                | Long term alternative 1 <u>without</u> EWRs | 2060                           | LHWP2-Polihali, Vioolsdrift (Size option 1), Gariep to Bloem pipeline, Boskraai Dam and Makhaleng Dam      | Supply to users prioritised                                  |

|                     |                                             |      |                                                                                                                               |                             |
|---------------------|---------------------------------------------|------|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| 3.2b                | Long term alternative 1 <u>with</u> EWRs    | 2060 | LHWP2-Polihali, Vioolsdrift (Size option 1), Gariep to Bloem pipeline, Boskraai Dam and Makhaleng Dam                         | EWR prioritised             |
| 3.3a <sup>[4]</sup> | Long term alternative 3 <u>without</u> EWRs | 2060 | LHWP2-Polihali, Vioolsdrift (size option 4 – 1200 million m <sup>3</sup> ), Gariep to Bloem pipeline, with Verbeeldingskraal, | Supply to users prioritised |
| 3.3b <sup>[4]</sup> | Long term alternative 1 <u>with</u> EWRs    | 2060 | LHWP2-Polihali, Vioolsdrift (size option 4 – 1200 million m <sup>3</sup> ), Gariep to Bloem pipeline, with Verbeeldingskraal, | EWR prioritised             |

**Notes:**

- 1) *The intervention options align with the large dam development options presented in Table 4.*
- 2) *Scenario 1c will be run and tested as a part of the implementation of the EWRs, once the trade-offs have been confirmed based on the longer-term realities and projections. This will be an interim scenario aimed at trying to mitigate possible short-term issues until the larger interventions are implemented and is thus an implementation focused matter.*
- 3) *This scenario includes additional consumptive water use through a transfer to Botswana and greater local water use for irrigation. It is thus not directly comparable with Scenario 3a, but still an important scenario to assess with the increased levels of catchment development and use.*
- 4) *A larger size of NVD was tested of 1 200 Mm<sup>3</sup> rather than the 2 800 Mm<sup>3</sup> as the feasibility study already raised concerns of the larger dam on the estuary, and the 2800 size has been included in Scenario 2.1.*

Additional scenarios may be required for estuary sensitivity quantification purposes. These will be confirmed after the initial scenarios are provided to the estuarine specialists for the Lower Orange River study. Where additional scenarios are required with more extreme dry or wet conditions at the estuary, hypothetical scenarios will be developed that push the flow regime in the required direction to help the specialists confirm critical thresholds for the estuary.

There was some optimisation of the scenarios from those originally proposed in the scenarios workshop and working document. This refinement to the final list of scenarios (provided in Table 6) was done to remove redundant scenarios and add in scenarios, where initial results necessitated.

#### **4 ECOLOGICALLY SUSTAINABLE BASE CONFIGURATION (ESBC)**

The process followed in terms of the establishment of the Ecologically Sustainable Base Configuration (ESBC) is described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWAF, February 2007a and 2007b).

The ESBC scenario, which could permit the maximum water use scenario, requires that the base condition for each water resource is at minimum established as either a D category or as whichever higher category is required to maintain all downstream nodes in at least a D category. However, where the ecological condition requires it, a higher ecological category needs to be set.

The ESBC scenario is established once this base condition is hydrologically and ecologically tested to ensure that it is feasible and can be achieved. In other words, the results will reflect whether the catchment water balance would be in surplus or deficit by implementing a D category EWR.

In terms of the Upper Orange River catchment, the D ecological category was not selected as the default ESBC. Rather the selected ecological category per IUA is the Present Ecological State (PES). The ESBCs for the Upper Orange River IUAs used for the scenario evaluation are listed in Table 7.

Additional to the establishment of the ESBC, the Recommended Ecological Category (REC) was also determined as an alternate scenario at the nodes. The REC is based on the ultimate target to achieve a sustainable system both ecologically and economically, considering the PES and REC. Thus, the REC can be the same as the PES or the REC. However, it may also be worse than the PES if a system is targeted for development that will impact the present state, or better where a higher level of protection is needed. Table 7 also indicates the REC per node.

The quantified EWRs and rationale for the REC per EWR site is provided in report RDM/WMA13/00/CON/CLA/0524, 'Quantification of Ecological Water Requirements'. The revised PES and REC after the initial assessment of the ecological consequences and system constraints are shown in the table below.

**Table 7: ESBC (PES) and REC for the Upper Orange River catchment**

| IUA | EWR site            | Sub-reach   | River      | EI                         | ES      | PES     | REC     |         |
|-----|---------------------|-------------|------------|----------------------------|---------|---------|---------|---------|
| 1   | Golden Gate         | UO_EWR 01_R | D21D-03094 | Little Caledon             | Mod     | High    | C       | B/C     |
| 2   | Caledon/ Leeu River | UO_EWR 01_I | D22D-03415 | Middle Caledon             | Mod     | Mod     | E       | D       |
| 3   | Caledon River       | UO_EWR 04_I | D24G-04958 | Lower Caledon              | High    | High    | D       | C/D     |
| 4   | Kraai River         | UO_EWR 08_I | D13M-05442 | Kraai                      | High    | High    | C       | B/C     |
| 5   | Upper Orange River  | UO_EWR 03_I | D12F-05348 | Upper Orange               | High    | High    | D       | D       |
|     |                     | UO_EWR 02_I | D12B-05297 | Sterkspruit                | Low     | Mod     | D       | C/D     |
| 6   | Gariiep Dam         | UO_FMP*     | D34E-05154 | Orange                     | High    | High    | No data | No data |
| 7   | Seekoei River       | UO_EWR 05_I | D32J-05237 | Seekoei                    | Mod     | Mod     | C       | C       |
| 8   | Vanderkloof Dam     | UO_EWR 10_I | D33K-03723 | Orange                     | High    | Mod     | C       | C       |
| 9   | Upper Modder River  | UO_EWR 07_I | C52B-03819 | Upper Modder               | Mod     | High    | D       | C       |
|     |                     | UO_EWR 06_R | C52H-03155 | Middle Modder (Soetdoring) | High    | High    | D       | C/D     |
| 10  | Modder-Riet Rivers  | UO_EWR 06_I | C51F-04071 | Upper Riet                 | High    | Mod     | C       | C       |
|     |                     | UO_EWR 09_I | No data    | Lower Riet                 | No data | No data | C       | B/C     |

*\*this section of the river has not been ecologically assessed because of the fact that it falls within the stretch of river between Gariiep and Vanderkloof dams for which a Flow Management Plan has been proposed.*

## 5 EVALUATED SCENARIOS AND HYDROLOGY

The sections to follow set out the scenarios that were evaluated for ecological consequences at the EWR sites listed per IUA in Table 7, and the hydrology that was modelled. Chapter 4 gives further detail on the ecological consequences results.

### 5.1 IUA1: Golden Gate

Ecological consequences were assessed for the Little Caledon (site UO\_EWR01\_R) within this IUA. No large dams are situated upstream of this EWR site.

Only two scenarios were assessed, namely present day without and with EWR as no future developments are planned for this catchment. Refer to Table 8 for the average flows (1920 - 2004) measured in million cubic meters (Mm<sup>3</sup>).

**Table 8: Average flows (1920-2004) for UO\_EWR01\_R**

| Average Flows (1920-2004) – Mm <sup>3</sup> |            |
|---------------------------------------------|------------|
|                                             | UO_EWR01_R |
| nMAR                                        | 25.9       |
| Sc1a (PRS)                                  | 25.3       |
| Sc1b                                        | 25.3       |

The hydrology that was available and used during the quantification of the EWR was adjusted and the EWR was re-assessed as part of the trade-off workshop held in March 2025 using the latest available hydrology. Although the overall natural mean annual run-off (nMAR) didn't change, the monthly flow patterns were changed. However, minimal changes were made to the EWR. A summary of the final revised EWR is presented in Table 9, with flows in million cubic metres per annum (Mm<sup>3</sup>/a).

**Table 9: Little Caledon - Summary of the final EWR results (flows in Mm<sup>3</sup>/a)**

| Quaternary Catchment            | D21D                |                     |
|---------------------------------|---------------------|---------------------|
| River                           | Little Caledon      |                     |
| Site code                       | UO_EWR01_R          |                     |
| Recommended Ecological Category | B/C                 |                     |
|                                 | 2024                | Revised, Mar 2025   |
| nMAR at EWR site                | 25.9                | 25.9                |
| Total EWR                       | 10.154 (39.20 %MAR) | 10.154 (39.27 %MAR) |
| Maintenance Low flows           | 5.981 (23.09 %MAR)  | 5.981 (23.13 %MAR)  |
| Drought Low flows               | 1.919 (7.41 %MAR)   | 1.919 (7.42 %MAR)   |
| Maintenance High flows          | 4.173 (16.11 %MAR)  | 4.173 (16.14 %MAR)  |

The seasonal distribution (hydrograph) plot was prepared using the flows provided for the scenarios and is illustrated in Figure 6. Table 10 provides the estimated non-compliances for all the months for the scenarios (values in red).

The scenario evaluated show small reductions from the natural flows for all the months, especially in the drier months of July and August.

The results indicate that the EWR could not be met for most of the time for all the months in Sc1a as well as Sc1b (EWR implemented).

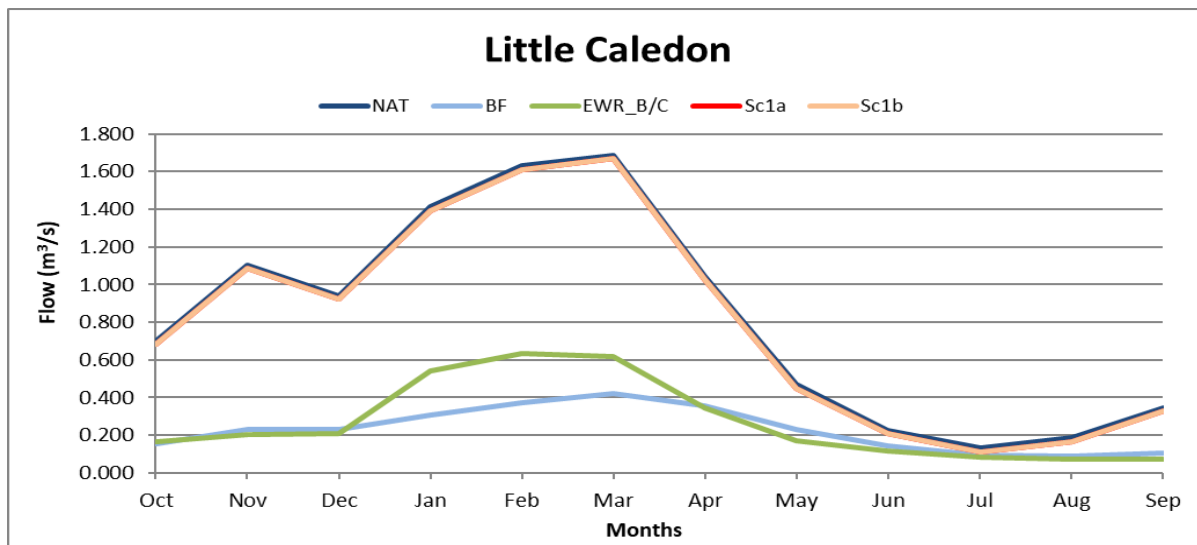


Figure 6: Seasonal distribution of scenarios at site UO\_EWR01\_R: Little Caledon

Table 10: Estimated non-compliances with EWR for all months at UO\_EWR01\_R

| Sc1a-EWR    |        |        |        |        |        |        |        |        |        |        |        |        |
|-------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Percentiles | Oct    | Nov    | Dec    | Jan    | Feb    | Mar    | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1         | 10.876 | 5.715  | 6.866  | 8.139  | 7.320  | 7.614  | 4.856  | 4.928  | 1.760  | 1.624  | 4.696  | 8.335  |
| 1           | 6.239  | 5.641  | 5.750  | 7.956  | 6.494  | 7.552  | 4.147  | 3.006  | 1.371  | 0.711  | 1.527  | 8.248  |
| 5           | 2.904  | 3.655  | 3.764  | 3.564  | 3.642  | 4.094  | 3.584  | 1.551  | 0.726  | 0.149  | 0.550  | 0.603  |
| 10          | 1.932  | 2.787  | 1.902  | 2.534  | 3.039  | 2.636  | 2.611  | 0.814  | 0.230  | 0.062  | 0.093  | 0.259  |
| 15          | 0.948  | 1.937  | 1.305  | 1.926  | 2.520  | 2.046  | 1.399  | 0.557  | 0.092  | 0.007  | 0.006  | 0.016  |
| 20          | 0.413  | 1.793  | 1.036  | 1.528  | 1.842  | 1.704  | 1.257  | 0.369  | 0.062  | -0.019 | -0.011 | -0.016 |
| 30          | 0.050  | 0.736  | 0.510  | 0.522  | 0.866  | 1.151  | 0.613  | 0.168  | -0.019 | -0.019 | -0.019 | -0.019 |
| 40          | -0.019 | 0.412  | 0.375  | 0.159  | 0.669  | 0.635  | 0.367  | -0.012 | -0.019 | -0.019 | -0.019 | -0.019 |
| 50          | -0.019 | 0.157  | 0.199  | 0.192  | 0.408  | 0.277  | 0.098  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 60          | -0.019 | 0.015  | 0.141  | 0.110  | 0.151  | 0.160  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.018 |
| 70          | -0.019 | 0.024  | -0.017 | 0.005  | -0.019 | 0.060  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 80          | -0.019 | -0.014 | -0.015 | -0.019 | -0.003 | 0.001  | -0.019 | -0.019 | -0.019 | -0.019 | -0.018 | -0.019 |
| 85          | -0.019 | -0.019 | -0.019 | -0.019 | 0.007  | 0.005  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 90          | -0.019 | -0.019 | -0.019 | -0.019 | -0.009 | -0.018 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.018 |
| 95          | -0.017 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 99          | -0.010 | 0.000  | -0.014 | -0.010 | -0.016 | -0.017 | -0.019 | -0.019 | -0.018 | -0.019 | -0.019 | -0.017 |
| 99.9        | -0.001 | 0.000  | -0.001 | -0.001 | -0.002 | -0.005 | -0.019 | -0.019 | -0.016 | -0.019 | -0.019 | -0.016 |
| Sc1b-EWR    |        |        |        |        |        |        |        |        |        |        |        |        |
| Percentiles | Oct    | Nov    | Dec    | Jan    | Feb    | Mar    | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1         | 10.876 | 5.715  | 6.866  | 8.139  | 7.320  | 7.614  | 4.856  | 4.928  | 1.760  | 1.624  | 4.696  | 8.335  |
| 1           | 6.239  | 5.641  | 5.750  | 7.956  | 6.494  | 7.552  | 4.147  | 3.006  | 1.371  | 0.711  | 1.527  | 8.248  |
| 5           | 2.904  | 3.655  | 3.764  | 3.564  | 3.642  | 4.094  | 3.584  | 1.551  | 0.726  | 0.149  | 0.550  | 0.603  |
| 10          | 1.932  | 2.787  | 1.902  | 2.534  | 3.039  | 2.636  | 2.611  | 0.814  | 0.230  | 0.062  | 0.093  | 0.259  |
| 15          | 0.948  | 1.937  | 1.305  | 1.926  | 2.520  | 2.046  | 1.399  | 0.557  | 0.092  | 0.007  | 0.006  | 0.016  |
| 20          | 0.413  | 1.793  | 1.036  | 1.528  | 1.842  | 1.704  | 1.257  | 0.369  | 0.062  | -0.019 | -0.011 | -0.016 |
| 30          | 0.050  | 0.736  | 0.510  | 0.522  | 0.866  | 1.151  | 0.613  | 0.168  | -0.019 | -0.019 | -0.019 | -0.019 |
| 40          | -0.019 | 0.412  | 0.375  | 0.159  | 0.669  | 0.635  | 0.367  | -0.012 | -0.019 | -0.019 | -0.019 | -0.019 |
| 50          | -0.019 | 0.157  | 0.199  | 0.192  | 0.408  | 0.277  | 0.098  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 60          | -0.019 | 0.015  | 0.141  | 0.110  | 0.151  | 0.160  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.018 |
| 70          | -0.019 | 0.024  | -0.017 | 0.005  | -0.019 | 0.060  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 80          | -0.019 | -0.014 | -0.015 | -0.019 | -0.003 | 0.001  | -0.019 | -0.019 | -0.019 | -0.019 | -0.018 | -0.019 |
| 85          | -0.019 | -0.019 | -0.019 | -0.019 | 0.007  | 0.005  | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 90          | -0.019 | -0.019 | -0.019 | -0.019 | -0.009 | -0.018 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.018 |
| 95          | -0.017 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 | -0.019 |
| 99          | -0.010 | 0.000  | -0.014 | -0.010 | -0.016 | -0.017 | -0.019 | -0.019 | -0.018 | -0.019 | -0.019 | -0.017 |
| 99.9        | -0.001 | 0.000  | -0.001 | -0.001 | -0.002 | -0.005 | -0.019 | -0.019 | -0.016 | -0.019 | -0.019 | -0.016 |

## 5.2 IUA2: Caledon/ Leeu River

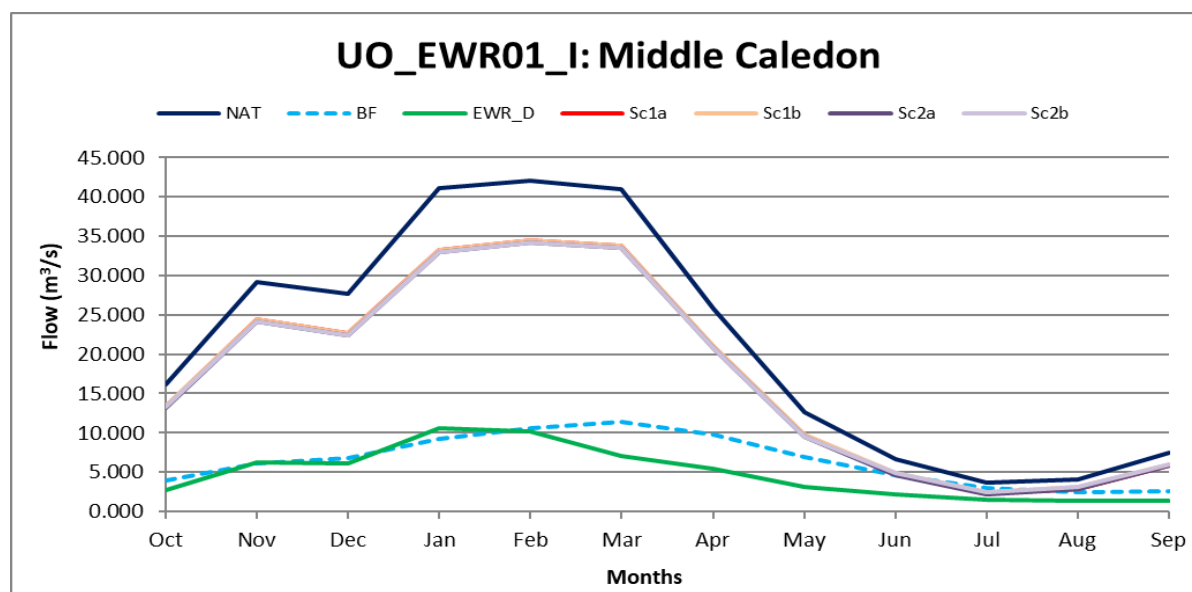
Ecological consequences were assessed for the Middle Caledon (site UO\_EWR01\_I) within this IUA. No large dams are situated upstream of this EWR site. Present day and medium-term development scenarios were assessed. No long-term water resource developments were available for this IUA. Table 11 for the average flows (1920 - 2004) measured in Mm<sup>3</sup>.

**Table 11: Average flows (1920-2004) for UO\_EWR01\_I**

| Average Flows (1920-2004) – Mm <sup>3</sup> |            |
|---------------------------------------------|------------|
|                                             | UO_EWR01_I |
| nMAR                                        | 674.0      |
| Sc1a (PRS)                                  | 545.8      |
| Sc1b                                        | 547.6      |
| Sc2a                                        | 538.9      |
| Sc2b                                        | 542.3      |

No changes were made to the EWR as determined during the high confidence study of the Reserve for the Upper Orange River.

The seasonal distribution (hydrograph) plot was prepared using the flows provided for the scenarios and is illustrated in Figure 7: Seasonal distribution of scenarios at site UO\_EWR01\_I: Middle Caledon.



**Figure 7: Seasonal distribution of scenarios at site UO\_EWR01\_I: Middle Caledon**

Table 12 provides the estimated non-compliances for all the months for the scenarios (values in red). The scenarios evaluated show reductions from the natural flows for all the months. However, very small reductions between present day (Sc1) and medium term (Sc2).

The table indicate that the EWR could not be met for especially the drier months June to September), even with the EWR implemented for Sc1 and Sc2. The wet months requirements

could be met for most of the time, except during drought periods (95 to 99.9 percentiles). However, the deficits are less with the EWR implemented.

**Table 12: Estimated non-compliances with EWR for all months at UO\_EWR01\_I**

| Sc1a-EWR    |         |         |         |         |         |         |        |        |        |        |        |         |
|-------------|---------|---------|---------|---------|---------|---------|--------|--------|--------|--------|--------|---------|
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep     |
| 0.1         | 185.944 | 113.255 | 133.173 | 172.373 | 133.810 | 173.512 | 99.933 | 82.813 | 32.332 | 31.503 | 68.897 | 144.839 |
| 1           | 101.831 | 106.362 | 106.224 | 140.417 | 125.581 | 141.182 | 81.789 | 61.814 | 30.378 | 15.326 | 26.899 | 143.126 |
| 5           | 50.399  | 77.147  | 52.218  | 78.896  | 68.837  | 100.033 | 60.861 | 31.789 | 17.920 | 6.131  | 12.189 | 10.423  |
| 10          | 37.622  | 47.918  | 37.230  | 56.987  | 55.671  | 61.211  | 44.147 | 20.998 | 7.383  | 2.180  | 1.473  | 4.992   |
| 15          | 18.610  | 32.199  | 29.372  | 47.970  | 53.753  | 47.330  | 29.011 | 14.241 | 4.520  | 1.544  | 1.065  | 1.992   |
| 20          | 11.863  | 28.811  | 23.201  | 38.644  | 42.781  | 39.361  | 23.701 | 9.546  | 2.795  | 0.386  | 0.395  | 0.688   |
| 30          | 5.424   | 19.107  | 15.979  | 19.132  | 30.304  | 28.524  | 17.544 | 5.005  | 1.124  | -0.089 | -0.200 | -0.508  |
| 40          | 2.725   | 12.662  | 9.526   | 11.330  | 20.663  | 17.684  | 10.382 | 1.682  | 0.108  | -0.501 | -0.890 | -0.677  |
| 50          | 0.697   | 9.053   | 9.360   | 12.777  | 15.013  | 14.333  | 6.147  | 0.574  | -0.355 | -0.577 | -0.930 | -0.725  |
| 60          | -0.316  | 5.360   | 7.847   | 11.010  | 9.894   | 11.183  | 4.773  | 0.054  | -0.401 | -0.452 | -0.842 | -0.626  |
| 70          | -0.100  | 3.919   | 6.578   | 5.250   | 5.732   | 7.930   | 3.235  | 0.089  | -0.361 | -0.464 | -0.677 | -0.435  |
| 80          | -0.164  | 1.247   | 2.322   | 2.268   | 4.795   | 5.741   | 2.477  | 0.171  | -0.143 | -0.414 | -0.498 | -0.293  |
| 85          | -0.139  | 0.413   | 2.075   | 1.669   | 3.322   | 3.513   | 1.679  | 0.073  | -0.107 | -0.407 | -0.456 | -0.278  |
| 90          | -0.224  | 0.156   | 1.947   | 0.398   | 2.616   | 2.150   | -0.040 | -0.226 | -0.187 | -0.428 | -0.430 | -0.269  |
| 95          | -0.309  | 0.097   | 0.318   | -0.683  | 0.083   | 0.623   | -0.685 | -0.608 | -0.457 | -0.457 | -0.441 | -0.341  |
| 99          | -0.473  | -0.550  | -0.256  | -0.617  | -0.247  | -0.985  | -0.945 | -0.765 | -0.558 | -0.475 | -0.456 | -0.403  |
| 99.9        | -0.355  | -0.380  | -0.401  | -0.538  | -0.308  | -0.658  | -0.898 | -0.771 | -0.566 | -0.472 | -0.462 | -0.413  |
| Sc1b-EWR    |         |         |         |         |         |         |        |        |        |        |        |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep     |
| 0.1         | 185.944 | 113.255 | 133.173 | 172.373 | 133.810 | 173.512 | 99.933 | 82.813 | 32.334 | 31.503 | 68.897 | 144.839 |
| 1           | 101.831 | 106.362 | 106.224 | 140.417 | 125.581 | 141.182 | 81.789 | 61.814 | 30.379 | 15.326 | 26.899 | 143.126 |
| 5           | 50.399  | 74.871  | 52.218  | 78.895  | 68.838  | 100.033 | 60.861 | 31.789 | 17.920 | 5.882  | 12.189 | 10.423  |
| 10          | 37.622  | 47.918  | 37.231  | 56.987  | 55.672  | 61.211  | 44.147 | 20.998 | 7.383  | 2.179  | 1.473  | 4.992   |
| 15          | 18.610  | 32.199  | 28.838  | 47.971  | 53.753  | 47.312  | 29.011 | 14.241 | 4.521  | 1.544  | 1.065  | 1.991   |
| 20          | 11.863  | 28.811  | 23.165  | 38.644  | 42.782  | 39.360  | 23.700 | 9.546  | 2.795  | 0.386  | 0.395  | 0.688   |
| 30          | 5.424   | 19.107  | 15.979  | 19.132  | 30.303  | 28.524  | 17.544 | 5.006  | 1.125  | -0.055 | -0.019 | -0.158  |
| 40          | 2.725   | 12.662  | 9.527   | 11.317  | 20.663  | 17.684  | 10.382 | 1.682  | 0.108  | -0.273 | -0.496 | -0.341  |
| 50          | 0.697   | 9.052   | 9.361   | 12.777  | 15.013  | 14.334  | 6.147  | 0.574  | -0.355 | -0.281 | -0.527 | -0.549  |
| 60          | -0.003  | 5.360   | 7.847   | 11.010  | 9.894   | 11.183  | 4.773  | 0.053  | -0.184 | -0.237 | -0.500 | -0.418  |
| 70          | 0.145   | 3.894   | 6.578   | 5.250   | 5.731   | 7.930   | 3.235  | 0.089  | -0.039 | -0.158 | -0.412 | -0.325  |
| 80          | -0.140  | 1.247   | 2.321   | 2.268   | 4.795   | 5.741   | 2.477  | 0.240  | 0.127  | -0.089 | -0.306 | -0.257  |
| 85          | -0.113  | 0.586   | 2.056   | 1.669   | 3.322   | 3.513   | 1.679  | 0.175  | 0.153  | -0.154 | -0.343 | -0.224  |
| 90          | -0.099  | 0.215   | 1.947   | 0.467   | 2.616   | 2.151   | 0.168  | -0.056 | -0.040 | -0.186 | -0.351 | -0.234  |
| 95          | -0.208  | 0.097   | 0.653   | -0.596  | 0.360   | 0.623   | -0.450 | -0.282 | -0.191 | -0.276 | -0.388 | -0.269  |
| 99          | -0.345  | -0.550  | -0.256  | -0.617  | 0.014   | -0.726  | -0.613 | -0.515 | -0.388 | -0.368 | -0.434 | -0.356  |
| 99.9        | -0.343  | -0.380  | -0.401  | -0.538  | -0.282  | -0.597  | -0.563 | -0.519 | -0.449 | -0.423 | -0.445 | -0.387  |
| Sc2a-EWR    |         |         |         |         |         |         |        |        |        |        |        |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep     |
| 0.1         | 185.759 | 113.068 | 132.938 | 172.156 | 133.623 | 173.332 | 99.739 | 82.633 | 32.116 | 31.323 | 68.717 | 144.659 |
| 1           | 101.601 | 106.181 | 105.954 | 140.079 | 125.401 | 141.002 | 81.608 | 61.635 | 30.193 | 15.137 | 26.720 | 142.946 |
| 5           | 50.194  | 74.451  | 51.982  | 78.291  | 68.651  | 99.858  | 60.654 | 31.610 | 17.772 | 5.956  | 12.018 | 10.171  |
| 10          | 37.349  | 47.732  | 36.841  | 56.740  | 55.398  | 61.110  | 43.967 | 20.745 | 7.149  | 1.877  | 1.269  | 4.787   |
| 15          | 18.327  | 32.008  | 29.050  | 47.691  | 53.562  | 47.219  | 28.653 | 14.046 | 4.279  | 1.358  | 0.864  | 1.818   |
| 20          | 11.606  | 28.487  | 22.758  | 38.034  | 42.551  | 39.146  | 23.414 | 9.301  | 2.575  | 0.156  | 0.304  | 0.408   |
| 30          | 5.004   | 18.722  | 15.560  | 19.061  | 30.032  | 28.318  | 17.305 | 4.810  | 0.940  | -0.168 | -0.424 | -0.606  |
| 40          | 2.483   | 12.333  | 9.201   | 10.803  | 20.363  | 17.514  | 10.149 | 1.516  | -0.092 | -0.693 | -0.910 | -0.664  |
| 50          | 0.364   | 8.788   | 8.968   | 12.373  | 14.751  | 14.116  | 5.925  | 0.339  | -0.581 | -0.652 | -1.007 | -0.712  |
| 60          | -0.415  | 4.987   | 7.418   | 10.651  | 9.553   | 10.895  | 4.528  | -0.231 | -0.486 | -0.584 | -0.819 | -0.591  |
| 70          | -0.203  | 3.391   | 6.155   | 4.862   | 5.267   | 7.665   | 2.965  | -0.181 | -0.306 | -0.547 | -0.637 | -0.425  |
| 80          | -0.171  | 0.966   | 1.828   | 1.829   | 4.448   | 5.492   | 2.228  | -0.086 | -0.327 | -0.426 | -0.457 | -0.314  |
| 85          | -0.158  | 0.359   | 1.750   | 1.205   | 3.034   | 3.241   | 1.399  | -0.142 | -0.304 | -0.408 | -0.416 | -0.260  |
| 90          | -0.147  | 0.134   | 1.602   | 0.091   | 2.256   | 1.849   | -0.303 | -0.398 | -0.341 | -0.392 | -0.430 | -0.272  |
| 95          | -0.284  | -0.019  | 0.157   | -0.778  | 0.028   | 0.289   | -0.880 | -0.553 | -0.460 | -0.406 | -0.417 | -0.352  |
| 99          | -0.476  | -0.601  | -0.324  | -0.802  | -0.437  | -1.049  | -0.932 | -0.770 | -0.611 | -0.457 | -0.479 | -0.429  |
| 99.9        | -0.356  | -0.431  | -0.472  | -0.637  | -0.374  | -0.842  | -1.075 | -0.883 | -0.695 | -0.452 | -0.485 | -0.432  |
| Sc2b-EWR    |         |         |         |         |         |         |        |        |        |        |        |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep     |
| 0.1         | 185.759 | 113.068 | 132.938 | 172.146 | 133.634 | 173.332 | 99.739 | 82.633 | 32.116 | 31.323 | 68.717 | 144.659 |
| 1           | 101.601 | 106.181 | 105.954 | 140.078 | 125.403 | 141.002 | 81.608 | 61.635 | 30.193 | 15.137 | 26.720 | 142.946 |
| 5           | 50.193  | 73.561  | 51.921  | 78.291  | 68.649  | 99.858  | 60.654 | 31.610 | 17.773 | 5.697  | 12.018 | 10.171  |
| 10          | 37.349  | 47.732  | 36.842  | 56.740  | 55.398  | 61.110  | 43.967 | 20.745 | 7.150  | 1.877  | 1.409  | 4.787   |
| 15          | 18.327  | 32.008  | 28.186  | 47.691  | 53.562  | 47.133  | 28.653 | 14.046 | 4.279  | 1.358  | 0.864  | 1.817   |
| 20          | 11.606  | 28.487  | 22.705  | 38.035  | 42.552  | 39.145  | 23.414 | 9.302  | 2.575  | 0.155  | 0.551  | 0.497   |
| 30          | 5.004   | 18.721  | 15.561  | 19.012  | 30.031  | 28.318  | 17.290 | 4.810  | 0.940  | -0.142 | -0.010 | -0.131  |
| 40          | 2.484   | 12.004  | 8.983   | 10.619  | 20.363  | 17.514  | 10.150 | 1.517  | -0.092 | -0.288 | -0.455 | -0.269  |
| 50          | 0.364   | 8.788   | 8.964   | 12.373  | 14.751  | 14.117  | 5.925  | 0.338  | -0.501 | -0.280 | -0.505 | -0.362  |
| 60          | 0.000   | 4.988   | 7.419   | 10.650  | 9.553   | 10.895  | 4.528  | -0.221 | -0.265 | -0.105 | -0.407 | -0.355  |
| 70          | 0.249   | 3.377   | 6.155   | 4.863   | 5.267   | 7.665   | 2.965  | 0.030  | -0.010 | -0.032 | -0.270 | -0.266  |
| 80          | -0.069  | 1.443   | 2.035   | 2.093   | 4.448   | 5.488   | 2.228  | 0.188  | 0.154  | 0.003  | -0.212 | -0.138  |
| 85          | -0.080  | 0.617   | 1.831   | 1.463   | 3.152   | 3.236   | 1.430  | 0.035  | 0.182  | -0.003 | -0.261 | -0.185  |
| 90          | -0.046  | 0.159   | 1.695   | 0.406   | 2.332   | 1.849   | 0.208  | -0.039 | -0.052 | -0.126 | -0.368 | -0.207  |
| 95          | -0.092  | 0.047   | 0.589   | -0.469  | 0.379   | 0.386   | -0.409 | -0.185 | -0.138 | -0.243 | -0.405 | -0.242  |
| 99          | -0.296  | -0.553  | -0.113  | -0.802  | -0.008  | -0.764  | -0.525 | -0.553 | -0.316 | -0.370 | -0.427 | -0.380  |
| 99.9        | -0.338  | -0.426  | -0.451  | -0.637  | -0.331  | -0.635  | -0.590 | -0.555 | -0.462 | -0.444 | -0.443 | -0.415  |

### 5.3 IUA3 Caledon

Ecological consequences were assessed for the Lower Caledon (site UO\_EWR04\_I) within this IUA. Welbedacht Dam is situated upstream of the EWR site. However, it is almost fully silted with less than 10% of its storage available.

All the scenarios were assessed, namely present day (Sc1), medium term (Sc2) and long term (Sc3) without and with EWR. Table 13 shows the average flows (1920 - 2004) measured in Mm<sup>3</sup>.

**Table 13: Average flows (1920-2004) for UO\_EWR04\_I**

| Average Flows (1920-2004) – Mm <sup>3</sup> |            |
|---------------------------------------------|------------|
|                                             | UO_EWR04_I |
| nMAR                                        | 1 353.6    |
| Sc1a (PRS)                                  | 1 111.7    |
| Sc1b                                        | 1 122.4    |
| Sc2a                                        | 1 093.4    |
| Sc2b                                        | 1 106.9    |
| Sc3a                                        | 1 080.7    |
| Sc3b                                        | 1 095.4    |

As part of the consequences workshop due to negative socio-economic impacts if the EWR is implemented, the requirements were adjusted by reducing the maintenance low flow requirements. A summary of the final revised EWR is presented in Table 14.

**Table 14: Lower Caledon - Summary of the final EWR results (flows in Mm<sup>3</sup> a)**

| Quaternary Catchment            | D24G                 |                      |
|---------------------------------|----------------------|----------------------|
| River                           | Lower Caledon        |                      |
| Site code                       | UO_EWR04_I           |                      |
| Recommended Ecological Category | C/D                  |                      |
|                                 | 2024                 | Revised, Mar 2025    |
| nMAR at EWR site                | 1 353.6              |                      |
| Total EWR                       | 398.387 (29.43 %MAR) | 372.665 (27.53 %MAR) |
| Maintenance Low flows           | 203.857 (15.06 %MAR) | 178.136 (13.16 %MAR) |
| Drought Low flows               | 36.860 (2.72 %MAR)   | 36.860 ( 2.72 %MAR)  |
| Maintenance High flows          | 194.530 (14.37 %MAR) | 194.530 (14.37 %MAR) |

The seasonal distribution (hydrograph) plot was prepared using the flows provided for the scenarios and is illustrated in Figure 8. Table 15 and Table 16 provide the estimated non-compliances for all the months for the scenarios (values in red).

The scenarios evaluated show reductions from the natural flows for all the months, especially in the drier months of July and August. The tables indicate that none of the scenarios could

meet the EWR all the time, even with the EWR implemented. However, with implementation of the EWR the deficits are lower.

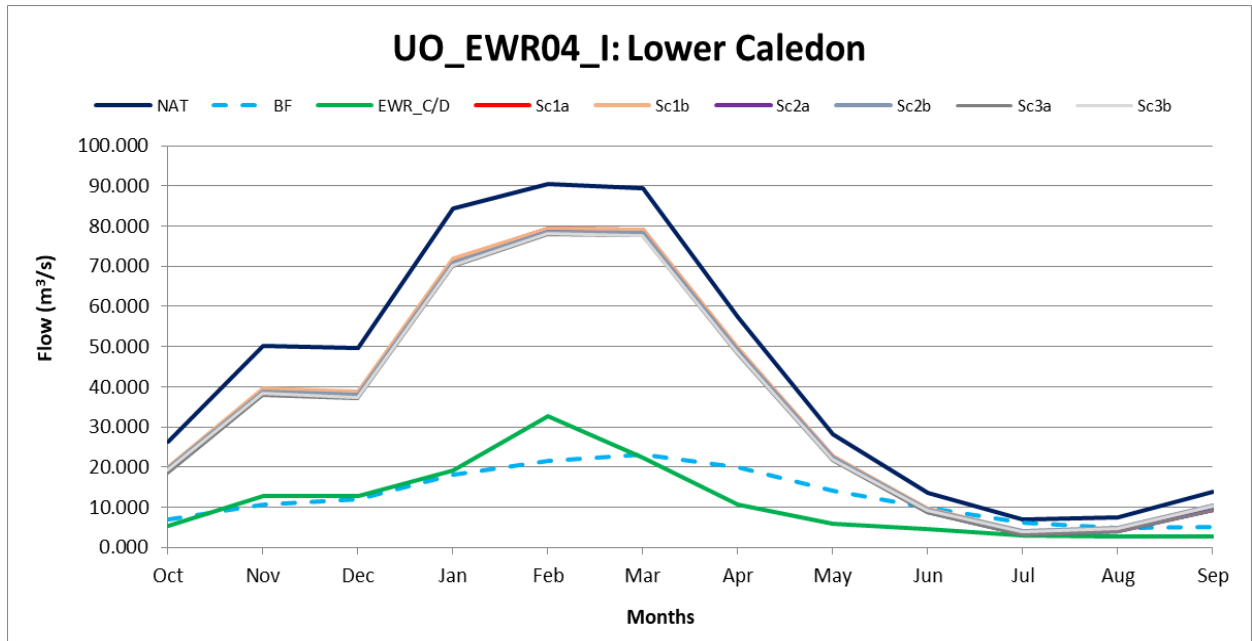


Figure 8: Seasonal distribution of scenarios at site UO\_EWR04\_I: Lower Caledon

**Table 15: Estimated non-compliances with EWR (Sc1 & Sc2) for all months at UO\_EWR04\_I**

| <b>Sc1a-EWR</b> |         |         |         |         |         |         |         |         |        |        |        |         |
|-----------------|---------|---------|---------|---------|---------|---------|---------|---------|--------|--------|--------|---------|
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug    | Sep     |
| 0.1             | 365.955 | 270.901 | 275.059 | 531.055 | 582.628 | 611.665 | 385.773 | 217.358 | 82.904 | 52.005 | 83.161 | 298.905 |
| 1               | 174.068 | 222.236 | 214.787 | 348.651 | 342.314 | 462.920 | 288.338 | 165.328 | 71.816 | 22.402 | 45.333 | 251.649 |
| 5               | 89.090  | 142.428 | 90.528  | 267.850 | 221.789 | 342.952 | 169.030 | 106.537 | 28.237 | 5.645  | 14.098 | 21.810  |
| 10              | 40.438  | 76.786  | 74.048  | 167.539 | 148.852 | 130.180 | 125.122 | 63.462  | 20.696 | 3.444  | 4.962  | 2.329   |
| 15              | 22.654  | 52.955  | 67.052  | 112.320 | 110.638 | 98.264  | 96.216  | 36.742  | 11.065 | 0.710  | -0.916 | 0.231   |
| 20              | 7.402   | 33.522  | 45.194  | 69.381  | 95.403  | 85.364  | 52.241  | 31.073  | 8.371  | -0.406 | -1.141 | -1.985  |
| 30              | -1.057  | 19.938  | 20.894  | 49.371  | 44.881  | 48.984  | 32.993  | 3.236   | -0.458 | -1.430 | -1.275 | -2.302  |
| 40              | -4.209  | 9.465   | 9.572   | 24.332  | 12.214  | 28.880  | 22.921  | -1.379  | -2.180 | -1.536 | -1.280 | -2.515  |
| 50              | -4.096  | 6.622   | 4.082   | 11.652  | 3.053   | 16.289  | 10.954  | -1.219  | -2.433 | -1.355 | -1.649 | -2.676  |
| 60              | -2.787  | -2.874  | 0.189   | 4.625   | -2.106  | 4.337   | 3.145   | -1.330  | -1.530 | -1.051 | -1.588 | -2.154  |
| 70              | -2.139  | -4.964  | 1.319   | 0.792   | -7.923  | 0.200   | 2.552   | -1.191  | -0.749 | -0.975 | -1.416 | -1.605  |
| 80              | -1.471  | -3.019  | -2.323  | -2.294  | -3.044  | -1.054  | 0.436   | -0.395  | -0.408 | -0.910 | -1.118 | -1.180  |
| 85              | -1.227  | -2.651  | -1.574  | -2.610  | -2.087  | -1.978  | -0.527  | -0.287  | -0.462 | -0.900 | -0.980 | -1.050  |
| 90              | -1.082  | -1.943  | -1.090  | -2.387  | -2.244  | -2.664  | -1.024  | -0.784  | -0.460 | -0.895 | -0.918 | -0.979  |
| 95              | -0.961  | -1.591  | -1.363  | -2.398  | -2.755  | -2.358  | -1.630  | -1.598  | -0.807 | -0.947 | -0.874 | -0.933  |
| 99              | -0.746  | -1.072  | -1.293  | -1.629  | -2.851  | -2.794  | -2.185  | -1.717  | -1.074 | -0.969 | -0.862 | -0.928  |
| 99.9            | -0.619  | -0.697  | -0.617  | -1.474  | -1.108  | -1.743  | -2.157  | -1.683  | -1.049 | -0.963 | -0.869 | -0.928  |
| <b>Sc1b-EWR</b> |         |         |         |         |         |         |         |         |        |        |        |         |
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug    | Sep     |
| 0.1             | 365.957 | 270.785 | 274.745 | 527.207 | 582.535 | 611.010 | 385.767 | 217.340 | 82.896 | 52.001 | 82.777 | 298.311 |
| 1               | 173.898 | 221.100 | 214.731 | 347.805 | 342.272 | 462.803 | 288.321 | 165.222 | 71.810 | 22.395 | 45.265 | 251.509 |
| 5               | 88.967  | 142.258 | 90.511  | 267.291 | 221.768 | 342.686 | 169.019 | 105.315 | 28.309 | 5.636  | 14.089 | 21.808  |
| 10              | 40.413  | 77.217  | 73.409  | 167.526 | 148.834 | 129.462 | 124.272 | 63.453  | 20.612 | 3.427  | 5.049  | 2.492   |
| 15              | 22.617  | 52.906  | 66.903  | 111.240 | 109.903 | 98.257  | 96.206  | 36.734  | 11.054 | 0.697  | -0.767 | 0.311   |
| 20              | 7.375   | 33.390  | 44.677  | 69.376  | 95.383  | 85.287  | 52.228  | 31.065  | 8.349  | -0.241 | -0.998 | -1.305  |
| 30              | 0.762   | 19.919  | 20.870  | 49.359  | 44.868  | 47.994  | 33.017  | 3.227   | -0.423 | -1.271 | -1.164 | -1.427  |
| 40              | -3.094  | 9.427   | 9.545   | 24.326  | 11.749  | 28.873  | 22.894  | -1.288  | -2.003 | -1.348 | -0.965 | -1.133  |
| 50              | -3.470  | 6.585   | 4.031   | 11.636  | 3.042   | 16.195  | 10.946  | -1.232  | -2.340 | -0.985 | -0.688 | -0.865  |
| 60              | -1.926  | -1.756  | 0.725   | 4.605   | -1.751  | 4.201   | 3.135   | -1.232  | -1.324 | -0.415 | -0.453 | -0.412  |
| 70              | -0.633  | -4.243  | 1.405   | 1.078   | -7.797  | 0.156   | 2.540   | -1.140  | -0.404 | 0.047  | -0.195 | -0.301  |
| 80              | -0.191  | -1.846  | -1.290  | -1.098  | -2.588  | -0.435  | 0.430   | -0.196  | 0.076  | 0.065  | -0.119 | -0.211  |
| 85              | -0.138  | -0.735  | -0.346  | -1.206  | -1.677  | -1.535  | -0.348  | 0.064   | 0.153  | 0.070  | -0.034 | -0.168  |
| 90              | -0.081  | -0.229  | -0.037  | -1.159  | -1.708  | -1.827  | -0.738  | 0.066   | 0.120  | 0.013  | -0.077 | -0.193  |
| 95              | -0.166  | -0.318  | 0.050   | -1.268  | -1.708  | -1.464  | -0.770  | -0.374  | 0.012  | -0.075 | -0.132 | -0.247  |
| 99              | -0.294  | -0.486  | -0.462  | -0.480  | -1.464  | -1.245  | -0.820  | -0.630  | -0.344 | -0.347 | -0.221 | -0.378  |
| 99.9            | -0.295  | -0.313  | -0.314  | -0.581  | -0.371  | -0.715  | -0.733  | -0.656  | -0.516 | -0.489 | -0.232 | -0.433  |
| <b>Sc2a-EWR</b> |         |         |         |         |         |         |         |         |        |        |        |         |
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug    | Sep     |
| 0.1             | 364.402 | 268.573 | 273.954 | 530.478 | 579.497 | 611.035 | 385.311 | 216.905 | 82.410 | 50.635 | 82.065 | 297.647 |
| 1               | 173.243 | 219.404 | 212.651 | 347.104 | 341.401 | 462.186 | 287.841 | 164.777 | 70.457 | 21.846 | 44.787 | 250.655 |
| 5               | 88.223  | 141.682 | 87.761  | 264.751 | 221.273 | 340.453 | 168.506 | 105.728 | 27.754 | 5.137  | 13.764 | 21.398  |
| 10              | 39.538  | 76.045  | 72.480  | 166.962 | 147.598 | 129.099 | 124.356 | 61.938  | 20.184 | 3.041  | 4.671  | 1.983   |
| 15              | 21.999  | 51.713  | 65.920  | 110.410 | 109.133 | 97.583  | 95.518  | 36.248  | 10.327 | 0.347  | -0.916 | -0.097  |
| 20              | 6.763   | 32.824  | 43.193  | 67.925  | 94.852  | 84.532  | 52.050  | 30.321  | 7.902  | -0.839 | -1.361 | -2.282  |
| 30              | -1.548  | 19.303  | 20.238  | 48.537  | 44.297  | 47.270  | 31.280  | 2.754   | -0.815 | -1.737 | -1.430 | -2.614  |
| 40              | -4.941  | 8.806   | 8.605   | 23.586  | 11.209  | 28.380  | 21.768  | -1.797  | -2.518 | -1.725 | -1.621 | -2.923  |
| 50              | -4.161  | 5.590   | 2.579   | 10.809  | 2.272   | 15.098  | 10.395  | -1.726  | -2.433 | -1.627 | -1.978 | -2.806  |
| 60              | -3.053  | -3.693  | -1.022  | 3.279   | -2.923  | 3.081   | 2.634   | -1.678  | -1.580 | -1.458 | -1.726 | -2.155  |
| 70              | -2.510  | -5.387  | 0.093   | -0.220  | -9.057  | -0.329  | 2.027   | -1.293  | -1.122 | -1.259 | -1.501 | -1.605  |
| 80              | -1.512  | -3.222  | -2.347  | -3.170  | -3.816  | -1.603  | -0.081  | -0.550  | -0.803 | -1.125 | -1.124 | -1.181  |
| 85              | -1.229  | -2.651  | -1.574  | -2.748  | -2.793  | -2.718  | -0.948  | -0.638  | -0.864 | -1.003 | -0.980 | -1.050  |
| 90              | -1.082  | -1.943  | -1.360  | -2.773  | -2.897  | -2.743  | -1.386  | -1.201  | -0.840 | -0.993 | -0.918 | -0.980  |
| 95              | -0.962  | -1.591  | -1.441  | -2.833  | -3.199  | -2.497  | -2.181  | -1.721  | -0.925 | -0.966 | -0.874 | -0.934  |
| 99              | -0.746  | -1.072  | -1.294  | -1.629  | -3.111  | -2.965  | -2.492  | -1.725  | -1.074 | -0.982 | -0.862 | -0.928  |
| 99.9            | -0.619  | -0.697  | -0.618  | -1.474  | -1.139  | -1.760  | -2.256  | -1.694  | -1.049 | -0.970 | -0.869 | -0.929  |
| <b>Sc2b-EWR</b> |         |         |         |         |         |         |         |         |        |        |        |         |
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug    | Sep     |
| 0.1             | 364.320 | 268.442 | 273.510 | 526.616 | 579.488 | 610.635 | 385.303 | 216.861 | 82.396 | 50.619 | 81.676 | 296.521 |
| 1               | 172.532 | 218.152 | 212.570 | 346.119 | 341.375 | 462.114 | 287.811 | 164.472 | 70.440 | 21.834 | 44.718 | 250.096 |
| 5               | 88.026  | 141.658 | 87.745  | 263.987 | 221.252 | 340.144 | 168.495 | 104.292 | 27.744 | 5.127  | 13.754 | 21.395  |
| 10              | 39.512  | 75.622  | 71.956  | 166.948 | 147.581 | 128.954 | 123.156 | 61.928  | 20.171 | 3.022  | 4.669  | 2.237   |
| 15              | 21.974  | 51.664  | 65.822  | 110.005 | 107.772 | 97.577  | 95.507  | 36.240  | 10.317 | 0.334  | -0.841 | 0.392   |
| 20              | 6.733   | 32.626  | 42.656  | 67.702  | 94.830  | 84.408  | 51.897  | 30.313  | 7.879  | -0.673 | -1.067 | -1.235  |
| 30              | 0.284   | 19.218  | 20.214  | 48.525  | 44.284  | 47.115  | 31.536  | 2.744   | -0.124 | -1.290 | -1.095 | -1.408  |
| 40              | -4.206  | 8.765   | 8.578   | 23.580  | 10.971  | 28.371  | 21.740  | -1.551  | -2.265 | -1.362 | -0.928 | -1.091  |
| 50              | -3.492  | 5.537   | 2.567   | 10.789  | 2.075   | 15.063  | 10.387  | -1.517  | -2.353 | -0.990 | -0.641 | -0.835  |
| 60              | -1.926  | -2.968  | -0.627  | 3.260   | -2.024  | 3.062   | 2.624   | -1.595  | -1.324 | -0.420 | -0.398 | -0.469  |
| 70              | -0.629  | -4.339  | 0.348   | -0.383  | -8.268  | -0.376  | 2.003   | -1.134  | -0.381 | 0.061  | -0.156 | -0.308  |
| 80              | -0.066  | -1.860  | -1.425  | -1.976  | -2.991  | -0.984  | 0.053   | -0.196  | 0.076  | 0.065  | -0.028 | -0.271  |
| 85              | -0.080  | -0.738  | -0.346  | -1.751  | -2.072  | -2.275  | -0.789  | 0.038   | 0.123  | 0.073  | 0.001  | -0.190  |
| 90              | -0.102  | -0.246  | -0.037  | -1.170  | -2.116  | -1.880  | -0.679  | 0.056   | 0.120  | 0.006  | -0.093 | -0.217  |
| 95              | -0.200  | -0.363  | 0.050   | -1.030  | -1.775  | -1.499  | -0.703  | -0.155  | 0.042  | -0.153 | -0.154 | -0.270  |
| 99              | -0.322  | -0.536  | -0.526  | -0.540  | -1.472  | -1.664  | -0.824  | -0.663  | -0.365 | -0.368 | -0.245 | -0.400  |
| 99.9            | -0.299  | -0.359  | -0.379  | -0.648  | -0.415  | -0.789  | -0.754  | -0.691  | -0.537 | -0.510 | -0.253 | -0.458  |

**Table 16: Estimated non-compliances with EWR (Sc3) for all months at UO\_EWR04\_I**

| <b>Sc3a-EWR</b> |         |         |         |         |         |         |         |         |        |        |        |         |  |
|-----------------|---------|---------|---------|---------|---------|---------|---------|---------|--------|--------|--------|---------|--|
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug    | Sep     |  |
| 0.1             | 363.893 | 268.040 | 272.904 | 529.931 | 578.462 | 610.447 | 384.825 | 216.410 | 80.953 | 50.160 | 81.033 | 296.558 |  |
| 1               | 172.634 | 218.470 | 212.075 | 345.911 | 340.893 | 461.690 | 287.270 | 164.116 | 69.810 | 21.371 | 44.200 | 249.833 |  |
| 5               | 87.308  | 141.060 | 87.232  | 262.590 | 220.793 | 338.077 | 168.030 | 104.549 | 27.276 | 4.689  | 13.406 | 20.933  |  |
| 10              | 38.899  | 75.224  | 71.412  | 166.316 | 147.125 | 128.650 | 123.338 | 61.467  | 19.720 | 2.612  | 4.440  | 1.611   |  |
| 15              | 21.472  | 50.738  | 63.939  | 109.491 | 107.842 | 97.059  | 95.042  | 35.775  | 9.864  | -0.032 | -0.916 | -0.252  |  |
| 20              | 6.364   | 32.243  | 42.031  | 67.257  | 94.311  | 83.917  | 51.955  | 29.362  | 7.450  | -0.911 | -1.403 | -2.333  |  |
| 30              | -0.796  | 18.830  | 19.553  | 47.987  | 43.823  | 46.410  | 30.399  | 2.303   | -1.196 | -1.802 | -1.556 | -2.980  |  |
| 40              | -5.009  | 8.405   | 7.900   | 23.119  | 10.477  | 27.908  | 21.204  | -2.174  | -2.859 | -2.091 | -1.941 | -3.138  |  |
| 50              | -4.524  | 4.914   | 1.897   | 10.350  | 0.902   | 14.534  | 9.928   | -2.103  | -2.617 | -1.992 | -2.213 | -2.807  |  |
| 60              | -3.467  | -4.164  | -1.443  | 2.860   | -3.372  | 2.111   | 2.145   | -1.962  | -1.735 | -1.792 | -1.851 | -2.155  |  |
| 70              | -2.551  | -5.502  | -0.542  | -1.400  | -9.443  | -0.918  | 1.464   | -1.356  | -1.488 | -1.496 | -1.534 | -1.606  |  |
| 80              | -1.512  | -3.295  | -2.411  | -3.539  | -4.169  | -2.092  | -0.383  | -0.841  | -1.140 | -1.160 | -1.133 | -1.181  |  |
| 85              | -1.229  | -2.652  | -1.683  | -2.959  | -2.990  | -3.173  | -1.101  | -1.004  | -1.046 | -1.039 | -0.984 | -1.050  |  |
| 90              | -1.083  | -1.943  | -1.609  | -2.910  | -2.964  | -2.761  | -1.751  | -1.500  | -1.056 | -0.993 | -0.921 | -0.980  |  |
| 95              | -0.963  | -1.593  | -1.446  | -2.834  | -3.488  | -2.584  | -2.541  | -1.721  | -1.026 | -0.966 | -0.876 | -0.934  |  |
| 99              | -0.746  | -1.074  | -1.294  | -1.632  | -3.111  | -2.965  | -2.553  | -1.725  | -1.074 | -0.982 | -0.865 | -0.928  |  |
| 99.9            | -0.619  | -0.698  | -0.618  | -1.478  | -1.139  | -1.760  | -2.262  | -1.694  | -1.049 | -0.970 | -0.870 | -0.929  |  |
| <b>Sc3b-EWR</b> |         |         |         |         |         |         |         |         |        |        |        |         |  |
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug    | Sep     |  |
| 0.1             | 363.849 | 267.825 | 272.361 | 526.053 | 578.515 | 610.106 | 384.818 | 216.364 | 80.939 | 50.145 | 80.645 | 295.379 |  |
| 1               | 172.540 | 216.377 | 211.976 | 344.775 | 340.879 | 461.629 | 287.241 | 163.810 | 69.793 | 21.358 | 44.133 | 248.681 |  |
| 5               | 87.057  | 141.043 | 87.097  | 261.660 | 220.771 | 337.913 | 168.019 | 103.732 | 27.267 | 4.680  | 13.395 | 20.930  |  |
| 10              | 38.873  | 74.422  | 70.944  | 165.918 | 147.108 | 128.628 | 122.323 | 61.456  | 19.708 | 2.587  | 4.424  | 2.523   |  |
| 15              | 21.445  | 50.688  | 63.905  | 109.479 | 105.915 | 97.029  | 94.855  | 35.763  | 9.851  | -0.033 | -0.841 | 0.620   |  |
| 20              | 6.334   | 32.048  | 41.431  | 66.380  | 94.295  | 83.770  | 51.753  | 28.812  | 7.425  | -0.742 | -1.066 | -1.307  |  |
| 30              | 0.002   | 18.755  | 19.529  | 47.975  | 43.810  | 45.944  | 30.255  | 2.294   | -0.965 | -1.374 | -1.145 | -1.408  |  |
| 40              | -4.626  | 8.365   | 7.890   | 23.112  | 10.446  | 27.898  | 21.165  | -1.928  | -2.480 | -1.369 | -0.988 | -1.091  |  |
| 50              | -3.588  | 4.876   | 1.861   | 10.330  | 0.521   | 13.844  | 9.920   | -1.894  | -2.353 | -1.021 | -0.688 | -0.868  |  |
| 60              | -1.933  | -3.379  | -1.066  | 2.840   | -2.458  | 2.287   | 2.070   | -1.753  | -1.324 | -0.425 | -0.484 | -0.510  |  |
| 70              | -0.633  | -4.345  | -0.019  | -0.777  | -8.671  | -0.870  | 1.453   | -1.130  | -0.409 | 0.018  | -0.220 | -0.458  |  |
| 80              | -0.229  | -1.848  | -1.425  | -2.345  | -3.326  | -1.474  | -0.252  | -0.186  | 0.076  | 0.059  | -0.155 | -0.295  |  |
| 85              | -0.196  | -0.739  | -0.353  | -1.752  | -2.271  | -2.760  | -0.932  | 0.038   | 0.044  | 0.053  | -0.092 | -0.256  |  |
| 90              | -0.150  | -0.290  | -0.037  | -1.194  | -2.192  | -1.906  | -0.683  | 0.056   | 0.026  | 0.006  | -0.144 | -0.246  |  |
| 95              | -0.298  | -0.382  | 0.050   | -1.027  | -1.781  | -1.464  | -0.731  | -0.415  | -0.127 | -0.176 | -0.203 | -0.290  |  |
| 99              | -0.338  | -0.559  | -0.542  | -0.559  | -1.474  | -1.258  | -0.842  | -0.681  | -0.383 | -0.572 | -0.324 | -0.418  |  |
| 99.9            | -0.301  | -0.386  | -0.381  | -0.671  | -0.431  | -0.765  | -0.783  | -0.710  | -0.556 | -0.598 | -0.566 | -0.473  |  |

#### 5.4 IUA4 Kraai

Ecological consequences were assessed for the Kraai River (site UO\_EWR08\_I) within this IUA. No large dams are situated upstream of the EWR site. All the scenarios were assessed, namely present day (Sc1), medium term (Sc2) and long term (Sc3) without and with EWR. Refer to Table 17 for the average flows (1920 - 2004) measured in Mm<sup>3</sup>.

**Table 17: Average flows (1920-2004) for UO\_EWR04\_I**

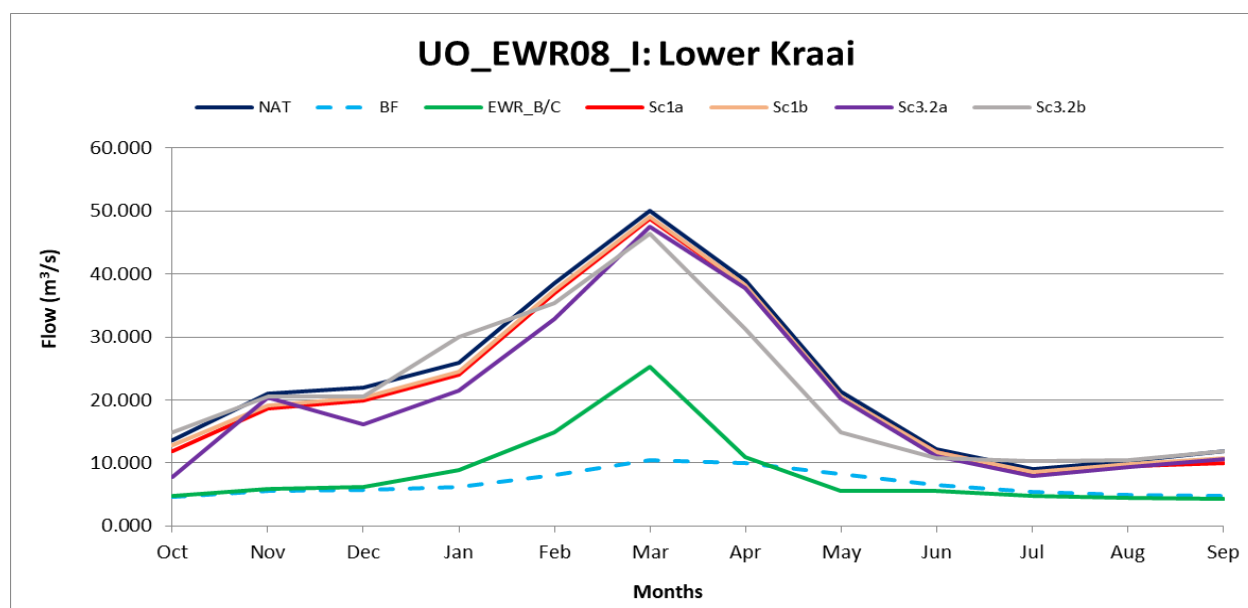
| <b>Average Flows (1920-2004) – Mm<sup>3</sup></b> |                   |
|---------------------------------------------------|-------------------|
|                                                   | <b>UO_EWR08_I</b> |
| nMAR                                              | 719.0             |
| Sc1a (PRS)                                        | 675.2             |
| Sc1b                                              | 688.3             |
| Sc2a                                              | 675.7             |
| Sc2b                                              | 692.2             |
| Sc3.2a                                            | 636.4             |
| Sc3.2b                                            | 673.6             |

As the present day and medium-term scenarios are very similar, only Sc1 and Sc3 were assessed. Due to the negative socio-economic impacts if the EWR is implemented, especially during drought periods, the requirements were adjusted by reducing the drought flow requirements with a minimum of 0.3 m<sup>3</sup>/s for the months of November to February. A summary of the final revised EWR is presented in Table 18.

**Table 18: Summary of the final EWR results (flows in Mm<sup>3</sup>/a)**

| Quaternary Catchment            | D13M                 |                      |
|---------------------------------|----------------------|----------------------|
| River                           | Lower Kraai          |                      |
| Site code                       | UO_EWR08_I           |                      |
| Recommended Ecological Category | B/C                  |                      |
|                                 | 2024                 | Revised, Mar 2025    |
| nMAR at EWR site                | 719.0                |                      |
| Total EWR                       | 334.513 (46.52 %MAR) | 329.531 (45.83 %MAR) |
| Maintenance Low flows           | 200.869 (27.94 %MAR) | 200.631 (27.90 %MAR) |
| Drought Low flows               | 40.997 (5.70 %MAR)   | 11.579 ( 1.61 %MAR)  |
| Maintenance High flows          | 133.644 (18.59 %MAR) | 128.900 (17.93 %MAR) |

The seasonal distribution (hydrograph) plot was prepared using the flows provided for the scenarios and is illustrated in Figure 9. **Table 19** provides the estimated non-compliances for all the months for the scenarios (values in red). The scenario evaluated show small reductions from the natural flows for all the months. The results indicate that the deficits are mainly during the wetter months in Sc1, when the EWR is not met all the time even when implemented (Sc1b). Scenario Sc3.2b shows that the EWR could be met all the time when the EWR is implemented with the proposed Boskraai Dam.



**Figure 9: Seasonal distribution of scenarios at site UO\_EWR08\_I: Lower Kraai**

**Table 19: Estimated non-compliances with EWR (Sc1 & Sc3) for all months at UO\_EWR08\_I**

| <b>Sc1a-EWR</b>   |         |         |         |         |         |         |         |         |        |        |         |         |
|-------------------|---------|---------|---------|---------|---------|---------|---------|---------|--------|--------|---------|---------|
| Percentiles       | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug     | Sep     |
| 0.1               | 221.755 | 156.394 | 126.971 | 254.755 | 344.654 | 224.126 | 292.630 | 140.209 | 53.533 | 61.235 | 122.575 | 153.429 |
| 1                 | 109.886 | 140.495 | 123.473 | 151.305 | 268.356 | 220.458 | 215.939 | 127.297 | 44.894 | 51.912 | 76.029  | 96.966  |
| 5                 | 40.953  | 81.902  | 67.582  | 75.741  | 121.804 | 117.253 | 77.422  | 70.280  | 32.177 | 13.691 | 27.934  | 36.162  |
| 10                | 18.996  | 43.552  | 44.878  | 40.435  | 72.750  | 64.228  | 64.736  | 37.056  | 21.675 | 9.832  | 8.248   | 15.963  |
| 15                | 6.475   | 17.555  | 34.796  | 34.478  | 38.997  | 53.988  | 59.420  | 24.449  | 10.637 | 4.924  | 5.640   | 5.727   |
| 20                | 2.876   | 14.698  | 25.055  | 24.194  | 33.009  | 32.109  | 46.780  | 21.414  | 8.525  | 4.895  | 3.853   | 2.763   |
| 30                | -0.006  | 5.459   | 10.368  | 14.182  | 13.382  | 9.547   | 30.774  | 10.178  | 3.865  | 2.416  | 1.837   | 0.942   |
| 40                | -0.705  | 0.175   | 4.784   | 5.523   | 2.354   | 10.188  | 15.640  | 6.593   | 3.631  | 1.787  | 1.190   | -1.177  |
| 50                | -0.876  | -0.392  | -0.351  | -0.214  | -1.975  | 4.455   | 7.170   | 5.578   | 3.598  | 2.354  | 1.168   | -1.258  |
| 60                | -0.923  | -0.733  | -1.004  | -2.442  | -0.503  | 2.384   | 4.635   | 4.916   | 3.852  | 2.379  | 1.170   | -0.485  |
| 70                | -0.592  | -0.423  | -0.957  | -1.752  | 0.982   | 2.584   | 3.670   | 4.613   | 4.257  | 2.278  | 1.412   | 0.047   |
| 80                | -0.539  | -0.437  | -0.907  | -1.255  | -0.908  | 3.042   | 3.838   | 4.489   | 3.163  | 2.369  | 1.458   | 0.004   |
| 85                | -0.448  | -0.416  | -0.654  | -0.914  | -0.831  | 2.615   | 3.534   | 2.278   | 2.773  | 2.044  | 1.469   | -0.077  |
| 90                | -0.478  | -0.519  | -0.520  | -0.686  | -1.344  | 1.228   | 2.392   | 2.169   | 2.141  | 1.903  | 1.223   | -0.139  |
| 95                | -0.491  | -0.510  | -0.371  | -0.224  | -0.930  | -1.272  | 0.842   | 1.066   | 1.633  | 1.607  | 0.917   | -0.252  |
| 99                | -0.500  | -0.302  | -0.190  | -0.122  | -0.121  | -1.012  | -0.833  | 0.187   | 1.095  | 1.210  | 0.671   | -0.313  |
| 99.9              | -0.502  | -0.250  | -0.126  | -0.093  | -0.087  | -0.849  | -0.603  | -0.054  | 1.009  | 0.909  | 0.570   | -0.313  |
| <b>Sc1b-EWR</b>   |         |         |         |         |         |         |         |         |        |        |         |         |
| Percentiles       | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug     | Sep     |
| 0.1               | 221.743 | 156.389 | 122.712 | 254.673 | 344.305 | 224.068 | 292.623 | 140.198 | 53.525 | 61.165 | 122.561 | 153.419 |
| 1                 | 109.880 | 140.475 | 122.637 | 151.287 | 267.827 | 220.439 | 215.937 | 127.291 | 44.885 | 51.896 | 75.893  | 96.951  |
| 5                 | 40.939  | 79.810  | 67.556  | 75.740  | 120.526 | 116.944 | 77.419  | 70.271  | 32.121 | 13.675 | 27.929  | 36.125  |
| 10                | 18.979  | 43.533  | 44.866  | 40.429  | 72.712  | 64.222  | 64.685  | 37.051  | 21.651 | 9.823  | 8.239   | 16.871  |
| 15                | 7.922   | 17.544  | 33.577  | 34.475  | 38.996  | 53.973  | 59.408  | 24.437  | 10.632 | 4.976  | 6.178   | 5.723   |
| 20                | 2.875   | 14.464  | 25.046  | 24.177  | 32.775  | 32.099  | 46.772  | 21.397  | 8.523  | 4.891  | 5.026   | 2.995   |
| 30                | 0.388   | 5.452   | 10.363  | 14.170  | 13.368  | 9.532   | 30.763  | 10.173  | 3.898  | 2.550  | 3.127   | 1.559   |
| 40                | 0.980   | 0.319   | 5.649   | 5.517   | 2.805   | 10.170  | 15.620  | 6.583   | 3.617  | 2.207  | 1.824   | 0.501   |
| 50                | 0.633   | 0.517   | 2.074   | 1.771   | -0.465  | 5.717   | 7.169   | 5.570   | 3.643  | 2.800  | 1.573   | 0.499   |
| 60                | 0.951   | 0.744   | 0.206   | -0.078  | 0.869   | 3.028   | 5.028   | 4.910   | 3.923  | 2.559  | 1.467   | 0.702   |
| 70                | 0.804   | 0.867   | 0.616   | -0.496  | 2.162   | 3.883   | 3.695   | 4.889   | 4.301  | 2.300  | 1.498   | 0.970   |
| 80                | 0.419   | 0.984   | 0.112   | -0.224  | 0.248   | 3.805   | 3.805   | 4.750   | 3.313  | 2.426  | 1.517   | 1.038   |
| 85                | 0.477   | 0.883   | 0.221   | -0.296  | 0.341   | 3.361   | 3.575   | 2.361   | 2.972  | 2.121  | 1.500   | 1.015   |
| 90                | 0.437   | 0.300   | -0.256  | -0.299  | -0.444  | 1.590   | 2.343   | 2.151   | 2.375  | 1.934  | 1.215   | 1.009   |
| 95                | 0.098   | 0.067   | -0.290  | -0.200  | -0.281  | -0.425  | 0.914   | 1.429   | 1.711  | 1.595  | 0.984   | 0.695   |
| 99                | -0.147  | -0.307  | -0.188  | -0.122  | -0.120  | -0.231  | -0.332  | 0.802   | 1.082  | 1.197  | 0.974   | 0.456   |
| 99.9              | -0.204  | -0.254  | -0.129  | -0.094  | -0.088  | -0.066  | -0.059  | 0.363   | 1.001  | 0.899  | 0.958   | 0.416   |
| <b>Sc3.2a-EWR</b> |         |         |         |         |         |         |         |         |        |        |         |         |
| Percentiles       | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug     | Sep     |
| 0.1               | 83.647  | 303.118 | 119.587 | 244.099 | 345.046 | 225.304 | 293.665 | 140.605 | 52.867 | 61.674 | 123.418 | 154.091 |
| 1                 | 78.122  | 189.295 | 100.850 | 143.681 | 269.303 | 222.963 | 216.305 | 127.703 | 44.103 | 52.221 | 76.027  | 97.747  |
| 5                 | 32.977  | 107.779 | 57.740  | 69.007  | 113.825 | 117.479 | 77.143  | 69.897  | 31.236 | 17.247 | 35.036  | 41.633  |
| 10                | 11.675  | 35.037  | 38.815  | 38.796  | 64.773  | 64.512  | 64.665  | 36.528  | 20.897 | 11.438 | 15.171  | 23.246  |
| 15                | 3.937   | 20.418  | 22.999  | 32.667  | 35.349  | 53.352  | 59.131  | 23.926  | 11.473 | 6.122  | 6.423   | 11.724  |
| 20                | 1.511   | 14.851  | 19.739  | 25.292  | 28.290  | 32.384  | 47.015  | 20.893  | 8.141  | 4.194  | 3.818   | 6.419   |
| 30                | -2.040  | 7.580   | 6.901   | 12.561  | 10.605  | 13.437  | 32.434  | 9.514   | 3.416  | 1.803  | 1.348   | 0.588   |
| 40                | -2.814  | -1.821  | 2.265   | 3.068   | -2.634  | 10.240  | 15.414  | 6.016   | 3.511  | 1.232  | 0.362   | -1.802  |
| 50                | -3.780  | -2.136  | -1.849  | -3.167  | -3.867  | 2.724   | 7.306   | 5.711   | 2.937  | 1.745  | 0.195   | -2.643  |
| 60                | -2.752  | -2.892  | -3.243  | -4.763  | -4.472  | 0.561   | 4.213   | 4.947   | 3.283  | 1.585  | 0.160   | -2.096  |
| 70                | -1.569  | -1.608  | -1.944  | -2.240  | -4.927  | 0.927   | 2.045   | 4.077   | 3.409  | 1.296  | 0.125   | -1.187  |
| 80                | -0.830  | -0.858  | -0.960  | -1.313  | -2.951  | -1.017  | 2.302   | 3.947   | 2.316  | 1.375  | 0.181   | -0.602  |
| 85                | -0.656  | -0.655  | -0.696  | -0.959  | -2.228  | -1.172  | -0.259  | 1.408   | 2.040  | 1.116  | 0.122   | -0.465  |
| 90                | -0.571  | -0.567  | -0.554  | -0.724  | -1.627  | -2.744  | -1.402  | 0.985   | 0.868  | 0.932  | -0.218  | -0.398  |
| 95                | -0.522  | -0.534  | -0.397  | -0.253  | -0.975  | -2.574  | -1.368  | -0.467  | 0.436  | 0.460  | -0.357  | -0.352  |
| 99                | -0.522  | -0.320  | -0.210  | -0.143  | -0.144  | -1.051  | -1.043  | -0.511  | -0.441 | -0.376 | -0.356  | -0.350  |
| 99.9              | -0.522  | -0.265  | -0.145  | -0.112  | -0.110  | -0.885  | -0.649  | -0.511  | -0.441 | -0.376 | -0.356  | -0.350  |
| <b>Sc3.2b-EWR</b> |         |         |         |         |         |         |         |         |        |        |         |         |
| Percentiles       | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun    | Jul    | Aug     | Sep     |
| 0.1               | 115.913 | 299.435 | 114.088 | 152.455 | 168.547 | 224.765 | 293.665 | 120.359 | 65.431 | 57.104 | 123.132 | 87.669  |
| 1                 | 113.385 | 152.463 | 99.692  | 146.150 | 156.609 | 221.568 | 216.305 | 79.011  | 45.725 | 53.203 | 75.843  | 84.430  |
| 5                 | 78.507  | 85.699  | 61.311  | 108.961 | 116.980 | 117.169 | 67.759  | 38.962  | 33.985 | 39.076 | 26.606  | 40.589  |
| 10                | 19.526  | 42.454  | 46.520  | 90.760  | 77.995  | 42.674  | 58.009  | 28.266  | 18.997 | 14.818 | 14.925  | 25.289  |
| 15                | 6.599   | 16.629  | 33.673  | 53.287  | 49.070  | 15.103  | 41.618  | 18.658  | 9.236  | 8.156  | 7.406   | 16.675  |
| 20                | 4.560   | 11.243  | 23.560  | 35.663  | 28.556  | 12.041  | 32.232  | 8.759   | 3.334  | 4.135  | 5.275   | 5.469   |
| 30                | 1.057   | 2.922   | 11.856  | 13.246  | 4.703   | 9.220   | 11.536  | 2.258   | 2.938  | 3.565  | 3.253   | 3.237   |
| 40                | 1.565   | 1.760   | 4.548   | 5.507   | 6.351   | 11.998  | 5.043   | 2.541   | 2.574  | 2.520  | 2.052   | 1.824   |
| 50                | 1.603   | 2.693   | 4.306   | 7.423   | 9.684   | 17.911  | 4.950   | 2.948   | 2.957  | 2.724  | 2.232   | 2.123   |
| 60                | 2.001   | 2.042   | 4.922   | 5.478   | 3.142   | 11.723  | 4.708   | 4.029   | 3.032  | 3.053  | 1.905   | 2.074   |
| 70                | 1.791   | 1.930   | 2.592   | 2.943   | 4.213   | 5.631   | 2.446   | 3.949   | 2.852  | 1.976  | 1.643   | 1.669   |
| 80                | 1.304   | 1.508   | 2.134   | 1.148   | 1.645   | 5.821   | 3.066   | 2.486   | 1.927  | 1.366  | 1.321   | 1.376   |
| 85                | 1.133   | 1.205   | 1.049   | 0.536   | 1.425   | 5.103   | 2.017   | 1.647   | 1.781  | 1.300  | 1.062   | 1.193   |
| 90                | 1.101   | 0.690   | 0.339   | 0.294   | 1.040   | 3.875   | 1.676   | 1.106   | 1.208  | 1.082  | 1.007   | 1.061   |
| 95                | 0.830   | 0.536   | 0.126   | 0.225   | 0.470   | 1.287   | 0.764   | 0.908   | 0.935  | 0.987  | 0.987   | 0.951   |
| 99                | 0.466   | -0.002  | 0.052   | 0.046   | 0.680   | 0.609   | 0.559   | 0.805   | 0.903  | 0.959  | 0.980   | 0.872   |
| 99.9              | 0.461   | -0.011  | 0.082   | 0.052   | 0.109   | 0.275   | 0.525   | 0.559   | 0.845  | 0.959  | 0.977   | 0.828   |

## 5.5 IUA5: Upper Orange River

Ecological consequences were assessed for the Upper Orange (site UO\_EWR03\_I) and Sterkspruit (UO\_EWR02\_I) within this IUA. Dams in Lesotho impacts on the flows at the Upper Orange EWR site and the Jozana's Hoek Dam in the upper reaches of the Sterkspruit resulting in reduced floods and freshets.

Only present-day scenarios were assessed for the Sterkspruit as no future developments are planned for this catchment. However, present day, medium term and long term with some interventions were assessed for the Orange River EWR site. Refer to Table 20 for the average flows (1920 - 2004) at the two EWR sites measured in Mm<sup>3</sup>.

**Table 20: Average flows (1920-2004) for UO\_EWR02\_I**

| Average Flows (1920-2004) – Mm <sup>3</sup> |                   |
|---------------------------------------------|-------------------|
|                                             | <b>UO_EWR02_I</b> |
| nMAR                                        | 30.7              |
| Sc1a (PRS)                                  | 25.2              |
| Sc1b                                        | 25.2              |
|                                             | <b>UO_EWR03_I</b> |
| nMAR                                        | 4 259.5           |
| Sc1a (PRS)                                  | 3 456.3           |
| Sc1b                                        | 3 456.6           |
| Sc2a                                        | 2 979.0           |
| Sc2b                                        | 2 979.9           |
| Sc3a                                        | 2 892.2           |
| Sc3b                                        | 2 897.6           |
| Sc3.1a                                      | 2 610.3           |
| Sc3.1b                                      | 2 615.0           |

No changes were made to the EWR as determined during the high confidence study of the Reserve for the Upper Orange River or the Sterkspruit.

The seasonal distribution (hydrograph) plots were prepared using the flows provided for the scenarios and is illustrated in Figure 10: Seasonal distribution of scenarios (Sc1 & Sc2) at site UO\_EWR03\_I: Upper Orange, Figure 11 and Figure 12.

The graphs indicate that all the flow components are reduced during the scenarios, especially the peaks due to the proposed dams in the medium and long term.

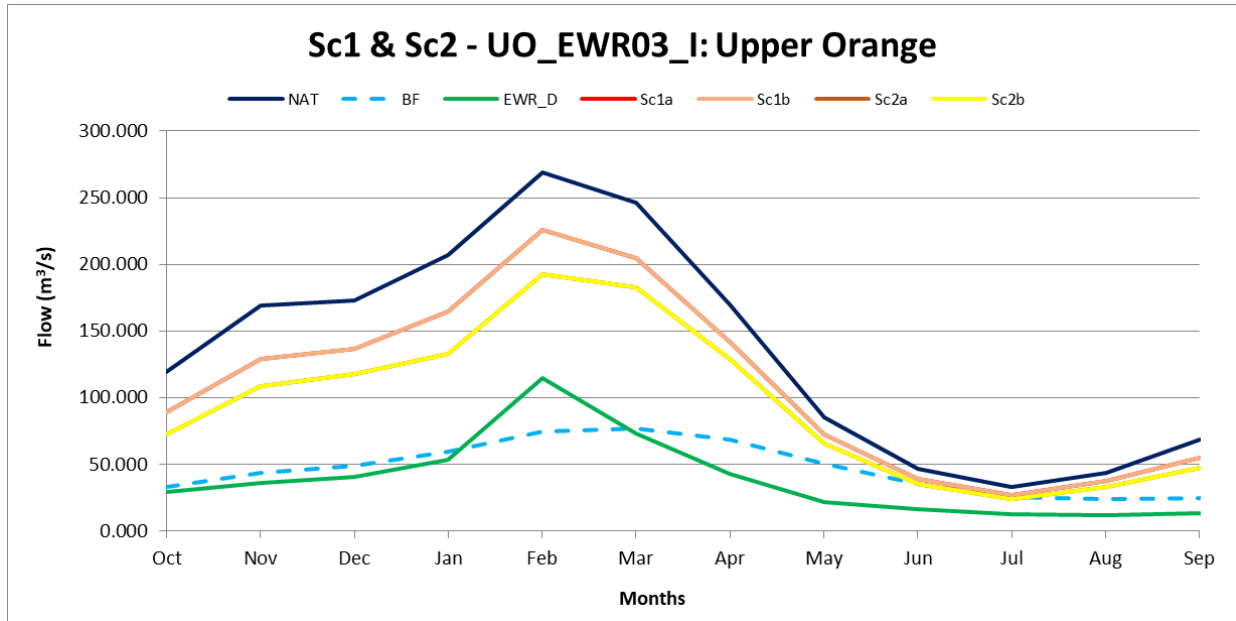


Figure 10: Seasonal distribution of scenarios (Sc1 & Sc2) at site UO\_EWR03\_I: Upper Orange

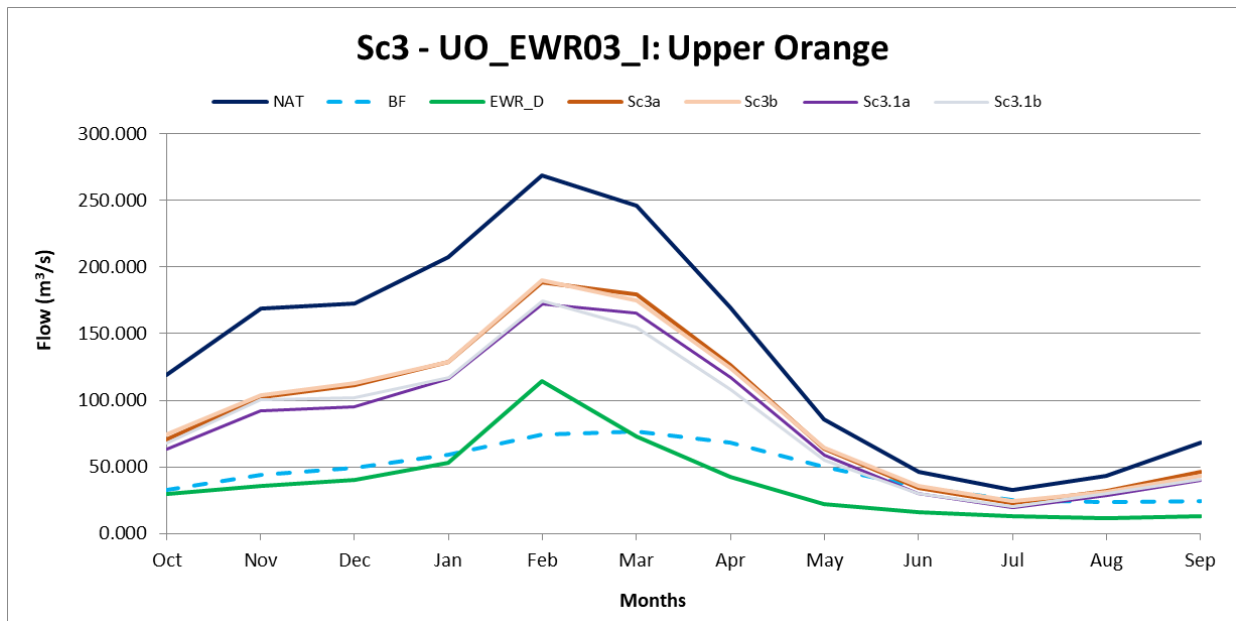
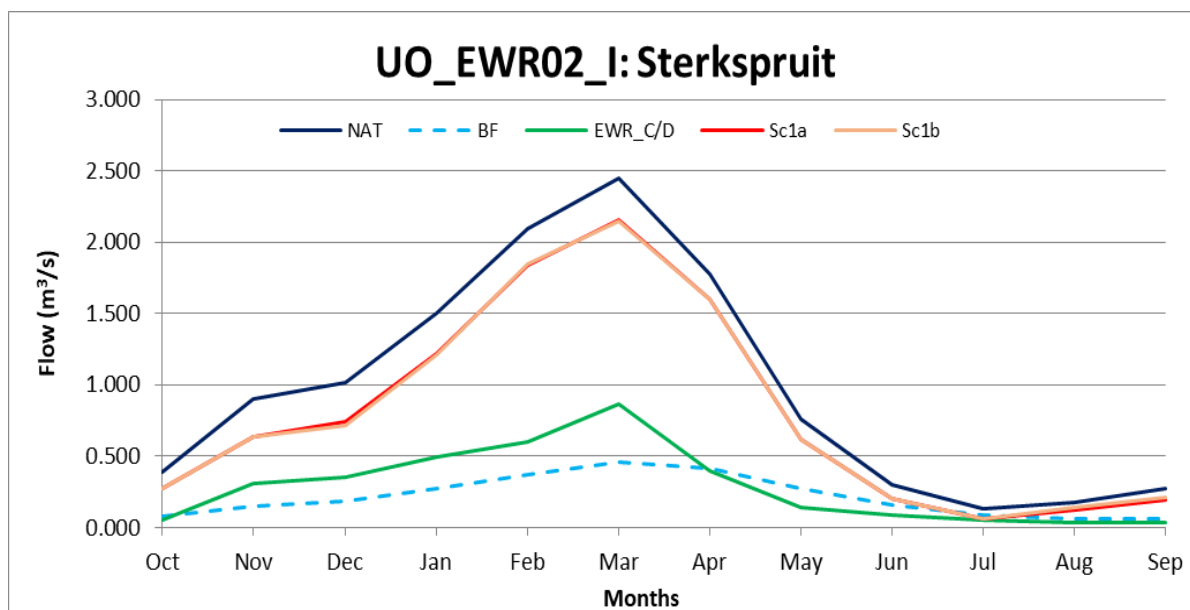


Figure 11: Seasonal distribution of scenarios (Sc3) at site UO\_EWR03\_I: Upper Orange



**Figure 12: Seasonal distribution of scenarios at site UO\_EWR02\_I: Sterkspruit**

Table 21, Table 22 and Table 23 provide the estimated non-compliances for all the months for the scenarios (values in red).

The scenarios for the Sterkspruit evaluated show reductions from the natural flows for all the months. However, very small reductions between present day without (Sc1a) and with EWR (Sc1b).

The results indicate that the EWR could be met for most of the time for Sc1 and Sc2 irrespective if the EWR was implemented or not. Non-compliances were mostly during drought periods (95 to 99.9 percentiles). Scenarios Sc3a and Sc3.1a show more deficits, however, when EWR is implemented, these deficits are reduced and only during drought periods.

The EWR could not be met in either Sc1a or Sc1b. This is mostly due to Jozana’s Hoek Dam in the upper reaches of the Sterkspruit with limited release capacities.

**Table 21: Estimated non-compliances with EWR (Sc1 & Sc2) for all months at UO\_EWR03\_I**

| Sc1a-EWR    |         |         |         |         |         |         |         |         |         |         |         |         |
|-------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1         | 628.895 | 559.259 | 564.905 | 502.372 | 713.725 | 687.432 | 465.686 | 470.503 | 166.528 | 110.056 | 315.811 | 550.081 |
| 1           | 579.534 | 544.894 | 455.091 | 471.213 | 565.679 | 627.723 | 442.792 | 284.255 | 162.228 | 104.016 | 233.997 | 461.942 |
| 5           | 312.076 | 394.035 | 328.533 | 391.959 | 404.840 | 362.689 | 400.887 | 175.333 | 117.237 | 76.533  | 102.637 | 214.927 |
| 10          | 135.522 | 213.324 | 279.110 | 298.812 | 304.846 | 299.575 | 237.972 | 132.080 | 66.396  | 46.508  | 72.134  | 99.073  |
| 15          | 117.664 | 172.732 | 186.358 | 246.316 | 252.405 | 265.854 | 187.779 | 99.626  | 40.567  | 28.775  | 42.083  | 66.029  |
| 20          | 91.897  | 155.343 | 151.552 | 172.589 | 201.357 | 193.315 | 140.020 | 77.494  | 30.985  | 23.454  | 36.167  | 30.418  |
| 30          | 35.611  | 96.553  | 122.587 | 110.937 | 79.019  | 152.311 | 107.624 | 45.973  | 16.277  | 11.344  | 23.034  | 22.873  |
| 40          | 18.315  | 59.931  | 73.902  | 84.099  | 39.535  | 112.891 | 79.828  | 36.782  | 7.670   | 3.407   | 7.897   | 15.219  |
| 50          | 3.388   | 42.789  | 52.909  | 73.415  | 31.875  | 85.378  | 52.346  | 18.012  | 8.346   | 2.044   | 4.959   | 4.649   |
| 60          | 6.557   | 28.415  | 27.125  | 56.567  | 30.078  | 61.146  | 38.387  | 13.465  | 8.790   | 2.902   | 3.891   | 0.435   |
| 70          | 3.385   | 26.412  | 17.295  | 24.622  | 28.143  | 52.351  | 31.967  | 11.436  | 5.376   | 1.389   | 5.173   | 1.449   |
| 80          | 3.420   | 23.174  | 12.740  | 17.998  | 36.371  | 45.464  | 28.969  | 11.589  | 4.632   | 1.726   | 5.085   | -0.290  |
| 85          | 3.159   | 22.126  | 14.193  | 21.145  | 31.378  | 33.295  | 20.170  | 9.253   | 4.915   | 1.049   | 4.917   | 0.324   |
| 90          | 2.043   | 11.089  | 11.212  | 12.900  | 23.303  | 21.100  | 16.085  | 6.121   | 3.174   | 0.206   | 4.463   | 0.683   |
| 95          | 0.328   | 2.456   | 0.884   | 9.007   | 14.526  | 13.067  | 14.092  | 5.271   | 0.947   | -0.204  | 3.918   | 0.040   |
| 99          | -0.526  | -2.365  | -1.796  | 1.474   | 4.321   | 0.462   | 3.249   | 0.263   | 0.426   | 0.206   | 2.974   | 0.327   |
| 99.9        | 0.461   | -4.523  | -1.607  | 1.340   | 2.355   | -0.705  | 1.423   | -0.247  | -0.037  | -0.296  | 1.906   | 0.432   |
| Sc1b-EWR    |         |         |         |         |         |         |         |         |         |         |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1         | 628.142 | 559.259 | 564.905 | 502.372 | 713.725 | 687.432 | 465.685 | 470.503 | 166.528 | 110.056 | 315.811 | 549.676 |
| 1           | 579.402 | 544.894 | 455.091 | 471.213 | 565.679 | 627.723 | 442.792 | 284.255 | 162.228 | 104.015 | 233.997 | 461.871 |
| 5           | 312.076 | 394.035 | 328.533 | 391.936 | 404.841 | 362.689 | 400.886 | 175.333 | 117.237 | 76.533  | 102.637 | 214.927 |
| 10          | 135.522 | 213.324 | 279.110 | 298.812 | 304.845 | 299.575 | 237.972 | 132.079 | 66.396  | 46.508  | 72.134  | 99.072  |
| 15          | 117.663 | 172.732 | 186.358 | 246.317 | 252.405 | 265.854 | 187.778 | 99.626  | 40.567  | 28.775  | 42.083  | 66.029  |
| 20          | 91.912  | 155.342 | 151.552 | 172.589 | 201.358 | 193.316 | 140.020 | 77.494  | 30.985  | 23.453  | 36.167  | 30.417  |
| 30          | 35.611  | 96.552  | 122.587 | 110.936 | 79.019  | 152.311 | 107.624 | 45.973  | 16.277  | 11.344  | 23.034  | 22.873  |
| 40          | 18.315  | 59.928  | 73.901  | 84.099  | 39.535  | 112.891 | 79.828  | 36.782  | 7.670   | 3.407   | 7.897   | 15.219  |
| 50          | 3.388   | 42.789  | 52.909  | 73.415  | 31.875  | 84.803  | 52.347  | 18.012  | 8.346   | 2.045   | 4.959   | 4.649   |
| 60          | 6.730   | 28.415  | 27.125  | 56.565  | 30.078  | 61.147  | 38.387  | 13.465  | 8.790   | 2.957   | 3.891   | 0.435   |
| 70          | 3.602   | 26.412  | 17.580  | 24.622  | 28.143  | 52.351  | 31.967  | 11.435  | 5.376   | 1.593   | 5.173   | 1.482   |
| 80          | 3.419   | 23.174  | 12.738  | 17.998  | 36.443  | 45.464  | 28.969  | 11.589  | 4.632   | 1.771   | 5.245   | -0.039  |
| 85          | 3.158   | 22.126  | 14.194  | 21.338  | 31.381  | 33.295  | 20.170  | 9.253   | 4.915   | 1.125   | 5.452   | 0.612   |
| 90          | 2.043   | 11.088  | 11.211  | 12.900  | 23.302  | 21.219  | 16.085  | 6.121   | 3.174   | 0.207   | 4.463   | 0.893   |
| 95          | 0.328   | 2.457   | 0.880   | 9.007   | 14.524  | 13.067  | 14.122  | 5.271   | 0.947   | -0.067  | 3.930   | 0.429   |
| 99          | -0.309  | -2.066  | -1.465  | 1.473   | 4.320   | 0.461   | 3.249   | 0.279   | 0.441   | 0.228   | 2.977   | 0.750   |
| 99.9        | 0.476   | -4.224  | -1.279  | 1.339   | 2.354   | -0.705  | 1.423   | -0.150  | 0.051   | -0.173  | 1.924   | 0.475   |
| Sc2a-EWR    |         |         |         |         |         |         |         |         |         |         |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1         | 550.423 | 536.706 | 536.464 | 371.928 | 561.387 | 610.335 | 409.870 | 441.266 | 162.288 | 100.995 | 282.615 | 420.928 |
| 1           | 390.297 | 526.112 | 431.269 | 370.382 | 533.595 | 570.124 | 406.270 | 259.810 | 147.177 | 92.288  | 166.238 | 389.773 |
| 5           | 257.240 | 291.280 | 281.766 | 318.462 | 325.858 | 322.406 | 354.309 | 162.223 | 112.481 | 55.708  | 97.710  | 195.274 |
| 10          | 117.257 | 179.939 | 217.204 | 228.296 | 241.806 | 262.121 | 227.203 | 110.208 | 53.522  | 33.305  | 56.287  | 84.194  |
| 15          | 79.422  | 138.092 | 156.039 | 190.677 | 196.607 | 205.819 | 160.775 | 85.597  | 32.611  | 21.879  | 35.427  | 53.926  |
| 20          | 55.908  | 101.673 | 134.389 | 131.382 | 143.776 | 165.893 | 122.322 | 61.628  | 21.349  | 17.711  | 30.589  | 26.898  |
| 30          | 28.749  | 68.680  | 84.035  | 79.607  | 44.077  | 115.395 | 87.793  | 39.936  | 10.095  | 7.313   | 10.895  | 13.830  |
| 40          | 4.726   | 47.791  | 56.682  | 61.115  | 9.550   | 91.465  | 67.363  | 26.991  | 6.212   | 2.156   | 5.113   | 9.299   |
| 50          | -1.905  | 29.857  | 39.218  | 31.129  | 10.549  | 62.336  | 33.395  | 15.539  | 6.071   | 1.067   | 2.253   | 3.703   |
| 60          | 1.243   | 17.860  | 16.641  | 17.495  | 8.994   | 50.570  | 26.552  | 11.913  | 5.174   | 1.886   | 3.233   | 0.097   |
| 70          | 0.798   | 17.078  | 10.391  | 14.023  | 13.127  | 32.202  | 28.328  | 9.093   | 3.911   | 0.269   | 4.324   | 1.236   |
| 80          | 2.462   | 14.746  | 7.562   | 11.362  | 16.885  | 38.554  | 22.617  | 9.884   | 3.773   | 1.196   | 4.859   | -0.474  |
| 85          | 2.969   | 15.534  | 10.095  | 10.088  | 16.868  | 25.823  | 17.698  | 8.614   | 3.322   | 0.443   | 4.700   | 0.195   |
| 90          | 1.664   | 9.412   | 8.460   | 6.306   | 8.611   | 13.503  | 14.083  | 5.831   | 2.382   | -0.560  | 3.740   | 0.499   |
| 95          | 0.140   | 0.854   | 0.584   | 6.358   | 8.291   | 8.178   | 12.117  | 5.002   | 0.163   | -0.870  | 3.366   | -0.379  |
| 99          | -0.590  | -3.317  | -1.980  | -0.668  | -2.565  | -4.023  | 2.148   | 0.076   | 0.256   | 0.022   | 2.238   | 0.030   |
| 99.9        | 0.378   | -4.681  | -1.791  | -1.600  | -2.803  | -4.326  | 0.822   | -0.431  | -0.120  | -0.479  | 1.239   | 0.021   |
| Sc2b-EWR    |         |         |         |         |         |         |         |         |         |         |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1         | 550.354 | 536.706 | 536.464 | 371.928 | 561.375 | 610.335 | 409.832 | 441.266 | 162.288 | 100.995 | 282.615 | 419.371 |
| 1           | 389.605 | 526.112 | 431.269 | 370.382 | 533.593 | 570.124 | 405.883 | 259.810 | 147.177 | 92.287  | 166.237 | 389.293 |
| 5           | 257.003 | 291.279 | 280.804 | 318.171 | 325.858 | 322.334 | 354.309 | 162.221 | 112.481 | 55.708  | 97.710  | 195.274 |
| 10          | 117.256 | 179.938 | 217.197 | 228.296 | 241.807 | 262.087 | 227.202 | 110.208 | 53.522  | 33.305  | 56.287  | 84.194  |
| 15          | 79.421  | 138.092 | 156.039 | 190.676 | 196.606 | 205.819 | 160.775 | 85.597  | 32.611  | 21.880  | 35.427  | 53.937  |
| 20          | 55.911  | 101.668 | 134.388 | 131.382 | 143.776 | 165.893 | 122.319 | 61.628  | 21.349  | 17.711  | 30.607  | 26.897  |
| 30          | 28.748  | 68.665  | 84.035  | 78.470  | 44.077  | 115.395 | 87.793  | 39.936  | 10.094  | 7.313   | 10.895  | 13.829  |
| 40          | 4.726   | 47.790  | 56.682  | 61.114  | 9.553   | 91.452  | 66.560  | 26.991  | 6.212   | 2.156   | 5.112   | 9.299   |
| 50          | -1.692  | 29.857  | 39.218  | 31.129  | 10.548  | 62.407  | 33.396  | 15.539  | 6.070   | 1.066   | 2.253   | 3.703   |
| 60          | 1.528   | 17.883  | 16.576  | 17.493  | 8.956   | 50.568  | 26.551  | 11.913  | 5.282   | 1.884   | 3.320   | 0.226   |
| 70          | 0.857   | 17.078  | 10.772  | 14.023  | 13.413  | 32.195  | 28.328  | 9.092   | 3.911   | 0.295   | 4.354   | 1.298   |
| 80          | 2.695   | 14.743  | 7.610   | 11.361  | 17.257  | 38.554  | 22.612  | 9.884   | 3.773   | 1.363   | 4.859   | -0.362  |
| 85          | 2.969   | 15.672  | 10.366  | 10.088  | 17.035  | 25.819  | 17.698  | 8.613   | 3.322   | 0.502   | 5.033   | 0.368   |
| 90          | 1.663   | 9.412   | 8.458   | 6.697   | 8.822   | 13.503  | 14.084  | 5.831   | 2.381   | -0.404  | 4.054   | 0.708   |
| 95          | 0.141   | 1.071   | 0.580   | 6.357   | 8.596   | 8.174   | 12.247  | 5.002   | 0.161   | -0.739  | 3.444   | 0.259   |
| 99          | -0.546  | -2.998  | -1.629  | -0.602  | -2.281  | -3.830  | 2.147   | 0.094   | 0.273   | 0.110   | 2.724   | 0.578   |
| 99.9        | -0.697  | -4.353  | -1.443  | -1.222  | -2.518  | -4.132  | 0.818   | -0.318  | -0.020  | 0.025   | 2.536   | 0.330   |

**Table 22: Estimated non-compliances with EWR (Sc3) for all months at UO\_EWR03\_I**

| <b>Sc3a-EWR</b>   |  | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
|-------------------|--|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Percentiles       |  |         |         |         |         |         |         |         |         |         |         |         |         |
| 0.1               |  | 544.652 | 531.535 | 529.608 | 367.810 | 554.769 | 602.980 | 405.132 | 436.338 | 158.572 | 100.104 | 280.597 | 417.074 |
| 1                 |  | 384.153 | 522.328 | 425.426 | 365.516 | 527.958 | 566.241 | 401.126 | 257.064 | 143.729 | 91.323  | 164.087 | 385.752 |
| 5                 |  | 253.208 | 288.979 | 245.445 | 316.095 | 319.409 | 319.196 | 352.177 | 159.197 | 110.120 | 53.582  | 94.650  | 191.292 |
| 10                |  | 113.483 | 160.651 | 204.277 | 223.491 | 236.141 | 258.462 | 224.490 | 108.395 | 51.626  | 31.513  | 53.425  | 80.980  |
| 15                |  | 78.477  | 132.735 | 149.930 | 185.976 | 190.311 | 202.002 | 157.071 | 82.702  | 30.992  | 21.192  | 38.510  | 56.103  |
| 20                |  | 55.664  | 93.264  | 123.666 | 129.314 | 139.024 | 161.494 | 118.231 | 59.335  | 20.245  | 18.178  | 29.595  | 33.217  |
| 30                |  | 28.510  | 64.475  | 73.771  | 72.837  | 33.338  | 112.191 | 85.227  | 38.110  | 10.374  | 7.832   | 9.236   | 12.553  |
| 40                |  | 7.237   | 43.538  | 49.894  | 54.247  | 4.895   | 88.650  | 66.093  | 25.005  | 5.680   | 1.271   | 3.819   | 8.630   |
| 50                |  | -3.974  | 18.827  | 34.576  | 28.558  | 6.192   | 60.359  | 30.556  | 14.864  | 4.974   | 0.096   | 3.595   | 1.589   |
| 60                |  | -0.861  | 14.592  | 15.932  | 21.000  | 5.724   | 47.360  | 24.763  | 10.791  | 4.644   | 0.651   | 1.644   | -1.056  |
| 70                |  | -1.271  | 14.114  | 10.144  | 12.604  | 9.974   | 30.276  | 26.040  | 9.415   | 2.902   | -0.979  | 3.419   | -1.425  |
| 80                |  | -0.047  | 10.884  | 4.037   | 11.163  | 14.185  | 36.777  | 20.614  | 9.462   | 2.909   | -0.102  | 3.661   | -1.408  |
| 85                |  | 0.698   | 10.755  | 6.381   | 7.113   | 15.518  | 23.001  | 16.324  | 7.574   | 2.100   | -0.604  | 3.453   | -2.002  |
| 90                |  | -1.048  | 3.237   | 5.173   | 2.459   | 4.861   | 10.719  | 12.819  | 5.170   | 1.784   | -1.422  | 2.658   | -1.823  |
| 95                |  | -1.843  | -3.219  | -3.221  | 2.552   | 5.883   | 6.257   | 11.263  | 3.458   | -0.935  | -2.091  | 1.877   | -1.759  |
| 99                |  | -3.050  | -9.383  | -6.449  | -4.963  | -7.044  | -6.218  | -0.148  | -1.649  | -0.878  | -0.778  | 1.269   | -1.627  |
| 99.9              |  | -1.805  | -9.515  | -5.948  | -5.612  | -7.236  | -7.285  | -1.297  | -1.953  | -0.761  | -1.011  | 0.532   | -1.655  |
| <b>Sc3b-EWR</b>   |  |         |         |         |         |         |         |         |         |         |         |         |         |
| Percentiles       |  | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1               |  | 541.099 | 531.535 | 529.608 | 367.810 | 554.769 | 602.980 | 404.334 | 436.338 | 158.572 | 100.104 | 280.597 | 377.307 |
| 1                 |  | 348.622 | 522.328 | 425.426 | 365.516 | 527.959 | 566.241 | 393.141 | 257.064 | 143.729 | 91.323  | 164.087 | 360.970 |
| 5                 |  | 240.726 | 224.635 | 245.445 | 266.263 | 319.409 | 317.459 | 333.789 | 159.198 | 110.121 | 53.582  | 94.650  | 159.667 |
| 10                |  | 113.483 | 160.518 | 182.721 | 217.811 | 236.141 | 244.018 | 224.490 | 108.394 | 51.626  | 31.798  | 53.426  | 74.202  |
| 15                |  | 76.978  | 132.916 | 130.496 | 171.602 | 190.311 | 184.566 | 157.071 | 82.702  | 30.992  | 21.192  | 36.998  | 57.389  |
| 20                |  | 69.166  | 93.264  | 119.059 | 114.339 | 113.235 | 150.090 | 118.231 | 59.336  | 23.089  | 18.178  | 29.349  | 44.632  |
| 30                |  | 30.880  | 65.671  | 80.556  | 83.852  | 26.978  | 111.059 | 85.227  | 38.110  | 12.741  | 9.447   | 9.236   | 13.027  |
| 40                |  | 11.441  | 57.953  | 62.609  | 60.427  | 14.263  | 85.095  | 63.324  | 25.005  | 7.187   | 4.123   | 3.500   | 8.630   |
| 50                |  | 4.772   | 26.382  | 44.002  | 37.678  | 22.151  | 60.359  | 29.264  | 15.786  | 5.366   | 1.061   | 2.456   | 3.260   |
| 60                |  | 6.308   | 15.651  | 17.286  | 20.696  | 8.625   | 34.781  | 24.764  | 10.883  | 6.069   | 2.367   | 1.411   | 2.286   |
| 70                |  | 8.353   | 14.285  | 10.579  | 12.799  | 15.290  | 29.731  | 26.040  | 12.819  | 5.107   | 2.131   | 3.115   | 0.402   |
| 80                |  | 2.541   | 8.957   | 6.304   | 11.163  | 22.606  | 31.167  | 20.090  | 11.637  | 4.062   | 1.122   | 2.845   | 0.287   |
| 85                |  | 2.178   | 6.551   | 5.948   | 10.060  | 17.196  | 24.856  | 15.664  | 10.201  | 3.434   | 0.852   | 2.849   | -0.509  |
| 90                |  | -0.151  | 2.355   | 4.897   | 7.400   | 14.642  | 9.391   | 12.013  | 6.711   | 2.464   | 0.106   | 2.252   | -0.106  |
| 95                |  | -0.408  | 0.401   | -0.651  | 1.579   | 8.169   | 2.227   | 3.903   | 4.751   | 0.617   | -0.158  | 1.033   | -0.470  |
| 99                |  | -0.165  | -0.165  | -0.155  | -0.489  | -0.518  | -0.976  | -0.236  | 1.003   | 1.206   | 1.283   | 0.205   | 0.242   |
| 99.9              |  | -0.731  | -1.014  | -0.202  | -2.817  | -2.285  | -3.551  | -1.865  | 0.344   | 0.418   | 0.077   | 0.220   | 0.210   |
| <b>Sc3.1a-EWR</b> |  |         |         |         |         |         |         |         |         |         |         |         |         |
| Percentiles       |  | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1               |  | 534.850 | 522.507 | 519.894 | 352.886 | 511.445 | 595.236 | 396.838 | 429.413 | 150.609 | 87.095  | 270.261 | 340.609 |
| 1                 |  | 374.075 | 507.993 | 415.224 | 324.960 | 495.272 | 558.126 | 385.279 | 249.661 | 135.707 | 72.019  | 155.626 | 323.780 |
| 5                 |  | 232.142 | 247.673 | 215.171 | 250.044 | 306.658 | 308.819 | 328.838 | 147.685 | 101.387 | 45.411  | 80.213  | 181.987 |
| 10                |  | 94.617  | 145.705 | 148.004 | 204.787 | 223.126 | 220.006 | 216.142 | 96.393  | 40.841  | 23.846  | 45.140  | 72.749  |
| 15                |  | 59.011  | 106.999 | 110.737 | 150.804 | 169.736 | 189.751 | 147.676 | 73.422  | 22.640  | 15.873  | 31.696  | 44.848  |
| 20                |  | 32.800  | 74.029  | 91.832  | 99.003  | 84.487  | 138.472 | 105.639 | 48.907  | 14.643  | 13.210  | 25.240  | 22.633  |
| 30                |  | 14.813  | 45.460  | 50.591  | 57.093  | 21.324  | 100.025 | 73.973  | 26.781  | 5.509   | 4.764   | 5.960   | 7.319   |
| 40                |  | 3.072   | 26.989  | 35.351  | 41.673  | -9.088  | 74.279  | 48.253  | 19.858  | 2.039   | 0.411   | 2.389   | 5.089   |
| 50                |  | -6.405  | 14.271  | 21.297  | 23.825  | -3.244  | 45.411  | 19.138  | 9.825   | 0.745   | -2.446  | 1.103   | 1.555   |
| 60                |  | -3.843  | 10.762  | 6.922   | 8.504   | -7.178  | 35.159  | 18.910  | 6.441   | 1.871   | -1.071  | -0.127  | -2.576  |
| 70                |  | -0.955  | 11.207  | 3.104   | 5.920   | -1.810  | 21.700  | 21.190  | 9.119   | 1.152   | -0.904  | 1.888   | -2.660  |
| 80                |  | -1.135  | 8.901   | 1.317   | 4.113   | 9.047   | 27.999  | 20.879  | 8.583   | 1.145   | -0.932  | 2.547   | -2.139  |
| 85                |  | -1.035  | 8.586   | 1.206   | 3.499   | 7.804   | 21.784  | 17.527  | 8.194   | 1.123   | -1.141  | 2.745   | -2.475  |
| 90                |  | -3.337  | 2.473   | -3.668  | 1.586   | 2.510   | 10.696  | 10.693  | 5.169   | 0.591   | -1.710  | 2.335   | -2.183  |
| 95                |  | -4.202  | -3.283  | -8.003  | 1.270   | 2.893   | 3.556   | 9.847   | 3.038   | -0.720  | -2.428  | 1.543   | -2.086  |
| 99                |  | -3.051  | -6.791  | -7.909  | -6.017  | -8.436  | -6.969  | -0.862  | -0.588  | -0.753  | -0.910  | 1.346   | -1.627  |
| 99.9              |  | -1.808  | -8.817  | -7.175  | -6.587  | -9.353  | -8.729  | -1.369  | -1.512  | -0.776  | -1.342  | 0.981   | -1.655  |
| <b>Sc3.1b-EWR</b> |  |         |         |         |         |         |         |         |         |         |         |         |         |
| Percentiles       |  | Oct     | Nov     | Dec     | Jan     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1               |  | 530.015 | 522.335 | 519.894 | 347.767 | 511.215 | 595.236 | 396.838 | 429.413 | 150.609 | 65.235  | 269.222 | 331.003 |
| 1                 |  | 339.001 | 506.272 | 415.224 | 316.138 | 492.979 | 558.126 | 385.279 | 249.661 | 135.707 | 54.052  | 145.238 | 263.725 |
| 5                 |  | 193.784 | 247.139 | 210.969 | 219.318 | 281.860 | 296.960 | 320.251 | 130.508 | 101.012 | 32.296  | 80.030  | 147.701 |
| 10                |  | 86.541  | 151.779 | 168.510 | 189.937 | 210.383 | 164.633 | 181.907 | 86.456  | 26.460  | 24.975  | 46.929  | 75.878  |
| 15                |  | 75.343  | 111.754 | 121.701 | 138.245 | 167.418 | 127.853 | 120.740 | 69.756  | 20.047  | 16.042  | 37.376  | 62.750  |
| 20                |  | 60.858  | 92.263  | 105.541 | 90.844  | 77.693  | 103.626 | 92.484  | 41.868  | 14.769  | 13.555  | 30.201  | 40.724  |
| 30                |  | 24.996  | 69.846  | 61.918  | 62.564  | 17.776  | 74.962  | 59.385  | 23.500  | 5.861   | 5.389   | 13.606  | 12.639  |
| 40                |  | 8.368   | 50.380  | 41.229  | 48.810  | 6.178   | 63.182  | 23.328  | 14.777  | 2.187   | 1.329   | 6.467   | 5.926   |
| 50                |  | 4.772   | 26.309  | 28.389  | 35.214  | 14.318  | 45.411  | 14.089  | 6.539   | 2.016   | 0.112   | 2.456   | 2.556   |
| 60                |  | 2.759   | 12.531  | 15.009  | 24.130  | 3.766   | 32.428  | 17.668  | 7.288   | 3.031   | 1.027   | 2.349   | 1.072   |
| 70                |  | 4.451   | 12.941  | 7.061   | 15.006  | 11.522  | 21.874  | 19.253  | 7.431   | 1.178   | 0.859   | 1.648   | 0.572   |
| 80                |  | 2.039   | 8.880   | 4.176   | 6.709   | 18.371  | 21.120  | 14.098  | 5.851   | 2.005   | 0.677   | 2.429   | 1.206   |
| 85                |  | 2.114   | 5.646   | 5.859   | 8.334   | 17.951  | 15.410  | 12.180  | 6.433   | 2.069   | 0.423   | 2.513   | -0.509  |
| 90                |  | 0.575   | 2.301   | 4.518   | 5.597   | 12.952  | 6.060   | 8.908   | 3.899   | 1.808   | -0.040  | 1.904   | -0.106  |
| 95                |  | -0.408  | 0.401   | -0.651  | 0.740   | 5.419   | 1.710   | 8.434   | 3.402   | -0.095  | -0.283  | 0.326   | -0.533  |
| 99                |  | -0.038  | -0.165  | -0.155  | -0.489  | -1.094  | -0.976  | 0.404   | 2.468   | 1.206   | 1.283   | 0.138   | 0.242   |
| 99.9              |  | -0.003  | -1.014  | -0.202  | -2.817  | -2.343  | -3.551  | 1.795   | 0.490   | 0.418   | 0.077   | 0.068   | 0.210   |

**Table 23: Estimated non-compliances with EWR for all months at UO\_EWR02\_I**

| Sc1a-EWR    |        |        |        |        |        |        |        |        |        |        |        |        |
|-------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Percentiles | Oct    | Nov    | Dec    | Jan    | Feb    | Mar    | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1         | 9.228  | 8.213  | 7.482  | 10.748 | 22.941 | 19.051 | 18.322 | 8.292  | 2.859  | 0.430  | 4.608  | 4.948  |
| 1           | 4.050  | 6.012  | 6.393  | 9.699  | 21.283 | 13.197 | 9.428  | 8.064  | 2.376  | 0.415  | 2.650  | 4.764  |
| 5           | 0.854  | 1.743  | 1.621  | 5.478  | 8.841  | 8.916  | 6.207  | 1.982  | 0.597  | 0.139  | 0.175  | 0.255  |
| 10          | 0.168  | 0.759  | 0.909  | 2.562  | 4.291  | 3.993  | 3.374  | 1.498  | 0.186  | 0.075  | 0.034  | 0.019  |
| 15          | 0.036  | 0.577  | 0.506  | 1.275  | 2.427  | 2.281  | 2.468  | 0.585  | 0.128  | 0.019  | -0.021 | -0.019 |
| 20          | -0.006 | -0.017 | 0.274  | 0.792  | 0.350  | 1.497  | 2.084  | 0.350  | 0.017  | -0.035 | -0.038 | -0.036 |
| 30          | -0.022 | -0.357 | 0.089  | -0.132 | -0.381 | 0.388  | 1.189  | 0.156  | -0.066 | -0.046 | -0.042 | -0.045 |
| 40          | -0.037 | -0.173 | -0.112 | -0.362 | -0.360 | -0.270 | 0.070  | -0.051 | -0.065 | -0.036 | -0.028 | -0.038 |
| 50          | -0.026 | -0.124 | -0.136 | -0.266 | -0.359 | -0.165 | -0.086 | -0.058 | -0.041 | -0.032 | -0.018 | -0.019 |
| 60          | -0.011 | -0.071 | -0.111 | -0.148 | -0.209 | -0.066 | -0.121 | -0.020 | -0.015 | -0.017 | -0.009 | -0.009 |
| 70          | -0.009 | -0.042 | -0.049 | -0.089 | -0.115 | -0.066 | -0.060 | 0.004  | -0.002 | -0.007 | -0.006 | -0.004 |
| 80          | -0.002 | -0.023 | -0.031 | -0.031 | -0.070 | -0.057 | -0.025 | 0.016  | 0.005  | 0.000  | -0.002 | -0.002 |
| 85          | -0.001 | -0.017 | -0.019 | -0.017 | -0.046 | -0.056 | -0.020 | 0.011  | 0.003  | -0.001 | -0.001 | 0.000  |
| 90          | 0.000  | -0.009 | -0.006 | -0.008 | -0.021 | -0.052 | -0.020 | 0.005  | 0.001  | 0.000  | -0.001 | 0.000  |
| 95          | 0.000  | -0.004 | -0.004 | -0.004 | -0.009 | -0.019 | -0.021 | 0.001  | 0.000  | -0.001 | 0.000  | 0.000  |
| 99          | 0.000  | 0.000  | -0.001 | -0.001 | -0.003 | -0.013 | -0.001 | 0.000  | -0.001 | 0.000  | 0.000  | 0.000  |
| 99.9        | 0.000  | 0.000  | 0.000  | -0.001 | 0.000  | -0.005 | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  |
| Sc1b-EWR    |        |        |        |        |        |        |        |        |        |        |        |        |
| Percentiles | Oct    | Nov    | Dec    | Jan    | Feb    | Mar    | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1         | 9.228  | 8.213  | 6.202  | 10.642 | 22.941 | 19.051 | 18.322 | 8.292  | 2.859  | 0.430  | 4.608  | 4.948  |
| 1           | 4.050  | 6.012  | 6.170  | 9.681  | 21.283 | 13.197 | 9.428  | 8.064  | 2.376  | 0.415  | 2.650  | 4.764  |
| 5           | 0.854  | 1.743  | 1.621  | 5.478  | 8.841  | 8.916  | 6.207  | 1.982  | 0.597  | 0.139  | 0.194  | 1.080  |
| 10          | 0.167  | 0.694  | 0.767  | 2.562  | 4.291  | 3.993  | 3.375  | 1.498  | 0.186  | 0.075  | 0.064  | 0.038  |
| 15          | 0.036  | 0.557  | 0.408  | 1.039  | 2.427  | 2.282  | 2.468  | 0.585  | 0.128  | 0.019  | -0.009 | -0.013 |
| 20          | -0.006 | -0.017 | 0.252  | 0.654  | 0.350  | 1.498  | 2.084  | 0.350  | 0.017  | -0.033 | -0.030 | -0.034 |
| 30          | -0.022 | -0.283 | 0.046  | -0.132 | -0.355 | 0.388  | 1.189  | 0.156  | -0.066 | -0.040 | -0.038 | -0.042 |
| 40          | -0.033 | -0.173 | -0.118 | -0.362 | -0.365 | -0.327 | 0.071  | -0.051 | -0.065 | -0.033 | -0.024 | -0.030 |
| 50          | -0.024 | -0.124 | -0.129 | -0.247 | -0.359 | -0.233 | -0.086 | -0.058 | -0.041 | -0.021 | -0.018 | -0.017 |
| 60          | -0.011 | -0.069 | -0.103 | -0.142 | -0.178 | -0.066 | -0.121 | -0.020 | -0.014 | -0.014 | -0.008 | -0.009 |
| 70          | -0.009 | -0.041 | -0.047 | -0.089 | -0.113 | -0.066 | -0.060 | 0.004  | -0.002 | -0.007 | -0.006 | -0.003 |
| 80          | -0.002 | -0.021 | -0.031 | -0.031 | -0.070 | -0.056 | -0.024 | 0.016  | 0.005  | 0.000  | -0.002 | -0.002 |
| 85          | -0.001 | -0.017 | -0.018 | -0.016 | -0.046 | -0.054 | -0.016 | 0.010  | 0.003  | -0.001 | -0.001 | 0.000  |
| 90          | 0.000  | -0.007 | -0.003 | -0.007 | -0.018 | -0.045 | -0.020 | 0.005  | 0.001  | -0.001 | -0.001 | 0.000  |
| 95          | 0.000  | -0.004 | -0.003 | -0.004 | -0.008 | -0.019 | -0.021 | 0.001  | 0.000  | -0.001 | 0.000  | 0.000  |
| 99          | 0.000  | 0.000  | 0.000  | -0.001 | -0.003 | -0.013 | -0.001 | 0.000  | -0.001 | 0.000  | 0.000  | 0.000  |
| 99.9        | 0.000  | 0.000  | 0.000  | -0.001 | 0.000  | -0.005 | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  |

### 5.6 IUA6 Gariep Dam

No scenarios were evaluated for this IUA as it forms part of the Flow Management Plan and as such only minimum flows (drought) were set as part of the EWR determination. However, the flows for the various scenarios were assessed and the initial minimum flow of 40 m<sup>3</sup>/s for all months were adjusted to 25 m<sup>3</sup>/s for all the months, irrespective of the final selected scenario to inform the Water Resource Class. The freshets as specified as part of the EWR quantification have not been changed and are as follows:

- November to January – 270 m<sup>3</sup>/s over 6 days, and
- February – 350 m<sup>3</sup>/s over 3 days.

### 5.7 IUA7: Seekoei River

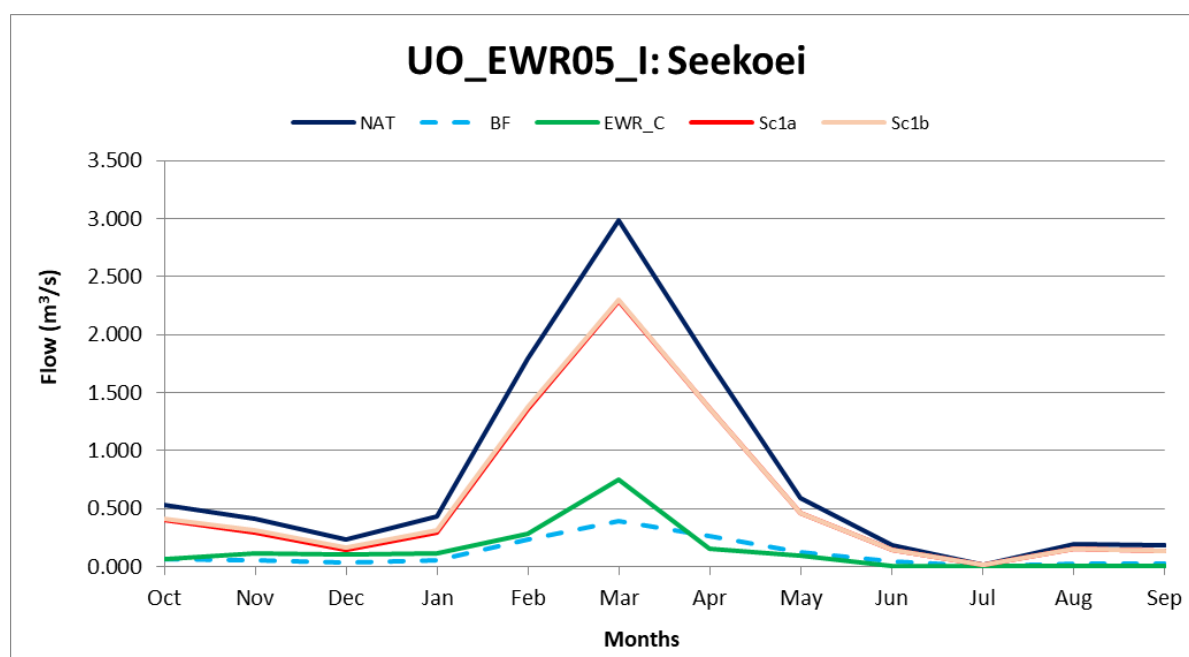
Ecological consequences were assessed for the Seekoei River (site UO\_EWR05\_I) within this IUA. No large dams are situated upstream of this EWR site.

Only two scenarios were assessed, namely present day without and with EWR as no future developments are planned for this catchment. Refer to for the average flows (1920 - 2004) measured in Mm<sup>3</sup>.

**Table 24: Average flows (1920-2004) for UO\_EWR05\_I**

| Average Flows (1920-2004) – Mm <sup>3</sup> |            |
|---------------------------------------------|------------|
|                                             | UO_EWR05_I |
| nMAR                                        | 24.3       |
| Sc1a (PRS)                                  | 18.4       |
| Sc1b                                        | 18.7       |

The seasonal distribution (hydrograph) plot was prepared using the flows provided for the scenarios and is illustrated in Figure 13. Table 25 provides the estimated non-compliances for all the months for the scenarios (values in red).



**Figure 13: Seasonal distribution of scenarios at site UO\_EWR05\_I: Seekoei**

The scenario evaluated show reductions from the natural flows for all the months.

The results indicate that the EWR could not be met for some of the time during the wet season, even if implemented. However, the implementation resulted in smaller deficits.

**Table 25: Estimated non-compliances with EWR for all months at UO\_EWR05\_I**

| <b>Sc1a-EWR</b> |        |        |        |        |        |        |        |        |       |       |       |        |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|-------|-------|-------|--------|
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb    | Mar    | Apr    | May    | Jun   | Jul   | Aug   | Sep    |
| 0.1             | 26.609 | 15.517 | 2.937  | 7.425  | 38.079 | 46.753 | 20.833 | 11.577 | 6.923 | 0.360 | 7.237 | 4.255  |
| 1               | 5.510  | 3.275  | 1.466  | 3.357  | 34.947 | 25.986 | 17.163 | 9.075  | 3.709 | 0.318 | 4.576 | 3.562  |
| 5               | -0.144 | -0.232 | 0.342  | 1.155  | 1.667  | 13.447 | 7.196  | 1.682  | 0.181 | 0.017 | 0.138 | 0.332  |
| 10              | -0.115 | -0.204 | 0.009  | 0.353  | 1.179  | 0.098  | 2.769  | 0.314  | 0.057 | 0.002 | 0.000 | 0.025  |
| 15              | -0.086 | -0.129 | -0.125 | -0.051 | 0.545  | -0.562 | 1.246  | -0.067 | 0.023 | 0.003 | 0.004 | -0.003 |
| 20              | -0.040 | -0.096 | -0.138 | -0.136 | 0.107  | -0.333 | 0.392  | -0.062 | 0.006 | 0.004 | 0.003 | -0.004 |
| 30              | -0.010 | -0.047 | -0.093 | -0.114 | -0.148 | 0.104  | 0.151  | -0.030 | 0.005 | 0.004 | 0.003 | 0.002  |
| 40              | 0.001  | -0.018 | -0.045 | -0.062 | -0.112 | -0.013 | 0.029  | -0.013 | 0.005 | 0.003 | 0.002 | 0.001  |
| 50              | 0.001  | -0.004 | -0.015 | -0.019 | -0.064 | -0.013 | 0.019  | -0.006 | 0.006 | 0.003 | 0.002 | 0.001  |
| 60              | 0.001  | 0.000  | -0.003 | -0.007 | -0.037 | -0.040 | 0.011  | -0.003 | 0.005 | 0.002 | 0.001 | 0.001  |
| 70              | 0.001  | 0.001  | 0.001  | 0.001  | -0.012 | -0.055 | -0.018 | -0.001 | 0.004 | 0.002 | 0.001 | 0.001  |
| 80              | 0.001  | 0.001  | 0.001  | 0.001  | 0.001  | -0.017 | -0.004 | 0.002  | 0.003 | 0.002 | 0.001 | 0.001  |
| 85              | 0.001  | 0.001  | 0.001  | 0.001  | 0.001  | -0.006 | -0.001 | 0.002  | 0.003 | 0.001 | 0.001 | 0.001  |
| 90              | 0.001  | 0.001  | 0.001  | 0.001  | 0.001  | -0.001 | 0.001  | 0.001  | 0.002 | 0.001 | 0.001 | 0.001  |
| 95              | 0.001  | 0.000  | 0.001  | 0.000  | 0.001  | 0.001  | 0.001  | 0.001  | 0.002 | 0.001 | 0.001 | 0.001  |
| 99              | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  | 0.001  | 0.001  | 0.001  | 0.001 | 0.001 | 0.001 | 0.000  |
| 99.9            | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  | 0.001  | 0.001  | 0.001  | 0.001 | 0.001 | 0.001 | 0.000  |
| <b>Sc1b-EWR</b> |        |        |        |        |        |        |        |        |       |       |       |        |
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb    | Mar    | Apr    | May    | Jun   | Jul   | Aug   | Sep    |
| 0.1             | 26.609 | 15.517 | 2.937  | 7.425  | 38.077 | 46.753 | 20.832 | 11.577 | 6.923 | 0.359 | 7.237 | 4.255  |
| 1               | 5.510  | 3.275  | 1.466  | 3.357  | 34.946 | 25.986 | 17.162 | 9.074  | 3.708 | 0.318 | 4.575 | 3.562  |
| 5               | -0.076 | -0.227 | 0.342  | 1.154  | 1.667  | 13.445 | 7.196  | 1.681  | 0.181 | 0.017 | 0.137 | 0.332  |
| 10              | -0.063 | -0.107 | 0.012  | 0.352  | 1.178  | 0.097  | 2.768  | 0.314  | 0.057 | 0.002 | 0.001 | 0.025  |
| 15              | -0.028 | -0.042 | -0.023 | -0.016 | 0.545  | -0.509 | 1.244  | -0.068 | 0.023 | 0.002 | 0.003 | -0.001 |
| 20              | -0.017 | -0.027 | -0.041 | -0.031 | 0.107  | -0.307 | 0.391  | -0.042 | 0.006 | 0.004 | 0.003 | 0.000  |
| 30              | -0.002 | -0.018 | -0.028 | -0.051 | -0.114 | 0.102  | 0.151  | -0.015 | 0.005 | 0.004 | 0.002 | 0.002  |
| 40              | 0.003  | -0.003 | -0.013 | -0.024 | -0.028 | 0.000  | 0.029  | -0.013 | 0.005 | 0.003 | 0.002 | 0.001  |
| 50              | 0.001  | 0.000  | -0.002 | -0.004 | -0.018 | 0.000  | 0.018  | -0.002 | 0.005 | 0.003 | 0.001 | 0.001  |
| 60              | 0.001  | 0.000  | 0.000  | -0.001 | -0.011 | -0.001 | 0.010  | -0.001 | 0.005 | 0.002 | 0.001 | 0.001  |
| 70              | 0.001  | 0.001  | 0.001  | 0.002  | -0.003 | -0.014 | -0.005 | 0.000  | 0.003 | 0.002 | 0.001 | 0.001  |
| 80              | 0.001  | 0.001  | 0.001  | 0.001  | 0.001  | -0.007 | 0.000  | 0.002  | 0.003 | 0.001 | 0.001 | 0.001  |
| 85              | 0.001  | 0.001  | 0.001  | 0.001  | 0.001  | -0.001 | 0.000  | 0.001  | 0.002 | 0.001 | 0.001 | 0.001  |
| 90              | 0.001  | 0.001  | 0.001  | 0.001  | 0.001  | 0.000  | 0.001  | 0.001  | 0.002 | 0.001 | 0.001 | 0.001  |
| 95              | 0.000  | 0.000  | 0.000  | 0.000  | 0.001  | 0.002  | 0.001  | 0.001  | 0.002 | 0.001 | 0.001 | 0.001  |
| 99              | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  | 0.001  | 0.001  | 0.001  | 0.001 | 0.001 | 0.000 | 0.000  |
| 99.9            | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  | 0.001  | 0.000  | 0.001  | 0.001 | 0.000 | 0.000 | 0.000  |

**5.8 IUA8: Vanderkloof Dam**

Ecological consequences were assessed for the Orange River at Marksdrift (site UO\_EWR10\_I) within this IUA. Both Gariep Dam and Vanderkloof Dam upstream of the site have a direct impact on the flows due to the operation of the dams for hydropower releases and for downstream users in the Lower Orange River. The operation of the dams impacts on all the flow components with reduced floods and increased baseflows.

All the scenarios, namely present day, medium term and long term with some interventions were assessed at this Orange River EWR site. Refer to Table 26 for the average flows (1920 - 2004) at the two EWR sites measured in Mm<sup>3</sup>.

**Table 26: Average flows (1920-2004) for UO\_EWR10\_I**

| <b>Average Flows (1920-2004) – Mm<sup>3</sup></b> |                   |
|---------------------------------------------------|-------------------|
|                                                   | <b>UO_EWR10_I</b> |
| nMAR                                              | 6 618.2           |
| Sc1a (PRS)                                        | 3 415.9           |
| Sc1b                                              | 3 545.2           |
| Sc2a                                              | 2 900.3           |

| <b>Average Flows (1920-2004) – Mm<sup>3</sup></b> |                   |
|---------------------------------------------------|-------------------|
|                                                   | <b>UO_EWR10_I</b> |
| Sc2b                                              | 3 076.9           |
| Sc2.1a                                            | 2 882.0           |
| Sc2.1b                                            | 2 979.0           |
| Sc3a                                              | 2 793.1           |
| Sc3b                                              | 2 911.0           |
| Sc3.1a                                            | 2 555.4           |
| Sc3.1b                                            | 2 698.7           |

As part of the consequences workshop due to negative socio-economic impacts if the EWR is implemented, the requirements were adjusted by reducing the maintenance low flows and the freshet and flood requirements. Thus, only the 65 m<sup>3</sup>/s freshet for the months October to April was included. A summary of the final revised EWR is presented in Table 27.

**Table 27: Orange (UO\_EWR10\_I) - Summary of the final EWR results (flows in Mm<sup>3</sup> per annum)**

| <b>Quaternary Catchment</b>     | <b>D33K</b>           |                       |
|---------------------------------|-----------------------|-----------------------|
| River                           | Orange at Marksdrift  |                       |
| Site code                       | UO_EWR10_I            |                       |
| Recommended Ecological Category | C                     |                       |
|                                 | 2024                  | Revised, Mar 2025     |
| nMAR at EWR site                | 6 618.2               |                       |
| Total EWR                       | 1684.770 (25.24 %MAR) | 1245.709 (18.66 %MAR) |
| Maintenance Low flows           | 1341.744 (20.10 %MAR) | 1174.947 (17.60 %MAR) |
| Drought Low flows               | 405.864 ( 6.08 %MAR)  | 405.864 ( 6.08 %MAR)  |
| Maintenance High flows          | 343.025 ( 5.14 %MAR)  | 70.761 ( 1.06 %MAR)   |

The seasonal distribution (hydrograph) plots were prepared using the flows provided for the scenarios and is illustrated in Figure 14,

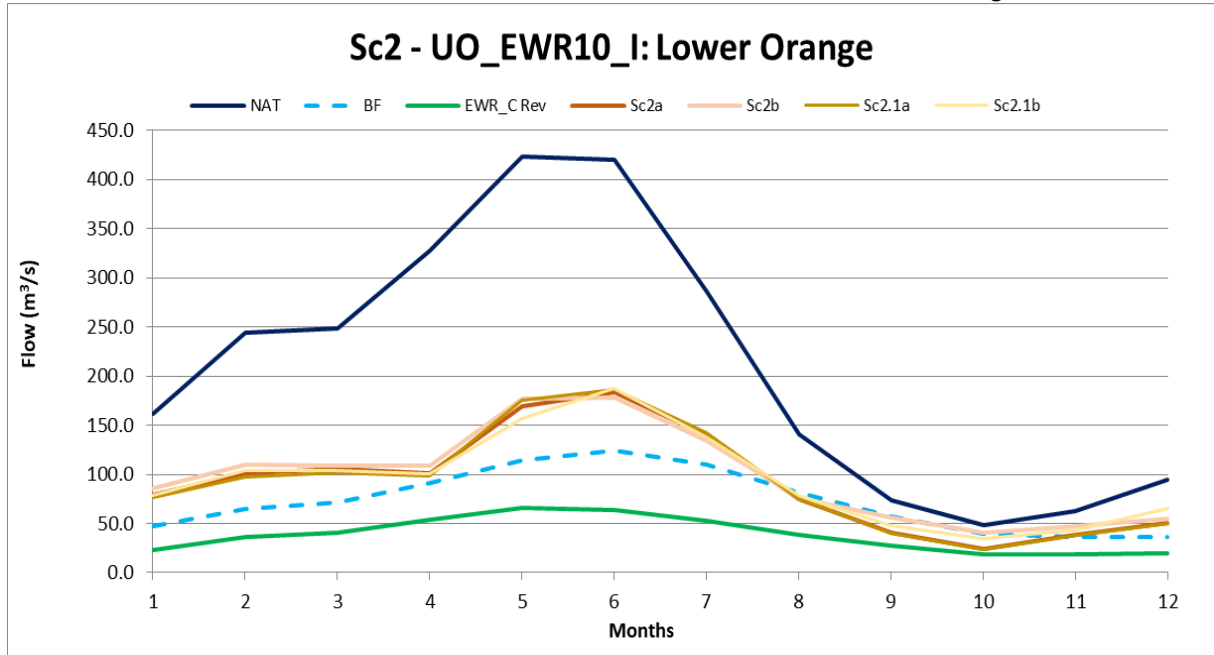


Figure 15 and Figure 16.

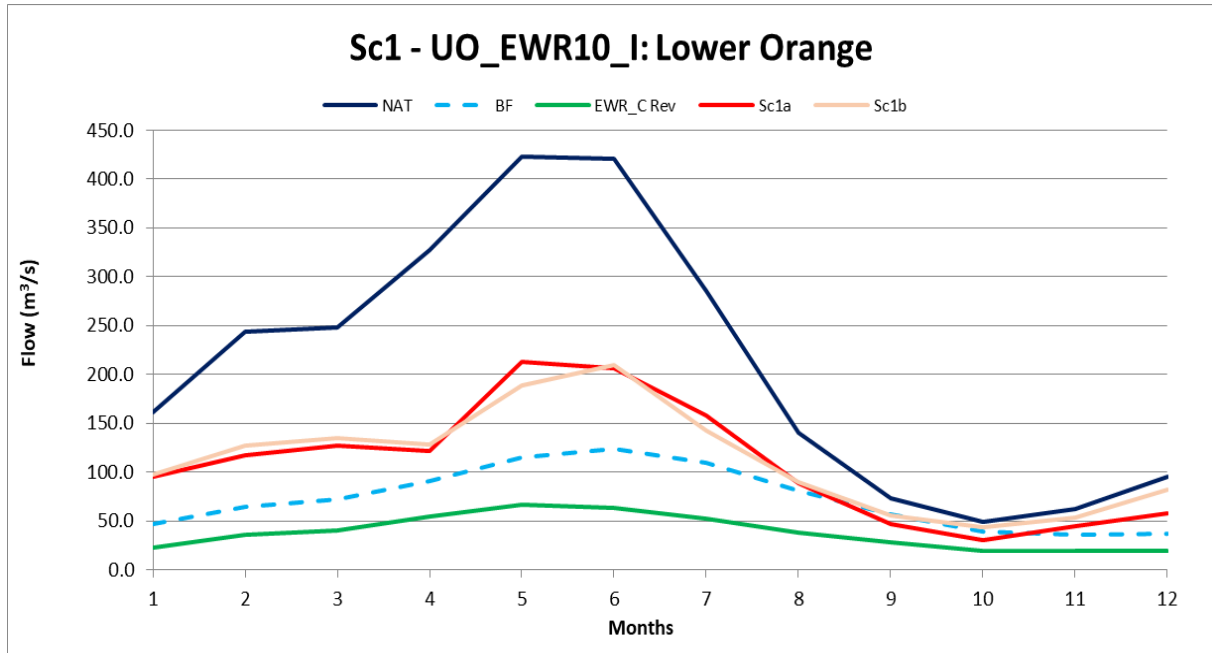


Figure 14: Seasonal distribution of scenarios (Sc1) at site UO\_EWR10\_I: Orange

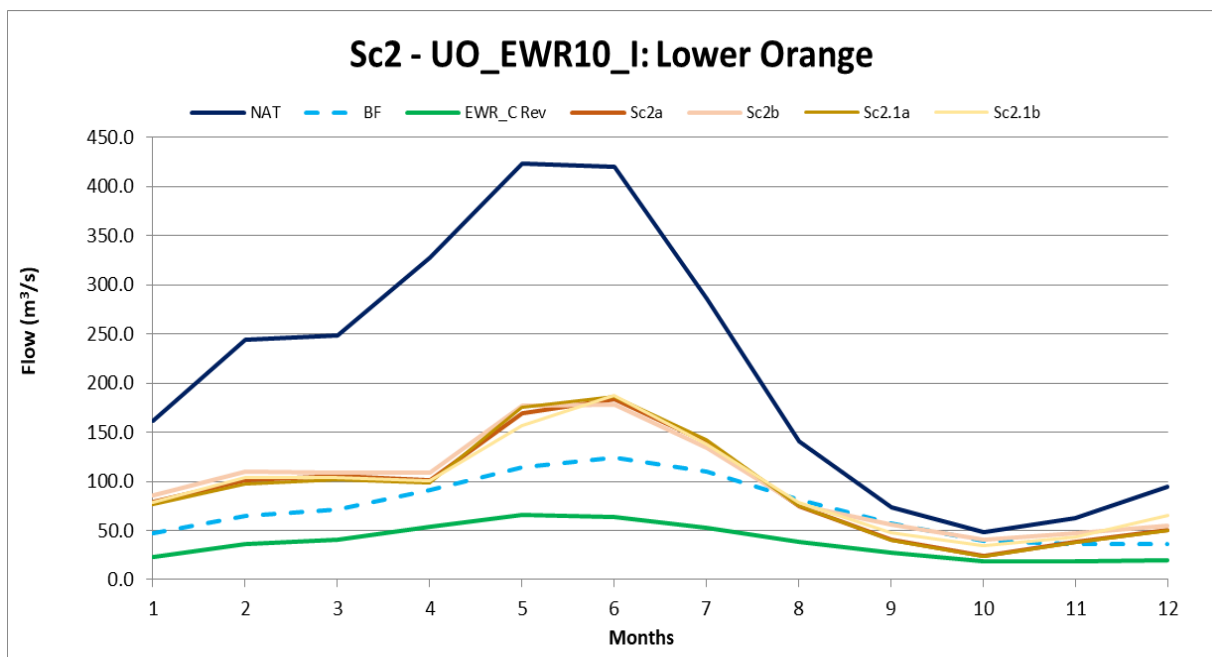
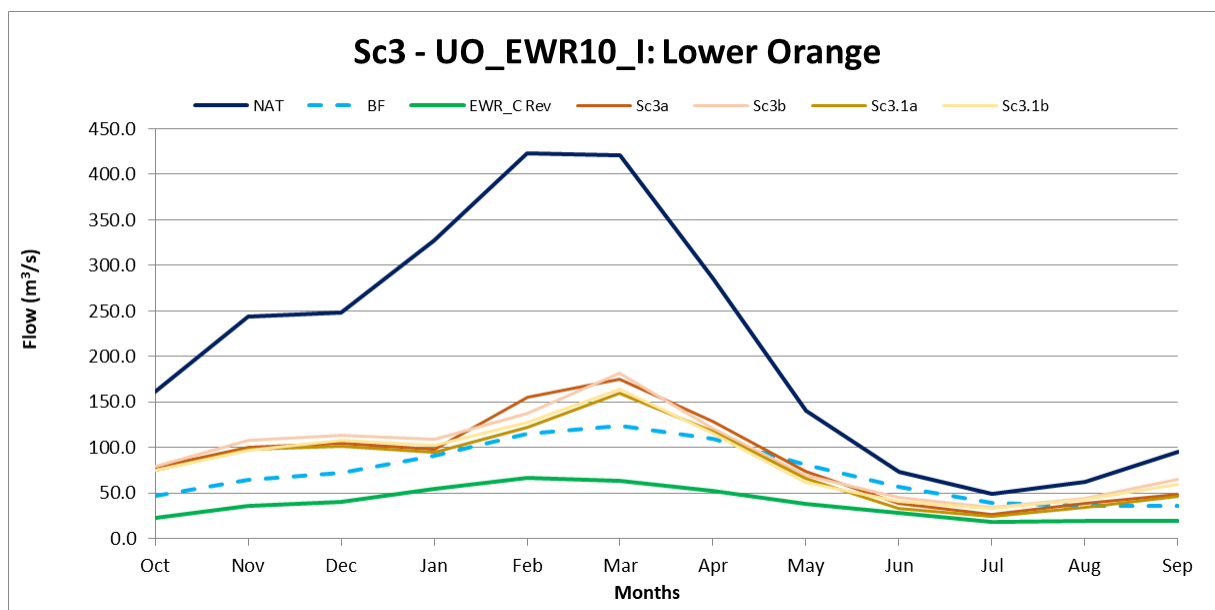


Figure 15: Seasonal distribution of scenarios (Sc2) at site UO\_EWR10\_I: Orange



**Figure 16: Seasonal distribution of scenarios at site UO\_EWR10\_I: Orange**

The graphs indicate that all the flow components are reduced during the scenarios, especially the peaks due to the all the existing large dams (Sc1) and proposed new dams (Sc2 and Sc3) in the upper catchment.

Table 28, Table 29 and Table 30 provide the estimated non-compliances for all the months for the scenarios (values in red). The tables indicate that the EWR could be met all the time for all the scenarios if the EWR is implemented. However, when not implemented the maintenance flows and some freshets (20 to 70 percentiles) in the wet and early dry months show deficits.

**Table 28: Estimated non-compliances with EWR (Sc1) for all months at UO\_EWR10\_I**

| <b>Sc1a-EWR</b> |         |         |         |         |          |          |          |         |         |         |         |         |
|-----------------|---------|---------|---------|---------|----------|----------|----------|---------|---------|---------|---------|---------|
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1             | 783.576 | 987.021 | 821.940 | 565.544 | 2002.503 | 1939.745 | 1315.348 | 760.511 | 241.032 | 102.394 | 465.819 | 559.153 |
| 1               | 646.537 | 945.432 | 724.863 | 454.426 | 1551.087 | 1711.715 | 901.569  | 571.471 | 231.818 | 75.370  | 245.296 | 339.101 |
| 5               | 154.493 | 256.986 | 274.987 | 238.254 | 868.077  | 543.796  | 594.927  | 243.941 | 107.301 | 32.763  | 71.981  | 80.109  |
| 10              | 40.099  | 49.871  | 76.939  | 100.076 | 536.318  | 356.121  | 347.086  | 132.902 | 77.275  | 18.591  | 9.960   | 18.535  |
| 15              | 40.178  | 33.172  | 47.942  | 29.920  | 354.651  | 229.258  | 240.447  | 106.958 | 25.724  | 1.636   | 8.505   | 18.575  |
| 20              | 40.436  | 33.183  | 48.205  | 30.780  | 107.568  | 159.410  | 172.060  | 57.352  | 6.605   | 1.772   | 8.207   | 18.756  |
| 30              | 41.018  | 33.949  | 49.070  | 32.394  | -5.805   | 70.827   | 41.363   | -0.152  | -10.856 | 1.962   | 7.818   | 19.275  |
| 40              | 42.373  | 36.512  | 50.699  | 34.098  | -2.748   | -13.142  | -20.724  | -12.168 | -7.647  | 3.715   | 9.311   | 20.478  |
| 50              | 44.761  | 40.757  | 53.396  | 36.754  | -0.550   | -9.697   | -15.037  | -7.278  | -4.284  | 5.743   | 11.720  | 22.329  |
| 60              | 47.899  | 47.661  | 57.400  | 39.988  | 6.415    | -5.494   | -5.380   | 0.757   | 1.901   | 9.380   | 14.952  | 25.053  |
| 70              | 50.908  | 53.638  | 59.813  | 38.525  | 9.538    | 2.735    | 1.834    | 7.509   | 7.132   | 11.528  | 17.381  | 27.561  |
| 80              | 49.815  | 58.553  | 64.499  | 46.086  | 22.926   | 13.595   | 15.795   | 14.079  | 10.371  | 12.772  | 18.486  | 27.890  |
| 85              | 46.938  | 57.914  | 69.297  | 50.172  | 28.547   | 18.490   | 20.500   | 15.654  | 11.194  | 12.741  | 19.124  | 28.386  |
| 90              | 44.975  | 56.540  | 71.968  | 51.675  | 32.085   | 20.462   | 23.225   | 17.004  | 11.516  | 13.038  | 19.437  | 30.128  |
| 95              | 45.896  | 58.049  | 73.893  | 47.184  | 33.131   | 20.724   | 25.441   | 18.435  | 12.202  | 12.959  | 19.170  | 31.609  |
| 99              | 46.911  | 54.516  | 59.305  | 48.464  | 26.798   | 18.492   | 25.136   | 17.765  | 12.578  | 12.766  | 17.489  | 30.834  |
| 99.9            | 43.733  | 52.188  | 54.648  | 51.447  | 23.498   | 21.360   | 25.970   | 18.961  | 14.241  | 13.766  | 17.200  | 30.042  |
| <b>Sc1b-EWR</b> |         |         |         |         |          |          |          |         |         |         |         |         |
| Percentiles     | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul     | Aug     | Sep     |
| 0.1             | 776.090 | 987.001 | 821.873 | 536.302 | 1314.381 | 1738.420 | 1315.342 | 760.233 | 240.971 | 100.353 | 433.881 | 481.709 |
| 1               | 571.492 | 945.302 | 724.848 | 449.315 | 949.578  | 1676.545 | 901.555  | 571.546 | 231.881 | 54.996  | 142.753 | 309.543 |
| 5               | 95.905  | 249.005 | 112.774 | 197.801 | 675.050  | 514.224  | 579.352  | 191.151 | 95.914  | 26.260  | 33.208  | 137.864 |
| 10              | 59.778  | 80.638  | 102.116 | 92.941  | 310.009  | 340.112  | 252.527  | 102.219 | 45.047  | 26.100  | 30.766  | 111.233 |
| 15              | 59.613  | 72.370  | 90.192  | 82.291  | 92.181   | 160.197  | 95.858   | 60.202  | 17.212  | 25.780  | 30.506  | 88.234  |
| 20              | 58.412  | 65.708  | 81.181  | 71.880  | 71.258   | 109.596  | 53.459   | 37.770  | 15.729  | 25.006  | 30.120  | 67.401  |
| 30              | 55.582  | 55.722  | 67.924  | 53.065  | 51.378   | 62.478   | 16.085   | 14.479  | 13.297  | 24.289  | 28.203  | 50.366  |
| 40              | 53.293  | 51.509  | 61.769  | 44.802  | 28.108   | 25.917   | 11.923   | 9.824   | 12.395  | 23.469  | 28.441  | 43.336  |
| 50              | 50.537  | 49.748  | 61.817  | 45.163  | 29.380   | 19.534   | 12.478   | 11.046  | 12.690  | 22.001  | 26.999  | 36.958  |
| 60              | 52.350  | 54.126  | 65.238  | 49.016  | 32.084   | 24.911   | 7.019    | 14.668  | 17.363  | 22.516  | 27.040  | 34.124  |
| 70              | 51.873  | 61.372  | 73.111  | 55.497  | 40.303   | 31.119   | 14.335   | 15.763  | 18.613  | 23.242  | 28.211  | 35.407  |
| 80              | 54.479  | 61.127  | 80.103  | 44.682  | 51.718   | 40.793   | 22.220   | 21.153  | 20.561  | 23.543  | 29.687  | 37.122  |
| 85              | 55.267  | 60.484  | 68.011  | 48.732  | 53.543   | 44.881   | 25.890   | 23.140  | 21.365  | 23.346  | 29.472  | 37.879  |
| 90              | 51.645  | 55.113  | 71.050  | 47.976  | 56.036   | 44.194   | 28.091   | 23.930  | 21.570  | 22.883  | 29.771  | 37.994  |
| 95              | 43.874  | 56.457  | 71.921  | 43.675  | 50.912   | 38.836   | 26.096   | 21.518  | 19.692  | 20.988  | 26.840  | 38.048  |
| 99              | 33.689  | 52.331  | 46.034  | 10.309  | 38.856   | 30.287   | 22.493   | 15.783  | 13.200  | 14.467  | 17.634  | 24.369  |
| 99.9            | 2.146   | 44.774  | 23.743  | 11.646  | 28.538   | 26.231   | 20.538   | 7.136   | 6.830   | 6.051   | 3.261   | 4.465   |

**Table 29: Estimated non-compliances with EWR (Sc2) for all months at UO\_EWR10\_I**

| Sc2a-EWR    |         |         |         |         |          |          |          |         |         |        |         |         |
|-------------|---------|---------|---------|---------|----------|----------|----------|---------|---------|--------|---------|---------|
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 662.129 | 959.431 | 789.719 | 475.861 | 1295.895 | 1777.067 | 1267.534 | 731.291 | 225.151 | 52.113 | 430.719 | 487.723 |
| 1           | 622.965 | 922.668 | 698.209 | 432.158 | 1022.395 | 1637.903 | 869.232  | 558.754 | 222.981 | 45.982 | 182.529 | 294.318 |
| 5           | 93.930  | 220.722 | 77.400  | 172.826 | 823.163  | 569.247  | 547.409  | 181.806 | 100.969 | 24.238 | 41.159  | 57.700  |
| 10          | 38.829  | 32.255  | 47.277  | 54.533  | 422.706  | 324.200  | 320.760  | 97.164  | 47.964  | 6.909  | 6.541   | 17.000  |
| 15          | 38.851  | 32.352  | 47.363  | 29.399  | 154.546  | 176.789  | 167.956  | 76.083  | 17.485  | -1.530 | 6.543   | 17.055  |
| 20          | 38.805  | 32.392  | 47.088  | 30.016  | 43.700   | 116.936  | 121.883  | 44.171  | -0.416  | -1.635 | 5.430   | 17.184  |
| 30          | 31.549  | 28.027  | 39.429  | 19.936  | -10.613  | 46.153   | 38.797   | -11.737 | -14.121 | -1.320 | 5.908   | 15.978  |
| 40          | 23.027  | 18.844  | 30.129  | 13.802  | -21.387  | -19.526  | -29.500  | -18.032 | -12.044 | -0.153 | 6.460   | 11.461  |
| 50          | 25.455  | 21.985  | 33.628  | 18.316  | -16.175  | -22.826  | -25.152  | -13.674 | -8.602  | 0.271  | 5.646   | 13.368  |
| 60          | 29.251  | 29.206  | 39.853  | 23.765  | -6.506   | -16.589  | -20.338  | -8.872  | -4.322  | 3.666  | 8.307   | 16.435  |
| 70          | 33.394  | 37.471  | 46.593  | 28.439  | 0.837    | -7.581   | -7.013   | -4.087  | 0.026   | 6.171  | 11.275  | 19.970  |
| 80          | 37.819  | 44.621  | 42.420  | 24.590  | 8.682    | -2.071   | 6.312    | 4.539   | 4.632   | 8.718  | 13.976  | 23.523  |
| 85          | 39.362  | 45.338  | 47.259  | 29.067  | 10.536   | 1.368    | 6.285    | 7.200   | 5.937   | 9.503  | 14.805  | 24.732  |
| 90          | 39.875  | 37.048  | 50.430  | 31.619  | 13.948   | 3.699    | 7.808    | 8.491   | 6.591   | 9.169  | 15.227  | 26.487  |
| 95          | 36.583  | 38.509  | 53.506  | 33.018  | 17.316   | 5.275    | 9.962    | 7.613   | 6.642   | 6.446  | 13.260  | 27.634  |
| 99          | 34.584  | 39.081  | 43.453  | 30.272  | 15.732   | 5.138    | 10.684   | 7.264   | 4.465   | 4.740  | 10.764  | 21.883  |
| 99.9        | 35.408  | 38.995  | 44.235  | 24.759  | 15.540   | 7.239    | 11.715   | 7.552   | 5.253   | 6.362  | 10.832  | 22.002  |
| Sc2b-EWR    |         |         |         |         |          |          |          |         |         |        |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 656.827 | 960.128 | 789.649 | 414.703 | 910.324  | 1606.230 | 1267.526 | 518.027 | 225.133 | 43.576 | 397.611 | 246.711 |
| 1           | 570.066 | 922.659 | 698.194 | 340.872 | 877.828  | 1586.495 | 869.216  | 480.309 | 222.907 | 33.773 | 124.033 | 219.927 |
| 5           | 66.345  | 220.295 | 83.904  | 98.985  | 429.189  | 514.227  | 496.198  | 93.807  | 83.988  | 30.651 | 30.429  | 38.041  |
| 10          | 54.305  | 58.156  | 73.029  | 80.414  | 133.652  | 243.882  | 193.751  | 50.689  | 32.397  | 30.129 | 29.323  | 37.023  |
| 15          | 53.925  | 51.788  | 65.221  | 70.244  | 128.710  | 95.430   | 50.359   | 37.989  | 28.064  | 29.567 | 27.025  | 36.329  |
| 20          | 52.690  | 50.356  | 62.005  | 54.044  | 112.352  | 49.187   | 41.183   | 34.985  | 27.718  | 28.574 | 26.824  | 34.622  |
| 30          | 47.358  | 42.914  | 50.275  | 41.889  | 98.784   | 23.746   | 18.956   | 28.068  | 23.402  | 26.707 | 26.319  | 32.910  |
| 40          | 44.126  | 37.797  | 42.245  | 31.289  | 80.510   | 19.290   | 18.485   | 18.115  | 18.345  | 22.876 | 24.632  | 29.868  |
| 50          | 40.701  | 36.430  | 39.550  | 27.805  | 53.081   | 13.864   | 16.443   | 16.889  | 15.939  | 20.507 | 22.500  | 28.535  |
| 60          | 39.631  | 35.333  | 43.048  | 31.353  | 46.000   | 12.739   | 8.412    | 15.312  | 17.256  | 20.009 | 20.410  | 27.020  |
| 70          | 38.058  | 40.645  | 51.008  | 36.654  | 41.632   | 19.101   | 9.749    | 16.448  | 16.470  | 17.965 | 20.716  | 25.463  |
| 80          | 38.586  | 46.075  | 41.035  | 26.337  | 40.234   | 25.868   | 15.660   | 15.679  | 16.366  | 16.779 | 20.727  | 26.431  |
| 85          | 39.761  | 46.676  | 33.504  | 30.244  | 44.171   | 30.299   | 17.008   | 17.433  | 16.521  | 15.897 | 20.022  | 26.954  |
| 90          | 40.515  | 35.693  | 36.003  | 32.062  | 46.507   | 30.995   | 19.364   | 15.850  | 15.918  | 14.443 | 19.662  | 27.418  |
| 95          | 28.495  | 35.095  | 34.893  | 32.411  | 49.793   | 21.467   | 19.437   | 15.267  | 12.885  | 12.456 | 16.575  | 28.707  |
| 99          | 16.331  | 27.662  | 24.283  | 29.668  | 34.037   | 17.178   | 11.799   | 10.199  | 8.672   | 10.019 | 10.046  | 15.856  |
| 99.9        | 2.185   | 14.252  | 24.842  | 31.594  | 27.455   | 14.580   | 10.225   | 8.369   | 8.094   | 7.563  | 4.835   | 6.444   |
| Sc2.1a-EWR  |         |         |         |         |          |          |          |         |         |        |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 661.423 | 959.433 | 789.719 | 475.861 | 1508.585 | 1777.067 | 1267.534 | 731.291 | 225.151 | 43.652 | 428.041 | 478.854 |
| 1           | 615.906 | 922.668 | 698.209 | 432.158 | 1256.831 | 1637.903 | 869.232  | 558.754 | 222.981 | 34.354 | 179.868 | 292.769 |
| 5           | 93.763  | 219.523 | 82.103  | 172.509 | 820.355  | 566.071  | 547.409  | 186.219 | 100.969 | 23.932 | 41.159  | 59.543  |
| 10          | 35.236  | 28.500  | 49.111  | 54.105  | 422.706  | 324.200  | 326.919  | 104.907 | 53.343  | 7.983  | 10.273  | 20.419  |
| 15          | 21.141  | 19.065  | 31.917  | 9.115   | 180.820  | 179.667  | 205.599  | 86.553  | 18.840  | 0.433  | 8.885   | 13.812  |
| 20          | 20.820  | 13.272  | 26.699  | 9.540   | 78.522   | 134.269  | 137.900  | 44.171  | -2.478  | 0.063  | 8.026   | 9.657   |
| 30          | 21.438  | 14.321  | 27.635  | 11.218  | -25.859  | 61.607   | 23.800   | -11.289 | -13.841 | -2.317 | 1.709   | 10.090  |
| 40          | 22.947  | 17.100  | 29.879  | 13.655  | -22.315  | -21.444  | -28.045  | -15.882 | -13.639 | -2.525 | 3.110   | 11.376  |
| 50          | 25.404  | 21.596  | 33.346  | 18.063  | -16.264  | -27.427  | -32.697  | -21.530 | -12.845 | -0.355 | 4.643   | 13.311  |
| 60          | 29.195  | 28.879  | 39.107  | 23.107  | -6.796   | -17.139  | -20.443  | -13.073 | -5.999  | 3.275  | 7.908   | 16.425  |
| 70          | 33.284  | 36.782  | 45.244  | 27.053  | 0.586    | -7.516   | -7.551   | -4.310  | -0.289  | 6.051  | 11.163  | 19.956  |
| 80          | 37.623  | 42.890  | 42.446  | 24.601  | 8.140    | -2.011   | 1.981    | 3.653   | 4.376   | 8.632  | 13.937  | 23.509  |
| 85          | 38.976  | 44.960  | 47.265  | 29.084  | 10.040   | 1.409    | 4.857    | 7.016   | 5.801   | 9.369  | 14.792  | 24.639  |
| 90          | 39.162  | 37.048  | 50.471  | 31.710  | 13.967   | 3.699    | 7.728    | 8.235   | 6.149   | 9.169  | 15.191  | 26.297  |
| 95          | 38.303  | 38.509  | 53.643  | 34.016  | 17.337   | 5.275    | 10.112   | 7.613   | 6.073   | 6.446  | 12.566  | 26.898  |
| 99          | 34.584  | 39.076  | 54.022  | 34.479  | 19.189   | 5.454    | 10.986   | 7.264   | 4.658   | 5.855  | 10.764  | 21.883  |
| 99.9        | 35.408  | 38.970  | 54.241  | 38.066  | 18.923   | 9.049    | 11.745   | 7.552   | 6.354   | 7.448  | 10.832  | 22.002  |
| Sc2.1b-EWR  |         |         |         |         |          |          |          |         |         |        |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 657.300 | 960.130 | 789.649 | 422.034 | 910.332  | 1678.694 | 1267.526 | 730.780 | 225.133 | 64.062 | 405.025 | 452.239 |
| 1           | 574.774 | 922.660 | 698.194 | 414.187 | 877.909  | 1620.697 | 869.216  | 558.648 | 222.907 | 48.053 | 136.469 | 285.068 |
| 5           | 77.408  | 220.112 | 96.871  | 141.209 | 617.584  | 514.227  | 536.474  | 176.034 | 94.287  | 21.787 | 26.130  | 114.213 |
| 10          | 35.906  | 55.295  | 45.711  | 31.527  | 219.686  | 309.752  | 278.524  | 71.579  | 25.017  | 18.133 | 22.295  | 97.446  |
| 15          | 35.566  | 30.756  | 44.901  | 27.313  | 111.013  | 135.083  | 153.651  | 46.521  | 7.451   | 14.290 | 18.207  | 63.308  |
| 20          | 35.108  | 28.252  | 40.817  | 26.419  | 77.901   | 93.640   | 43.702   | 20.822  | 6.281   | 13.779 | 16.978  | 46.199  |
| 30          | 33.613  | 27.300  | 36.805  | 18.661  | 5.395    | 5.260    | 2.119    | 2.285   | 3.425   | 13.174 | 16.648  | 27.077  |
| 40          | 33.401  | 26.083  | 34.948  | 17.577  | 6.646    | 6.373    | 3.451    | 1.355   | 4.205   | 12.313 | 15.810  | 23.522  |
| 50          | 32.050  | 27.158  | 35.965  | 20.551  | 8.797    | 6.391    | 3.771    | 0.322   | 5.453   | 11.884 | 15.173  | 22.756  |
| 60          | 33.481  | 33.549  | 41.729  | 25.854  | 15.688   | 9.296    | 0.579    | 5.107   | 8.293   | 13.934 | 16.218  | 24.048  |
| 70          | 35.112  | 41.365  | 50.132  | 29.905  | 22.071   | 13.922   | 3.096    | 7.938   | 10.113  | 14.838 | 18.667  | 24.637  |
| 80          | 38.078  | 46.445  | 47.774  | 33.043  | 35.203   | 24.981   | 12.652   | 12.251  | 12.366  | 15.553 | 20.095  | 26.663  |
| 85          | 39.682  | 48.277  | 37.893  | 36.276  | 41.356   | 29.205   | 13.334   | 13.359  | 13.316  | 15.657 | 19.979  | 27.195  |
| 90          | 40.493  | 39.216  | 39.970  | 36.305  | 44.433   | 28.096   | 15.742   | 13.830  | 13.439  | 15.723 | 19.788  | 28.561  |
| 95          | 41.012  | 39.070  | 38.006  | 36.150  | 46.442   | 24.787   | 17.011   | 14.422  | 13.853  | 14.901 | 19.489  | 28.744  |
| 99          | 22.750  | 30.849  | 27.031  | 34.892  | 38.796   | 17.137   | 9.049    | 12.844  | 10.862  | 13.223 | 14.591  | 24.318  |
| 99.9        | 23.570  | 14.571  | 27.523  | 34.275  | 35.287   | 13.546   | 8.278    | 14.071  | 12.497  | 14.239 | 14.790  | 18.985  |

Table 30: Estimated non-compliances with EWR (Sc3) for all months at UO\_EWR10\_I

| Sc3a-EWR    |         |         |         |         |          |          |          |         |         |        |         |         |
|-------------|---------|---------|---------|---------|----------|----------|----------|---------|---------|--------|---------|---------|
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 652.345 | 943.425 | 780.919 | 442.734 | 1161.925 | 1754.578 | 1262.561 | 724.092 | 219.725 | 52.036 | 408.552 | 446.669 |
| 1           | 593.781 | 915.349 | 690.743 | 420.664 | 951.735  | 1629.121 | 862.856  | 553.044 | 217.607 | 48.950 | 168.035 | 289.305 |
| 5           | 87.275  | 213.556 | 67.291  | 144.367 | 744.639  | 513.684  | 527.223  | 186.691 | 82.504  | 37.127 | 65.588  | 30.714  |
| 10          | 39.358  | 32.874  | 47.881  | 29.488  | 352.424  | 326.543  | 283.686  | 106.923 | 57.250  | 15.060 | 15.016  | 17.451  |
| 15          | 39.366  | 32.972  | 47.886  | 30.177  | 95.083   | 138.075  | 144.054  | 59.633  | 16.014  | 4.390  | 7.097   | 17.490  |
| 20          | 39.086  | 33.195  | 47.438  | 30.605  | 36.722   | 122.828  | 90.741   | 31.691  | -4.984  | -0.724 | 7.087   | 17.312  |
| 30          | 28.501  | 27.513  | 36.207  | 17.562  | -9.651   | 8.936    | -5.318   | 0.083   | -13.560 | -0.433 | 6.986   | 12.093  |
| 40          | 23.492  | 18.232  | 30.722  | 14.501  | -16.686  | -20.365  | -30.901  | -18.058 | -11.911 | -0.144 | 3.999   | 11.798  |
| 50          | 25.929  | 22.529  | 34.194  | 18.961  | -15.476  | -24.060  | -27.900  | -14.837 | -12.393 | 0.160  | 6.008   | 13.701  |
| 60          | 29.717  | 29.839  | 40.453  | 24.407  | -5.857   | -16.014  | -19.995  | -12.543 | -5.667  | 4.002  | 9.301   | 16.809  |
| 70          | 33.854  | 38.065  | 47.302  | 29.236  | 2.633    | -7.901   | -6.928   | -3.871  | 0.172   | 6.802  | 12.421  | 20.344  |
| 80          | 38.257  | 43.875  | 45.367  | 25.221  | 5.846    | -2.237   | 4.281    | 4.533   | 5.093   | 9.444  | 15.100  | 23.822  |
| 85          | 39.795  | 45.982  | 47.815  | 29.669  | 10.454   | 1.633    | 5.303    | 6.797   | 6.382   | 9.802  | 15.818  | 24.902  |
| 90          | 40.176  | 37.338  | 51.008  | 32.007  | 14.376   | 3.616    | 8.068    | 8.352   | 5.768   | 8.894  | 15.101  | 25.960  |
| 95          | 35.585  | 38.980  | 54.180  | 31.474  | 17.374   | 4.994    | 10.151   | 6.993   | 5.129   | 6.143  | 12.788  | 25.725  |
| 99          | 34.646  | 39.554  | 32.731  | 22.729  | 6.729    | -0.539   | 9.176    | 7.628   | 4.549   | 3.672  | 11.095  | 21.925  |
| 99.9        | 35.766  | 39.482  | 33.341  | 15.845  | 0.458    | -1.501   | 9.453    | 8.536   | 4.318   | 5.076  | 11.142  | 21.405  |
| Sc3b-EWR    |         |         |         |         |          |          |          |         |         |        |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 649.559 | 950.729 | 780.849 | 413.081 | 903.782  | 1600.643 | 1262.554 | 512.846 | 219.706 | 39.849 | 400.062 | 418.479 |
| 1           | 566.269 | 916.493 | 690.727 | 386.900 | 872.648  | 1583.463 | 862.840  | 477.110 | 217.528 | 25.267 | 131.127 | 274.419 |
| 5           | 64.265  | 216.122 | 105.551 | 132.997 | 159.967  | 508.796  | 532.593  | 101.580 | 80.929  | 20.266 | 24.894  | 114.275 |
| 10          | 51.379  | 63.905  | 78.080  | 82.804  | 86.272   | 233.965  | 181.140  | 60.519  | 9.133   | 18.558 | 23.741  | 94.352  |
| 15          | 46.036  | 58.259  | 65.818  | 60.177  | 69.270   | 107.118  | 12.353   | 26.975  | 5.923   | 15.414 | 21.687  | 62.796  |
| 20          | 36.953  | 45.348  | 56.487  | 49.739  | 50.317   | 86.864   | 2.449    | 7.395   | 4.244   | 15.032 | 20.184  | 43.392  |
| 30          | 35.445  | 30.954  | 47.602  | 35.917  | 20.797   | 5.657    | 1.846    | 2.047   | 3.050   | 13.444 | 18.801  | 29.994  |
| 40          | 33.915  | 27.701  | 47.133  | 31.325  | 9.013    | 9.042    | 1.950    | 0.507   | 3.833   | 13.537 | 18.984  | 24.058  |
| 50          | 32.194  | 30.001  | 42.505  | 24.259  | 12.704   | 10.321   | 3.371    | 1.784   | 5.497   | 13.024 | 16.881  | 23.523  |
| 60          | 33.624  | 34.923  | 44.693  | 27.142  | 18.632   | 12.005   | 0.568    | 5.288   | 8.697   | 14.531 | 18.240  | 24.501  |
| 70          | 34.564  | 42.139  | 50.915  | 33.876  | 25.715   | 18.685   | 0.951    | 8.156   | 11.786  | 15.453 | 19.811  | 25.237  |
| 80          | 38.452  | 46.942  | 55.255  | 33.666  | 36.341   | 26.032   | 11.768   | 11.856  | 13.547  | 15.946 | 21.206  | 27.329  |
| 85          | 40.000  | 46.506  | 54.580  | 37.048  | 42.168   | 30.666   | 14.011   | 13.340  | 13.912  | 16.270 | 21.115  | 27.231  |
| 90          | 40.048  | 39.826  | 41.074  | 37.671  | 44.860   | 29.207   | 16.147   | 14.182  | 13.993  | 15.671 | 20.864  | 27.277  |
| 95          | 38.430  | 40.560  | 42.472  | 38.479  | 40.904   | 23.755   | 17.136   | 14.664  | 14.512  | 15.201 | 20.605  | 28.563  |
| 99          | 24.691  | 30.635  | 35.809  | 34.402  | 36.480   | 16.666   | 8.614    | 13.218  | 12.563  | 13.035 | 15.689  | 23.727  |
| 99.9        | 24.425  | 14.549  | 29.055  | 33.830  | 33.465   | 13.639   | 8.102    | 13.744  | 14.005  | 14.705 | 15.435  | 19.433  |
| Sc3.1a-EWR  |         |         |         |         |          |          |          |         |         |        |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 642.224 | 934.384 | 771.140 | 405.323 | 894.764  | 1667.497 | 1254.293 | 702.007 | 211.757 | 52.188 | 388.107 | 404.361 |
| 1           | 576.369 | 900.885 | 680.529 | 396.604 | 863.770  | 1607.149 | 850.505  | 542.993 | 209.528 | 51.231 | 125.551 | 274.076 |
| 5           | 67.196  | 199.897 | 47.944  | 110.347 | 557.548  | 499.984  | 495.874  | 185.241 | 79.903  | 24.894 | 34.790  | 17.409  |
| 10          | 39.240  | 32.808  | 47.778  | 29.549  | 120.112  | 242.972  | 260.693  | 79.988  | 17.512  | 5.074  | 6.574   | 17.370  |
| 15          | 38.864  | 32.830  | 46.918  | 30.208  | 60.748   | 139.706  | 134.649  | 41.916  | 0.031   | -1.253 | 6.270   | 16.880  |
| 20          | 38.045  | 33.013  | 45.962  | 30.628  | -6.979   | 57.590   | 28.779   | 11.219  | -14.862 | -1.162 | 5.829   | 16.285  |
| 30          | 23.679  | 24.504  | 34.725  | 17.565  | -12.115  | -22.713  | -19.509  | -20.148 | -14.839 | -3.188 | 2.902   | 10.551  |
| 40          | 23.462  | 17.825  | 30.673  | 14.507  | -15.026  | -26.845  | -31.490  | -19.019 | -15.497 | -2.103 | 3.544   | 11.739  |
| 50          | 25.914  | 22.456  | 34.152  | 18.894  | -15.550  | -26.759  | -29.633  | -17.806 | -12.630 | 0.038  | 5.897   | 13.692  |
| 60          | 29.684  | 29.769  | 39.714  | 23.269  | -6.201   | -18.176  | -19.971  | -12.750 | -5.771  | 3.890  | 9.198   | 16.804  |
| 70          | 33.810  | 37.839  | 42.019  | 28.329  | 0.697    | -11.649  | -7.526   | -4.062  | -0.285  | 6.634  | 12.257  | 20.284  |
| 80          | 38.088  | 42.594  | 42.956  | 25.202  | 4.158    | -3.312   | 0.821    | 3.314   | 4.519   | 8.813  | 14.520  | 23.507  |
| 85          | 38.946  | 38.839  | 47.781  | 29.663  | 10.299   | 1.119    | 5.207    | 6.088   | 4.695   | 8.450  | 14.626  | 23.469  |
| 90          | 38.292  | 37.338  | 50.916  | 31.996  | 14.359   | 3.110    | 7.552    | 5.872   | 4.050   | 7.506  | 13.356  | 22.565  |
| 95          | 34.773  | 38.980  | 53.788  | 25.757  | 10.354   | 4.723    | 9.242    | 6.938   | 4.311   | 6.140  | 10.934  | 22.506  |
| 99          | 33.505  | 39.502  | 30.790  | 16.051  | 1.922    | -3.355   | 7.646    | 7.635   | 4.125   | 1.745  | 9.052   | 21.037  |
| 99.9        | 30.914  | 39.477  | 24.238  | 14.844  | -0.263   | -1.929   | 9.223    | 8.573   | 2.437   | 2.737  | 9.068   | 16.477  |
| Sc3.1b-EWR  |         |         |         |         |          |          |          |         |         |        |         |         |
| Percentiles | Oct     | Nov     | Dec     | Jan     | Feb      | Mar      | Apr      | May     | Jun     | Jul    | Aug     | Sep     |
| 0.1         | 638.441 | 852.141 | 771.136 | 397.670 | 894.747  | 1585.005 | 1254.285 | 505.367 | 201.796 | 20.759 | 384.365 | 230.601 |
| 1           | 538.882 | 495.745 | 680.522 | 320.114 | 863.687  | 1500.814 | 850.493  | 469.859 | 110.025 | 20.533 | 115.603 | 196.113 |
| 5           | 52.677  | 208.173 | 101.760 | 96.754  | 139.380  | 452.238  | 477.432  | 75.144  | 37.199  | 19.188 | 24.894  | 109.729 |
| 10          | 50.716  | 60.264  | 71.382  | 59.655  | 78.399   | 216.867  | 131.420  | 28.858  | 6.126   | 15.616 | 21.001  | 75.018  |
| 15          | 43.937  | 45.294  | 60.007  | 53.567  | 56.369   | 98.143   | 10.070   | 6.791   | 5.173   | 14.712 | 18.835  | 58.186  |
| 20          | 36.158  | 35.988  | 50.126  | 43.270  | 41.915   | 50.909   | 1.152    | 2.561   | 3.888   | 14.634 | 17.753  | 41.028  |
| 30          | 32.549  | 30.020  | 44.882  | 30.352  | 13.840   | 5.245    | 1.408    | 1.747   | 2.518   | 13.138 | 17.409  | 28.930  |
| 40          | 29.838  | 26.523  | 43.694  | 27.919  | 8.343    | 5.474    | 1.180    | 0.393   | 2.952   | 12.894 | 16.651  | 23.662  |
| 50          | 29.969  | 27.553  | 40.911  | 23.770  | 12.697   | 7.391    | 2.307    | 1.784   | 5.267   | 12.345 | 16.605  | 22.757  |
| 60          | 31.794  | 33.697  | 42.479  | 26.792  | 18.206   | 11.582   | 0.568    | 5.114   | 7.695   | 14.442 | 17.333  | 23.997  |
| 70          | 33.954  | 38.682  | 50.700  | 31.685  | 24.753   | 18.153   | 0.951    | 7.413   | 11.625  | 14.888 | 19.022  | 24.989  |
| 80          | 38.309  | 42.029  | 49.896  | 33.098  | 35.746   | 25.948   | 10.701   | 10.048  | 13.014  | 15.376 | 20.304  | 26.281  |
| 85          | 39.003  | 41.906  | 38.957  | 36.369  | 40.429   | 28.815   | 13.336   | 12.797  | 13.342  | 15.442 | 20.210  | 25.418  |
| 90          | 34.897  | 39.203  | 40.738  | 34.966  | 42.205   | 26.850   | 15.748   | 13.867  | 13.505  | 14.346 | 19.353  | 25.383  |
| 95          | 31.262  | 39.472  | 41.766  | 32.694  | 39.806   | 18.481   | 13.038   | 11.656  | 12.792  | 13.481 | 17.227  | 23.829  |
| 99          | 18.886  | 30.635  | 35.809  | 31.895  | 33.678   | 16.666   | 8.614    | 10.557  | 8.957   | 10.107 | 14.129  | 16.957  |
| 99.9        | 1.532   | 14.549  | 29.055  | 33.580  | 25.134   | 13.639   | 8.102    | 8.265   | 8.935   | 9.226  | 6.507   | 5.785   |

## 5.9 IUA9: Upper Modder River

Ecological consequences were assessed at two EWR sites in the Upper Modder (sites UO\_EWR07\_I and UO\_EWR06\_R) within this IUA. Both these sites are impacted by the discharges from numerous WWTWs in the larger Bloemfontein area. Rustfontein Dam is in the upper reaches of the Modder River upstream the EWR sites. The discharges from WWTWs resulted in increased baseflows, especially during the dry months. The dam impacts on the freshet/ flood components of the flow regime.

Only present day and medium-term scenarios were assessed at the two EWR sites. Limited long-term developments are foreseen in this IUA. Refer to Table 31 for the average flows (1920 - 2004) at the two EWR sites measured in Mm<sup>3</sup>.

**Table 31: Average flows (1920-2004) for UO\_EWR07\_I and UO\_EWR06\_R**

| Average Flows (1920-2004) – Mm <sup>3</sup> |            |            |
|---------------------------------------------|------------|------------|
|                                             | UO_EWR07_I | UO_EWR06_R |
| nMAR                                        | 61.0       | 113.7      |
| Sc1a (PRS)                                  | 33.6       | 125.9      |
| Sc1b                                        | 33.6       | 125.9      |
| Sc2a                                        | 35.6       | 123.9      |
| Sc2b                                        | 34.9       | 122.5      |

No changes were made to the EWRs as determined during the high confidence study of the Reserve for the Upper Orange River.

The seasonal distribution (hydrograph) plots were prepared using the flows provided for the scenarios and is illustrated in Figure 17 and Figure 18. Table 32 and Table 33 provide the estimated non-compliances for all the months for the scenarios (values in red).

The results indicate that the EWR could be met for most of the time at both sites for Sc1 and Sc2 irrespective if the EWR was implemented or not. Some small non-compliances for site UO\_EWR06\_R during drought periods for months March to November in Sc2b.

The graphs indicate that for site UO\_EWR07\_I the high flows have decreased due to the upstream dam and increased baseflows due to WWTW discharges. At site UO\_EWR06\_R all the flow components have increased compared to the natural flows as a results of the discharges from the wastewater treatment works (WWTWs).

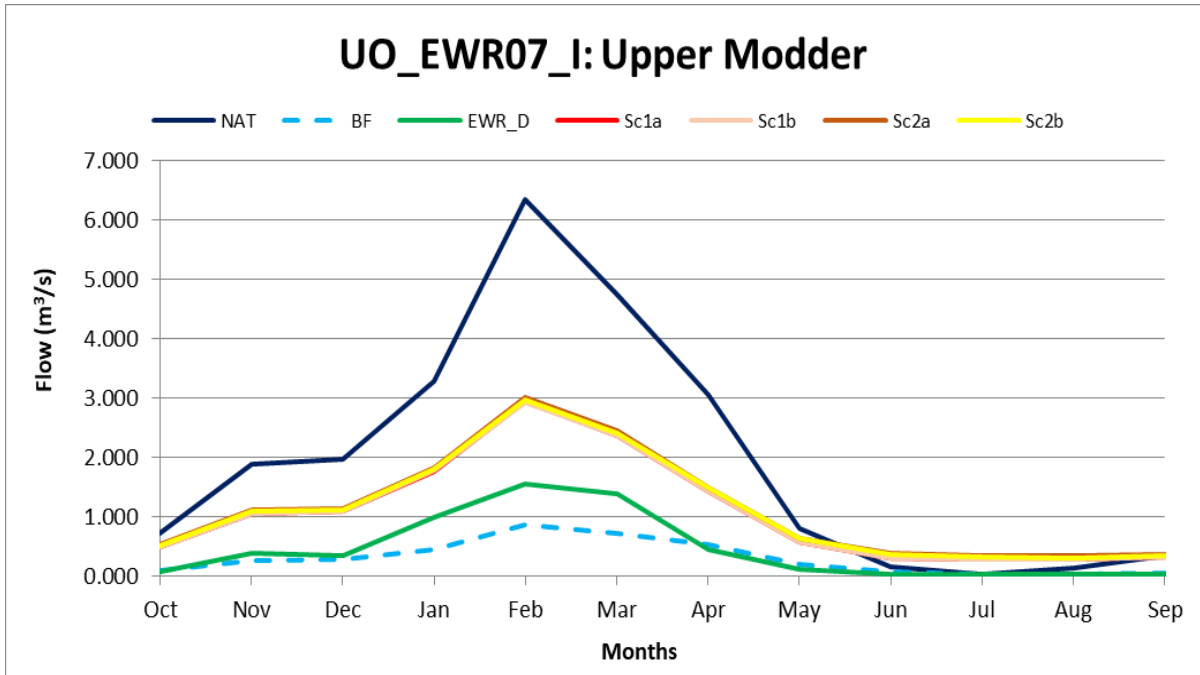


Figure 17: Seasonal distribution of scenarios at site UO\_EWR07\_I: Upper Modder

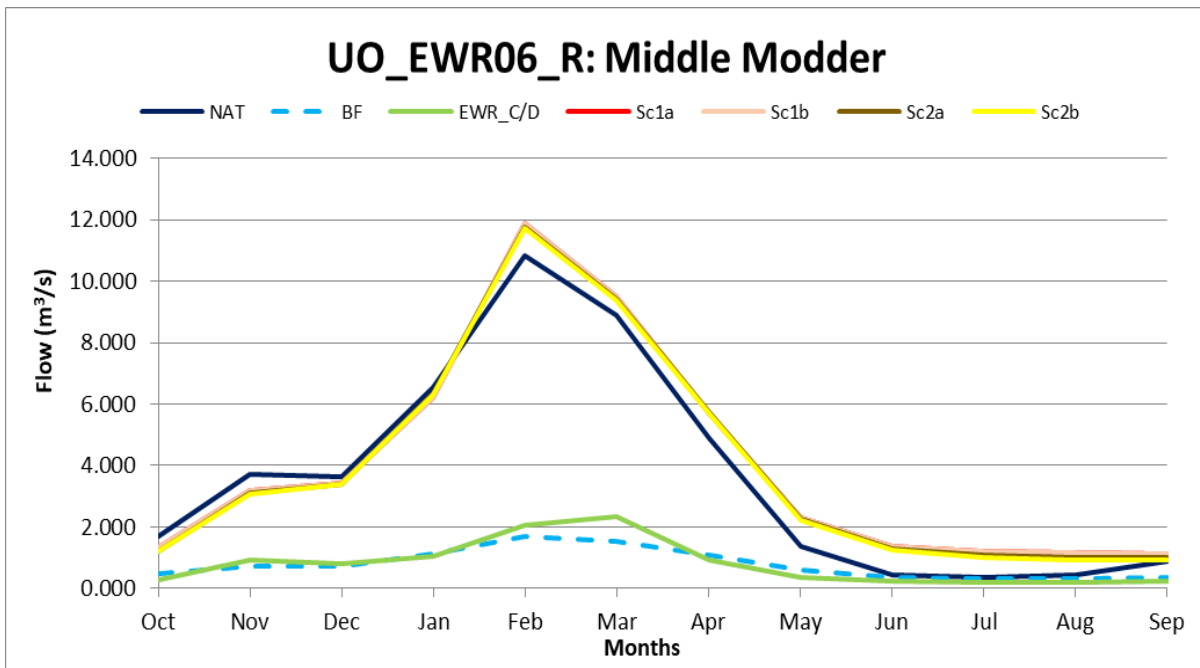


Figure 18: Seasonal distribution of scenarios at site UO\_EWR06\_R: Middle Modder

**Table 32: Estimated non-compliances with EWR for all months at UO\_EWR07\_I**

| <b>Sc1a-EWR</b> |       |       |       |       |        |        |       |       |       |       |       |       |
|-----------------|-------|-------|-------|-------|--------|--------|-------|-------|-------|-------|-------|-------|
| Percentiles     | Oct   | Nov   | Dec   | Jan   | Feb    | Mar    | Apr   | May   | Jun   | Jul   | Aug   | Sep   |
| 0.1             | 7.315 | 9.598 | 5.789 | 8.316 | 36.602 | 21.708 | 9.524 | 6.371 | 0.969 | 0.464 | 1.644 | 4.744 |
| 1               | 3.473 | 7.393 | 5.741 | 8.143 | 21.707 | 15.657 | 8.596 | 4.179 | 0.855 | 0.313 | 0.857 | 1.936 |
| 5               | 1.286 | 1.883 | 2.837 | 4.680 | 8.281  | 3.483  | 3.362 | 1.291 | 0.329 | 0.234 | 0.329 | 0.462 |
| 10              | 0.522 | 1.184 | 1.954 | 2.064 | 4.149  | 0.824  | 2.323 | 0.555 | 0.218 | 0.210 | 0.213 | 0.289 |
| 15              | 0.466 | 0.731 | 1.202 | 0.833 | 0.460  | -1.179 | 1.468 | 0.390 | 0.212 | 0.236 | 0.199 | 0.228 |
| 20              | 0.340 | 0.347 | 0.853 | 0.448 | 0.094  | -0.908 | 0.721 | 0.221 | 0.236 | 0.239 | 0.195 | 0.189 |
| 30              | 0.259 | 0.475 | 0.533 | 0.206 | -0.889 | 0.500  | 0.541 | 0.206 | 0.266 | 0.259 | 0.205 | 0.181 |
| 40              | 0.233 | 0.356 | 0.433 | 0.385 | -0.248 | 0.780  | 0.486 | 0.245 | 0.275 | 0.273 | 0.213 | 0.189 |
| 50              | 0.197 | 0.320 | 0.363 | 0.323 | 0.131  | 0.754  | 0.418 | 0.236 | 0.283 | 0.280 | 0.241 | 0.202 |
| 60              | 0.184 | 0.185 | 0.291 | 0.204 | 0.185  | 0.509  | 0.336 | 0.257 | 0.284 | 0.280 | 0.245 | 0.192 |
| 70              | 0.170 | 0.137 | 0.203 | 0.141 | 0.162  | 0.303  | 0.215 | 0.268 | 0.283 | 0.277 | 0.241 | 0.182 |
| 80              | 0.166 | 0.090 | 0.106 | 0.076 | 0.097  | 0.189  | 0.183 | 0.271 | 0.282 | 0.276 | 0.238 | 0.171 |
| 85              | 0.155 | 0.115 | 0.115 | 0.058 | 0.113  | 0.127  | 0.230 | 0.272 | 0.280 | 0.275 | 0.238 | 0.170 |
| 90              | 0.148 | 0.117 | 0.177 | 0.064 | 0.127  | 0.184  | 0.246 | 0.273 | 0.280 | 0.275 | 0.237 | 0.169 |
| 95              | 0.102 | 0.114 | 0.137 | 0.127 | 0.133  | 0.208  | 0.240 | 0.268 | 0.279 | 0.164 | 0.122 | 0.008 |
| 99              | 0.001 | 0.085 | 0.050 | 0.113 | 0.137  | 0.164  | 0.048 | 0.094 | 0.002 | 0.001 | 0.001 | 0.001 |
| 99.9            | 0.000 | 0.029 | 0.028 | 0.067 | 0.039  | 0.123  | 0.038 | 0.011 | 0.001 | 0.001 | 0.001 | 0.000 |
| <b>Sc1b-EWR</b> |       |       |       |       |        |        |       |       |       |       |       |       |
| Percentiles     | Oct   | Nov   | Dec   | Jan   | Feb    | Mar    | Apr   | May   | Jun   | Jul   | Aug   | Sep   |
| 0.1             | 7.277 | 9.598 | 5.789 | 8.316 | 36.294 | 21.705 | 9.494 | 6.371 | 0.969 | 0.464 | 1.644 | 4.744 |
| 1               | 3.474 | 7.393 | 5.741 | 8.143 | 21.653 | 15.628 | 8.590 | 4.179 | 0.855 | 0.313 | 0.857 | 1.936 |
| 5               | 1.286 | 1.883 | 2.846 | 4.680 | 8.255  | 3.483  | 3.362 | 1.291 | 0.329 | 0.234 | 0.329 | 0.462 |
| 10              | 0.521 | 1.184 | 1.954 | 2.064 | 4.115  | 0.825  | 2.323 | 0.555 | 0.218 | 0.210 | 0.213 | 0.289 |
| 15              | 0.466 | 0.731 | 1.202 | 0.833 | 0.460  | -1.179 | 1.468 | 0.390 | 0.212 | 0.236 | 0.199 | 0.228 |
| 20              | 0.340 | 0.347 | 0.853 | 0.448 | 0.094  | -0.908 | 0.721 | 0.222 | 0.236 | 0.239 | 0.195 | 0.190 |
| 30              | 0.258 | 0.475 | 0.533 | 0.205 | -0.888 | 0.500  | 0.541 | 0.206 | 0.266 | 0.259 | 0.205 | 0.181 |
| 40              | 0.233 | 0.356 | 0.433 | 0.385 | -0.248 | 0.780  | 0.486 | 0.244 | 0.275 | 0.273 | 0.213 | 0.189 |
| 50              | 0.197 | 0.319 | 0.362 | 0.323 | 0.131  | 0.753  | 0.418 | 0.236 | 0.283 | 0.280 | 0.241 | 0.202 |
| 60              | 0.184 | 0.185 | 0.290 | 0.204 | 0.185  | 0.509  | 0.336 | 0.258 | 0.284 | 0.280 | 0.245 | 0.192 |
| 70              | 0.170 | 0.136 | 0.180 | 0.142 | 0.162  | 0.303  | 0.215 | 0.268 | 0.283 | 0.277 | 0.241 | 0.182 |
| 80              | 0.166 | 0.090 | 0.107 | 0.076 | 0.097  | 0.189  | 0.183 | 0.271 | 0.282 | 0.276 | 0.238 | 0.171 |
| 85              | 0.155 | 0.119 | 0.114 | 0.057 | 0.134  | 0.127  | 0.229 | 0.272 | 0.280 | 0.275 | 0.238 | 0.170 |
| 90              | 0.148 | 0.117 | 0.177 | 0.067 | 0.127  | 0.184  | 0.246 | 0.273 | 0.280 | 0.275 | 0.237 | 0.169 |
| 95              | 0.102 | 0.114 | 0.137 | 0.138 | 0.133  | 0.208  | 0.240 | 0.268 | 0.279 | 0.165 | 0.121 | 0.062 |
| 99              | 0.029 | 0.086 | 0.056 | 0.149 | 0.135  | 0.178  | 0.107 | 0.095 | 0.023 | 0.004 | 0.015 | 0.001 |
| 99.9            | 0.003 | 0.032 | 0.056 | 0.071 | 0.045  | 0.174  | 0.072 | 0.014 | 0.003 | 0.001 | 0.002 | 0.000 |
| <b>Sc2a-EWR</b> |       |       |       |       |        |        |       |       |       |       |       |       |
| Percentiles     | Oct   | Nov   | Dec   | Jan   | Feb    | Mar    | Apr   | May   | Jun   | Jul   | Aug   | Sep   |
| 0.1             | 7.405 | 9.702 | 5.891 | 8.413 | 36.666 | 21.796 | 9.646 | 6.477 | 1.069 | 0.566 | 1.489 | 4.857 |
| 1               | 3.416 | 7.488 | 5.828 | 8.256 | 21.792 | 15.770 | 8.698 | 4.296 | 0.955 | 0.420 | 0.925 | 2.046 |
| 5               | 1.211 | 1.899 | 2.939 | 4.775 | 8.384  | 3.591  | 3.480 | 1.398 | 0.429 | 0.336 | 0.438 | 0.537 |
| 10              | 0.605 | 1.280 | 2.040 | 2.153 | 4.248  | 0.939  | 2.424 | 0.654 | 0.322 | 0.316 | 0.303 | 0.363 |
| 15              | 0.488 | 0.749 | 1.286 | 0.928 | 0.563  | -1.080 | 1.578 | 0.490 | 0.308 | 0.342 | 0.300 | 0.316 |
| 20              | 0.396 | 0.371 | 0.943 | 0.544 | -0.101 | -0.807 | 0.827 | 0.330 | 0.337 | 0.344 | 0.293 | 0.299 |
| 30              | 0.332 | 0.565 | 0.548 | 0.287 | -0.797 | 0.601  | 0.490 | 0.300 | 0.370 | 0.360 | 0.304 | 0.273 |
| 40              | 0.291 | 0.471 | 0.511 | 0.410 | -0.147 | 0.867  | 0.545 | 0.341 | 0.375 | 0.377 | 0.310 | 0.278 |
| 50              | 0.278 | 0.398 | 0.452 | 0.391 | 0.171  | 0.849  | 0.519 | 0.331 | 0.382 | 0.383 | 0.352 | 0.290 |
| 60              | 0.269 | 0.279 | 0.335 | 0.192 | 0.275  | 0.611  | 0.436 | 0.353 | 0.381 | 0.381 | 0.345 | 0.294 |
| 70              | 0.266 | 0.198 | 0.206 | 0.213 | 0.258  | 0.329  | 0.301 | 0.361 | 0.380 | 0.378 | 0.335 | 0.265 |
| 80              | 0.233 | 0.137 | 0.134 | 0.142 | 0.196  | 0.245  | 0.285 | 0.362 | 0.376 | 0.372 | 0.228 | 0.212 |
| 85              | 0.223 | 0.140 | 0.148 | 0.120 | 0.191  | 0.220  | 0.319 | 0.361 | 0.366 | 0.268 | 0.149 | 0.045 |
| 90              | 0.105 | 0.141 | 0.108 | 0.092 | 0.186  | 0.291  | 0.322 | 0.188 | 0.133 | 0.083 | 0.062 | 0.015 |
| 95              | 0.021 | 0.082 | 0.048 | 0.088 | 0.064  | 0.294  | 0.127 | 0.132 | 0.047 | 0.006 | 0.001 | 0.001 |
| 99              | 0.001 | 0.017 | 0.010 | 0.043 | 0.003  | 0.085  | 0.030 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| 99.9            | 0.000 | 0.004 | 0.008 | 0.045 | -0.009 | 0.009  | 0.004 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 |
| <b>Sc2b-EWR</b> |       |       |       |       |        |        |       |       |       |       |       |       |
| Percentiles     | Oct   | Nov   | Dec   | Jan   | Feb    | Mar    | Apr   | May   | Jun   | Jul   | Aug   | Sep   |
| 0.1             | 7.367 | 9.701 | 5.891 | 8.406 | 36.121 | 21.772 | 9.339 | 6.477 | 1.069 | 0.566 | 1.758 | 4.857 |
| 1               | 3.409 | 7.488 | 5.827 | 8.186 | 21.668 | 15.534 | 8.644 | 4.296 | 0.955 | 0.420 | 0.972 | 2.046 |
| 5               | 1.211 | 1.899 | 2.939 | 4.775 | 8.040  | 3.591  | 3.480 | 1.398 | 0.429 | 0.318 | 0.438 | 0.515 |
| 10              | 0.605 | 1.262 | 2.040 | 2.153 | 4.088  | 0.939  | 2.424 | 0.654 | 0.322 | 0.315 | 0.303 | 0.358 |
| 15              | 0.488 | 0.659 | 1.286 | 0.928 | 0.563  | -1.080 | 1.578 | 0.490 | 0.308 | 0.340 | 0.299 | 0.301 |
| 20              | 0.405 | 0.346 | 0.942 | 0.543 | 0.011  | -0.851 | 0.812 | 0.315 | 0.337 | 0.342 | 0.293 | 0.270 |
| 30              | 0.306 | 0.565 | 0.427 | 0.287 | -0.796 | 0.601  | 0.632 | 0.298 | 0.369 | 0.360 | 0.303 | 0.269 |
| 40              | 0.285 | 0.410 | 0.504 | 0.410 | -0.204 | 0.866  | 0.521 | 0.332 | 0.374 | 0.377 | 0.309 | 0.273 |
| 50              | 0.272 | 0.296 | 0.426 | 0.389 | 0.124  | 0.848  | 0.517 | 0.323 | 0.382 | 0.379 | 0.335 | 0.285 |
| 60              | 0.247 | 0.255 | 0.294 | 0.170 | 0.275  | 0.566  | 0.378 | 0.352 | 0.380 | 0.379 | 0.339 | 0.274 |
| 70              | 0.214 | 0.192 | 0.195 | 0.170 | 0.258  | 0.323  | 0.299 | 0.359 | 0.378 | 0.377 | 0.334 | 0.259 |
| 80              | 0.144 | 0.137 | 0.124 | 0.122 | 0.172  | 0.240  | 0.269 | 0.360 | 0.365 | 0.218 | 0.083 | 0.061 |
| 85              | 0.082 | 0.132 | 0.138 | 0.056 | 0.156  | 0.158  | 0.307 | 0.260 | 0.139 | 0.069 | 0.053 | 0.026 |
| 90              | 0.058 | 0.116 | 0.115 | 0.071 | 0.177  | 0.253  | 0.301 | 0.145 | 0.068 | 0.015 | 0.010 | 0.003 |
| 95              | 0.037 | 0.067 | 0.103 | 0.121 | 0.056  | 0.154  | 0.110 | 0.112 | 0.030 | 0.003 | 0.002 | 0.001 |
| 99              | 0.001 | 0.010 | 0.012 | 0.062 | 0.014  | 0.010  | 0.008 | 0.004 | 0.002 | 0.001 | 0.001 | 0.001 |
| 99.9            | 0.000 | 0.003 | 0.011 | 0.062 | 0.021  | 0.005  | 0.004 | 0.004 | 0.001 | 0.001 | 0.001 | 0.000 |

**Table 33: Estimated non-compliances with EWR for all months at UO\_EWR06\_R**

| <b>Sc1a-EWR</b> |        |        |        |        |         |         |        |        |        |        |        |        |
|-----------------|--------|--------|--------|--------|---------|---------|--------|--------|--------|--------|--------|--------|
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 27.557 | 40.291 | 26.897 | 41.586 | 199.342 | 123.154 | 44.043 | 25.913 | 5.702  | 1.099  | 4.695  | 18.432 |
| 1               | 11.781 | 31.294 | 25.426 | 41.219 | 104.680 | 86.952  | 43.782 | 25.875 | 3.124  | 0.787  | 2.264  | 5.488  |
| 5               | 2.733  | 8.076  | 11.220 | 26.722 | 49.584  | 37.393  | 17.538 | 4.926  | 1.004  | 0.682  | 0.801  | 0.460  |
| 10              | 0.489  | 5.489  | 8.338  | 15.288 | 26.615  | 15.102  | 11.923 | 2.261  | 0.736  | 0.687  | 0.565  | 0.301  |
| 15              | 0.195  | 1.725  | 4.245  | 9.199  | 12.946  | 5.167   | 7.814  | 1.344  | 0.761  | 0.758  | 0.635  | 0.383  |
| 20              | 0.264  | 0.251  | 3.343  | 6.569  | 9.825   | 5.009   | 4.440  | 0.994  | 0.875  | 0.893  | 0.746  | 0.515  |
| 30              | 0.471  | 0.448  | 1.218  | 4.237  | 1.670   | 3.821   | 2.717  | 0.930  | 1.086  | 1.110  | 0.972  | 0.697  |
| 40              | 0.644  | 0.428  | 0.999  | 2.783  | 0.865   | 3.084   | 1.782  | 1.090  | 1.228  | 1.211  | 1.099  | 0.845  |
| 50              | 0.703  | 0.554  | 0.667  | 1.088  | 1.135   | 2.630   | 1.488  | 1.135  | 1.256  | 1.234  | 1.132  | 0.895  |
| 60              | 0.684  | 0.569  | 0.620  | 0.545  | 0.893   | 1.488   | 1.192  | 1.148  | 1.254  | 1.229  | 1.137  | 0.899  |
| 70              | 0.575  | 0.522  | 0.528  | 0.491  | 0.776   | 0.999   | 0.954  | 1.124  | 1.235  | 1.209  | 0.934  | 0.691  |
| 80              | 0.461  | 0.436  | 0.468  | 0.472  | 0.489   | 0.618   | 0.853  | 1.094  | 1.066  | 1.014  | 0.844  | 0.580  |
| 85              | 0.425  | 0.266  | 0.333  | 0.445  | 0.472   | 0.517   | 0.820  | 1.026  | 0.964  | 0.927  | 0.817  | 0.566  |
| 90              | 0.390  | 0.212  | 0.281  | 0.365  | 0.380   | 0.465   | 0.743  | 0.806  | 0.896  | 0.908  | 0.754  | 0.522  |
| 95              | 0.272  | 0.169  | 0.213  | 0.262  | 0.272   | 0.487   | 0.587  | 0.742  | 0.752  | 0.654  | 0.583  | 0.320  |
| 99              | 0.161  | 0.144  | 0.145  | 0.186  | 0.218   | 0.242   | 0.386  | 0.609  | 0.595  | 0.564  | 0.488  | 0.243  |
| 99.9            | -0.001 | 0.143  | 0.177  | 0.159  | 0.260   | 0.269   | 0.374  | 0.520  | 0.579  | 0.562  | 0.491  | 0.000  |
| <b>Sc1b-EWR</b> |        |        |        |        |         |         |        |        |        |        |        |        |
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 27.520 | 40.288 | 26.897 | 41.586 | 199.034 | 123.151 | 44.040 | 25.824 | 5.702  | 1.099  | 4.695  | 18.432 |
| 1               | 11.783 | 31.266 | 25.426 | 41.219 | 104.626 | 86.922  | 43.754 | 24.985 | 3.124  | 0.787  | 2.264  | 5.488  |
| 5               | 2.733  | 8.076  | 11.268 | 26.722 | 49.449  | 37.393  | 17.538 | 4.926  | 1.004  | 0.682  | 0.801  | 0.460  |
| 10              | 0.489  | 5.489  | 8.338  | 15.285 | 26.581  | 15.102  | 11.923 | 2.261  | 0.736  | 0.687  | 0.565  | 0.301  |
| 15              | 0.195  | 1.725  | 4.258  | 9.199  | 12.946  | 5.167   | 7.814  | 1.344  | 0.761  | 0.758  | 0.635  | 0.383  |
| 20              | 0.264  | 0.251  | 3.343  | 6.569  | 9.830   | 5.001   | 4.428  | 0.994  | 0.875  | 0.893  | 0.746  | 0.515  |
| 30              | 0.471  | 0.448  | 1.218  | 4.236  | 1.670   | 3.821   | 2.717  | 0.930  | 1.086  | 1.110  | 0.972  | 0.697  |
| 40              | 0.644  | 0.428  | 0.999  | 2.783  | 0.865   | 3.084   | 1.782  | 1.090  | 1.228  | 1.211  | 1.099  | 0.845  |
| 50              | 0.703  | 0.554  | 0.667  | 1.088  | 1.135   | 2.630   | 1.488  | 1.135  | 1.256  | 1.234  | 1.132  | 0.895  |
| 60              | 0.684  | 0.569  | 0.620  | 0.545  | 0.893   | 1.488   | 1.192  | 1.148  | 1.254  | 1.229  | 1.137  | 0.899  |
| 70              | 0.575  | 0.522  | 0.534  | 0.491  | 0.776   | 0.999   | 0.954  | 1.124  | 1.235  | 1.209  | 0.934  | 0.691  |
| 80              | 0.461  | 0.436  | 0.468  | 0.472  | 0.489   | 0.618   | 0.853  | 1.094  | 1.066  | 1.014  | 0.844  | 0.580  |
| 85              | 0.425  | 0.266  | 0.333  | 0.445  | 0.472   | 0.517   | 0.820  | 1.026  | 0.964  | 0.927  | 0.817  | 0.566  |
| 90              | 0.390  | 0.212  | 0.289  | 0.370  | 0.384   | 0.465   | 0.743  | 0.806  | 0.896  | 0.908  | 0.754  | 0.521  |
| 95              | 0.276  | 0.169  | 0.213  | 0.268  | 0.272   | 0.487   | 0.587  | 0.742  | 0.753  | 0.654  | 0.585  | 0.344  |
| 99              | 0.181  | 0.153  | 0.146  | 0.193  | 0.218   | 0.261   | 0.391  | 0.607  | 0.614  | 0.574  | 0.413  | -0.031 |
| 99.9            | 0.001  | 0.146  | 0.186  | 0.159  | 0.263   | 0.272   | 0.386  | 0.521  | 0.581  | 0.563  | 0.018  | -0.027 |
| <b>Sc2a-EWR</b> |        |        |        |        |         |         |        |        |        |        |        |        |
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 27.732 | 39.079 | 25.280 | 41.774 | 198.383 | 122.904 | 44.201 | 25.812 | 5.571  | 1.201  | 4.635  | 18.945 |
| 1               | 11.758 | 30.437 | 23.199 | 41.405 | 104.037 | 85.524  | 44.011 | 22.728 | 3.281  | 0.895  | 2.342  | 5.956  |
| 5               | 2.418  | 8.096  | 11.628 | 27.111 | 49.327  | 37.516  | 17.789 | 5.149  | 1.113  | 0.719  | 0.752  | 0.567  |
| 10              | 0.509  | 5.796  | 8.555  | 15.528 | 26.813  | 15.577  | 12.387 | 2.469  | 0.847  | 0.757  | 0.654  | 0.380  |
| 15              | 0.185  | 1.824  | 4.558  | 9.437  | 13.129  | 5.080   | 8.259  | 1.440  | 0.848  | 0.834  | 0.705  | 0.417  |
| 20              | 0.226  | 0.221  | 3.683  | 6.939  | 9.699   | 4.178   | 4.887  | 1.073  | 0.956  | 0.963  | 0.804  | 0.576  |
| 30              | 0.485  | 0.475  | 1.141  | 4.734  | 2.027   | 3.821   | 2.820  | 1.022  | 1.134  | 1.166  | 1.030  | 0.723  |
| 40              | 0.520  | 0.428  | 0.924  | 3.043  | 0.972   | 3.521   | 1.938  | 1.153  | 1.255  | 1.133  | 0.792  | 0.549  |
| 50              | 0.412  | 0.520  | 0.680  | 1.024  | 1.117   | 2.891   | 1.449  | 1.170  | 1.192  | 1.025  | 0.764  | 0.520  |
| 60              | 0.403  | 0.427  | 0.556  | 0.560  | 0.913   | 1.501   | 1.097  | 1.141  | 1.110  | 0.913  | 0.752  | 0.497  |
| 70              | 0.333  | 0.270  | 0.440  | 0.417  | 0.701   | 0.843   | 0.974  | 1.057  | 0.984  | 0.866  | 0.734  | 0.453  |
| 80              | 0.307  | 0.163  | 0.225  | 0.305  | 0.376   | 0.590   | 0.883  | 0.820  | 0.847  | 0.776  | 0.662  | 0.413  |
| 85              | 0.267  | 0.132  | 0.163  | 0.251  | 0.290   | 0.470   | 0.584  | 0.718  | 0.791  | 0.754  | 0.559  | 0.328  |
| 90              | 0.230  | 0.096  | 0.133  | 0.223  | 0.188   | 0.318   | 0.454  | 0.662  | 0.642  | 0.593  | 0.503  | 0.285  |
| 95              | 0.181  | 0.064  | 0.111  | 0.172  | 0.130   | 0.225   | 0.396  | 0.574  | 0.569  | 0.528  | 0.456  | 0.248  |
| 99              | 0.082  | 0.055  | 0.075  | 0.112  | 0.151   | 0.161   | 0.317  | 0.465  | 0.541  | 0.522  | 0.362  | -0.031 |
| 99.9            | 0.000  | 0.042  | 0.098  | 0.148  | 0.230   | 0.160   | 0.284  | 0.459  | 0.538  | 0.521  | 0.030  | -0.027 |
| <b>Sc2b-EWR</b> |        |        |        |        |         |         |        |        |        |        |        |        |
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr    | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 27.694 | 39.080 | 25.280 | 41.698 | 197.180 | 122.875 | 43.930 | 25.812 | 5.571  | 1.201  | 4.904  | 18.945 |
| 1               | 11.751 | 30.461 | 23.199 | 41.392 | 103.798 | 85.232  | 43.859 | 22.728 | 3.281  | 0.895  | 2.389  | 5.956  |
| 5               | 2.418  | 8.096  | 11.628 | 27.111 | 48.990  | 37.516  | 17.789 | 5.149  | 1.113  | 0.719  | 0.752  | 0.567  |
| 10              | 0.464  | 5.660  | 8.538  | 15.528 | 26.611  | 15.577  | 12.323 | 2.347  | 0.847  | 0.757  | 0.654  | 0.380  |
| 15              | 0.185  | 1.776  | 4.535  | 9.437  | 13.129  | 5.080   | 8.259  | 1.440  | 0.848  | 0.834  | 0.705  | 0.417  |
| 20              | 0.197  | 0.221  | 3.568  | 6.939  | 9.833   | 4.013   | 4.834  | 1.073  | 0.956  | 0.963  | 0.803  | 0.576  |
| 30              | 0.477  | 0.475  | 1.141  | 4.734  | 2.056   | 3.821   | 2.849  | 0.997  | 1.134  | 1.153  | 1.028  | 0.723  |
| 40              | 0.455  | 0.374  | 0.924  | 2.989  | 0.972   | 3.521   | 1.938  | 1.129  | 1.258  | 1.130  | 0.756  | 0.536  |
| 50              | 0.412  | 0.492  | 0.631  | 1.024  | 1.117   | 2.896   | 1.392  | 1.162  | 1.192  | 1.014  | 0.752  | 0.493  |
| 60              | 0.372  | 0.383  | 0.562  | 0.531  | 0.911   | 1.501   | 1.097  | 1.111  | 1.110  | 0.893  | 0.739  | 0.461  |
| 70              | 0.321  | 0.261  | 0.418  | 0.425  | 0.701   | 0.826   | 0.961  | 1.053  | 0.939  | 0.832  | 0.693  | 0.440  |
| 80              | 0.256  | 0.149  | 0.224  | 0.306  | 0.376   | 0.590   | 0.862  | 0.787  | 0.793  | 0.765  | 0.519  | 0.295  |
| 85              | 0.203  | 0.130  | 0.168  | 0.274  | 0.253   | 0.473   | 0.584  | 0.718  | 0.642  | 0.575  | 0.469  | 0.245  |
| 90              | 0.177  | 0.104  | 0.133  | 0.216  | 0.180   | 0.318   | 0.454  | 0.621  | 0.580  | 0.510  | 0.060  | -0.021 |
| 95              | 0.043  | 0.016  | 0.124  | 0.172  | 0.113   | 0.177   | 0.336  | 0.513  | 0.016  | -0.017 | -0.031 | -0.032 |
| 99              | -0.024 | -0.073 | 0.075  | 0.112  | 0.014   | 0.063   | -0.046 | -0.052 | -0.039 | -0.034 | -0.030 | -0.031 |
| 99.9            | -0.019 | -0.069 | 0.098  | 0.148  | 0.065   | -0.117  | -0.122 | -0.047 | -0.035 | -0.030 | -0.027 | -0.027 |

### 5.10 IUA10 Modder/ Riet

Ecological consequences were assessed at two EWR sites in the Upper and Lower Riet River (sites UO\_EWR06\_I and UO\_EWR09\_I) within this IUA. Both these sites are impacted by several upstream dams, and the lower Riet site by return flows from extensive irrigation practices.

Only present-day scenarios were assessed for the Upper Riet (UO\_EWR06\_I) and all the scenarios for the Lower Riet (UO\_EWR09\_I). Refer to Table 34 for the average flows (1920 - 2004) at the two EWR sites measured in Mm<sup>3</sup>.

**Table 34: Average flows (1920-2004) for UO\_EWR06\_I and UO\_EWR09\_I**

| Average Flows (1920-2004) – Mm <sup>3</sup> |            |            |
|---------------------------------------------|------------|------------|
|                                             | UO_EWR06_I | UO_EWR09_I |
| nMAR                                        | 105.2      | 373.8      |
| Sc1a (PRS)                                  | 76.2       | 213.8      |
| Sc1b                                        | 76.6       | 214.8      |
| Sc2a                                        |            | 214.4      |
| Sc2b                                        |            | 214.4      |
| Sc3a                                        |            | 219.0      |
| Sc3b                                        |            | 221.3      |

No changes were made to the EWRs as determined during the high confidence study of the Reserve for the Upper Orange River.

The seasonal distribution (hydrograph) plots were prepared using the flows provided for the scenarios and is illustrated in Figure 19, Figure 20 and Figure 21.

The graphs indicate that for site UO\_EWR06\_I the flows are reduced during the summer months due to water use in the upper catchment. The flows at site UO\_EWR09\_I show further reductions in the summer months with increased flows during the dry months. This is due to the extensive irrigation in the lower Riet River.

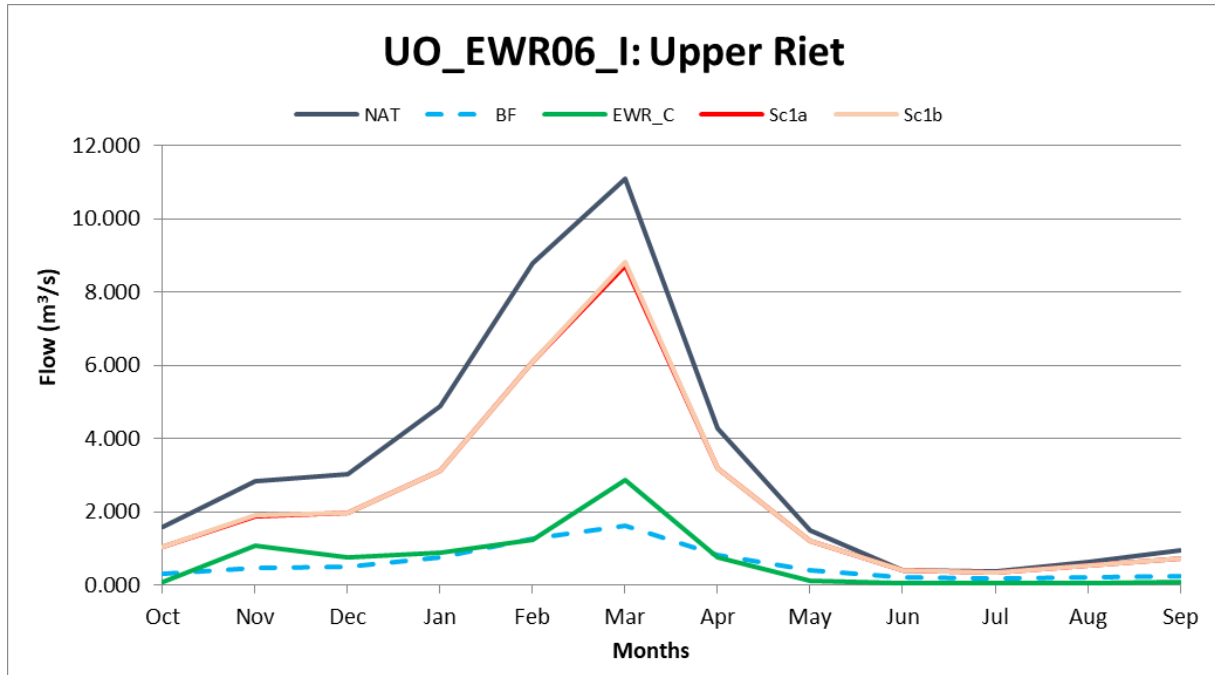


Figure 19: Seasonal distribution of scenarios at site UO\_EWR06\_I: Upper Riet

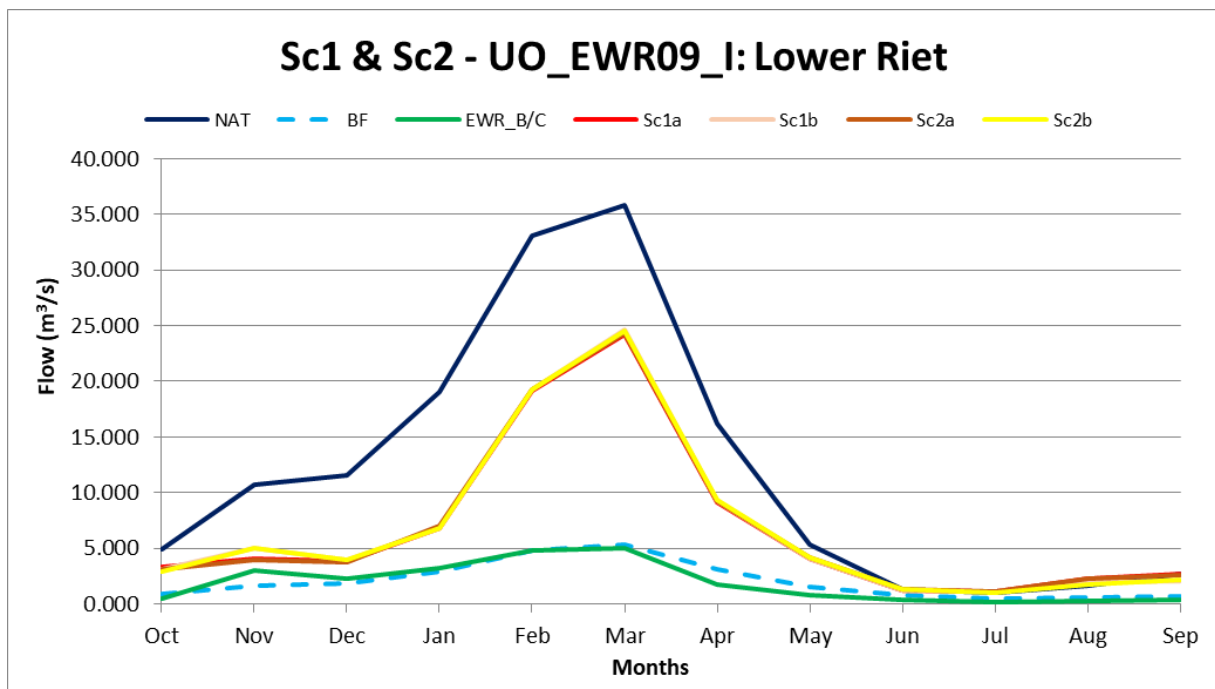


Figure 20: Seasonal distribution of scenarios (Sc1 & Sc2) at site UO\_EWR09\_I: Lower Riet

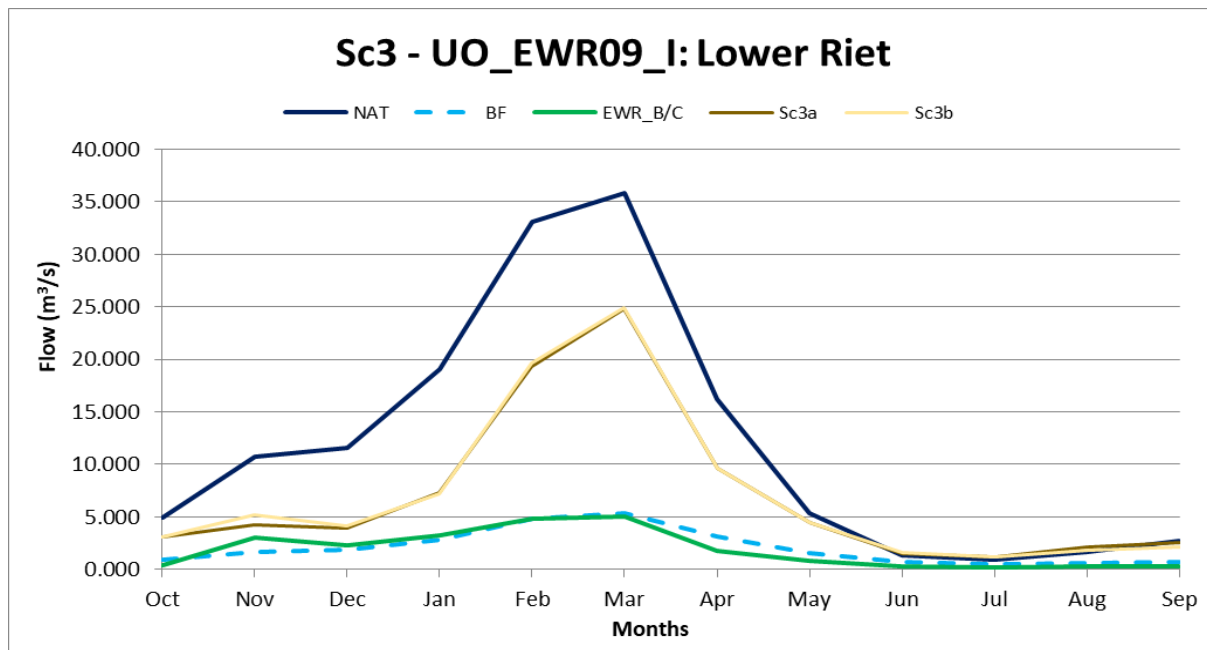


Figure 21: Seasonal distribution of scenarios (Sc3) at site UO\_EWR09\_I: Lower Riet

Table 36, Table 37 and Table 38 provide the estimated non-compliances for all the months for the scenarios (values in red). The results indicate that the EWR could be met for most of the time at both sites for all the scenarios irrespective if the EWR was implemented or not. However, small non-compliances for site UO\_EWR09\_I for the high flows (5 to 30 percentiles) during the wetter months.

Table 35: Estimated non-compliances with EWR for all months at UO\_EWR06\_I

| Sc1a-EWR    |       |        |       |        |         |         |        |        |       |       |        |        |
|-------------|-------|--------|-------|--------|---------|---------|--------|--------|-------|-------|--------|--------|
| Percentiles | Oct   | Nov    | Dec   | Jan    | Feb     | Mar     | Apr    | May    | Jun   | Jul   | Aug    | Sep    |
| 0.1         | 9.244 | 18.779 | 7.622 | 33.805 | 106.137 | 154.689 | 39.326 | 24.878 | 6.649 | 6.192 | 15.024 | 15.018 |
| 1           | 9.036 | 13.342 | 7.395 | 19.759 | 59.175  | 98.045  | 29.230 | 19.778 | 6.279 | 4.613 | 6.295  | 6.028  |
| 5           | 4.332 | 4.196  | 5.769 | 11.877 | 21.442  | 32.630  | 12.091 | 5.249  | 1.391 | 0.933 | 1.515  | 3.204  |
| 10          | 2.187 | 0.130  | 2.598 | 5.565  | 11.519  | 1.629   | 6.193  | 1.374  | 0.217 | 0.224 | 0.491  | 1.016  |
| 15          | 1.692 | -0.289 | 2.169 | 2.725  | 5.235   | -0.336  | 2.801  | 0.426  | 0.165 | 0.140 | 0.242  | 0.757  |
| 20          | 1.248 | -0.401 | 1.701 | 1.685  | 3.627   | -0.392  | 1.693  | 0.166  | 0.120 | 0.141 | 0.218  | 0.335  |
| 30          | 0.609 | 0.584  | 0.960 | 1.157  | 1.793   | 1.094   | 0.563  | 0.096  | 0.026 | 0.107 | 0.132  | 0.172  |
| 40          | 0.327 | 0.539  | 0.939 | 1.378  | 1.695   | 1.189   | 0.411  | 0.088  | 0.044 | 0.095 | 0.128  | 0.212  |
| 50          | 0.295 | 0.340  | 0.408 | 0.568  | 1.194   | 1.013   | 0.337  | 0.076  | 0.047 | 0.066 | 0.128  | 0.222  |
| 60          | 0.276 | 0.223  | 0.335 | 0.340  | 0.605   | 0.364   | 0.222  | 0.060  | 0.047 | 0.061 | 0.126  | 0.205  |
| 70          | 0.257 | 0.171  | 0.209 | 0.156  | 0.278   | 0.159   | 0.086  | 0.050  | 0.044 | 0.059 | 0.115  | 0.179  |
| 80          | 0.196 | 0.133  | 0.151 | 0.084  | 0.046   | 0.077   | 0.018  | 0.046  | 0.042 | 0.057 | 0.100  | 0.154  |
| 85          | 0.181 | 0.126  | 0.102 | 0.045  | -0.015  | -0.032  | 0.002  | 0.045  | 0.043 | 0.055 | 0.092  | 0.136  |
| 90          | 0.163 | 0.126  | 0.126 | 0.025  | -0.048  | -0.059  | 0.034  | 0.044  | 0.041 | 0.049 | 0.079  | 0.123  |
| 95          | 0.134 | 0.138  | 0.157 | 0.037  | -0.009  | 0.061   | 0.064  | 0.041  | 0.039 | 0.047 | 0.071  | 0.119  |
| 99          | 0.030 | 0.078  | 0.065 | 0.011  | 0.052   | 0.095   | 0.068  | 0.032  | 0.023 | 0.020 | 0.015  | 0.014  |
| 99.9        | 0.009 | 0.020  | 0.048 | 0.012  | 0.004   | 0.085   | 0.066  | 0.027  | 0.021 | 0.019 | 0.014  | 0.011  |
| Sc1b-EWR    |       |        |       |        |         |         |        |        |       |       |        |        |
| Percentiles | Oct   | Nov    | Dec   | Jan    | Feb     | Mar     | Apr    | May    | Jun   | Jul   | Aug    | Sep    |
| 0.1         | 9.028 | 18.606 | 7.622 | 33.296 | 105.546 | 154.647 | 39.325 | 24.878 | 6.649 | 6.192 | 15.024 | 15.018 |
| 1           | 8.999 | 13.309 | 7.395 | 19.670 | 59.072  | 97.619  | 29.224 | 19.778 | 6.279 | 4.613 | 6.295  | 6.028  |
| 5           | 4.332 | 4.196  | 5.769 | 11.877 | 21.442  | 32.492  | 12.091 | 5.249  | 1.391 | 0.933 | 1.515  | 3.204  |
| 10          | 2.186 | 0.142  | 2.598 | 5.566  | 11.519  | 1.628   | 6.192  | 1.373  | 0.217 | 0.224 | 0.491  | 1.016  |
| 15          | 1.692 | 0.128  | 2.055 | 2.724  | 5.235   | 0.357   | 2.801  | 0.426  | 0.165 | 0.140 | 0.242  | 0.757  |
| 20          | 1.248 | -0.065 | 1.701 | 1.685  | 3.627   | -0.331  | 1.693  | 0.166  | 0.120 | 0.141 | 0.218  | 0.335  |
| 30          | 0.610 | 0.640  | 0.960 | 1.157  | 1.792   | 1.333   | 0.563  | 0.107  | 0.026 | 0.106 | 0.134  | 0.172  |
| 40          | 0.327 | 0.578  | 0.939 | 1.378  | 1.695   | 1.189   | 0.409  | 0.097  | 0.047 | 0.095 | 0.129  | 0.212  |
| 50          | 0.295 | 0.376  | 0.408 | 0.568  | 1.194   | 1.027   | 0.355  | 0.082  | 0.048 | 0.066 | 0.129  | 0.222  |
| 60          | 0.276 | 0.243  | 0.333 | 0.427  | 0.605   | 0.364   | 0.249  | 0.065  | 0.048 | 0.061 | 0.128  | 0.205  |
| 70          | 0.257 | 0.177  | 0.208 | 0.156  | 0.278   | 0.165   | 0.086  | 0.051  | 0.045 | 0.058 | 0.116  | 0.179  |
| 80          | 0.196 | 0.144  | 0.151 | 0.083  | 0.046   | 0.107   | 0.017  | 0.046  | 0.043 | 0.057 | 0.101  | 0.154  |
| 85          | 0.181 | 0.140  | 0.102 | 0.046  | 0.006   | 0.020   | 0.003  | 0.045  | 0.043 | 0.055 | 0.096  | 0.135  |
| 90          | 0.163 | 0.131  | 0.126 | 0.024  | -0.002  | -0.012  | 0.039  | 0.043  | 0.043 | 0.048 | 0.081  | 0.122  |
| 95          | 0.134 | 0.149  | 0.158 | 0.041  | 0.015   | 0.070   | 0.072  | 0.041  | 0.039 | 0.042 | 0.062  | 0.112  |
| 99          | 0.026 | 0.078  | 0.065 | 0.012  | 0.068   | 0.096   | 0.071  | 0.031  | 0.022 | 0.020 | 0.015  | 0.014  |
| 99.9        | 0.009 | 0.018  | 0.048 | 0.012  | 0.015   | 0.089   | 0.066  | 0.027  | 0.021 | 0.019 | 0.014  | 0.011  |

**Table 36: Estimated non-compliances with EWR (Sc1 & Sc2) for all months at UO\_EWR09\_I**

| <b>Sc1a-EWR</b> |        |        |        |        |         |         |         |        |        |        |        |        |
|-----------------|--------|--------|--------|--------|---------|---------|---------|--------|--------|--------|--------|--------|
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr     | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 41.944 | 37.477 | 20.107 | 64.455 | 368.922 | 400.053 | 140.335 | 69.571 | 18.128 | 14.927 | 32.506 | 31.412 |
| 1               | 16.736 | 31.753 | 13.624 | 40.097 | 210.981 | 340.048 | 103.853 | 49.765 | 16.275 | 11.356 | 12.600 | 9.434  |
| 5               | 5.425  | -0.786 | 4.101  | 12.303 | 61.225  | 107.688 | 48.507  | 27.501 | 2.806  | 0.216  | 1.538  | 3.420  |
| 10              | 2.816  | -7.222 | 0.488  | 2.770  | 41.774  | 37.410  | 17.133  | 5.764  | -0.163 | 0.143  | 1.416  | 2.417  |
| 15              | 2.966  | -6.052 | -2.844 | 0.543  | 17.014  | -1.076  | 5.530   | 0.130  | -0.299 | 0.297  | 1.528  | 2.516  |
| 20              | 3.236  | -4.392 | -2.206 | -2.977 | 1.279   | -1.626  | 4.511   | -0.903 | -0.112 | 0.435  | 1.711  | 2.640  |
| 30              | 3.730  | 0.335  | -0.557 | -1.173 | 0.707   | -0.366  | 0.256   | -0.602 | 0.075  | 0.678  | 1.931  | 3.000  |
| 40              | 4.084  | 1.484  | 1.177  | 1.290  | -0.356  | -0.668  | -0.259  | -0.206 | 0.317  | 0.748  | 2.111  | 3.257  |
| 50              | 2.507  | 2.062  | 2.061  | 2.553  | 1.329   | 0.658   | 0.267   | 0.028  | 0.301  | 0.773  | 2.175  | 3.358  |
| 60              | 1.166  | 2.273  | 2.440  | 3.230  | 2.209   | 1.180   | 0.437   | 0.112  | 0.325  | 0.760  | 2.180  | 0.629  |
| 70              | 0.804  | 2.329  | 2.546  | 3.451  | 2.417   | 1.338   | 0.479   | 0.134  | 0.333  | 0.742  | 0.806  | 0.639  |
| 80              | 0.422  | 1.418  | 2.547  | 3.491  | 2.497   | 1.375   | 0.484   | 0.139  | 0.335  | 0.539  | 0.807  | 0.641  |
| 85              | 0.422  | 1.326  | 2.435  | 3.472  | 2.482   | 1.353   | 0.473   | 0.139  | 0.335  | 0.539  | 0.811  | 0.641  |
| 90              | 0.422  | 0.471  | 1.463  | 3.179  | 2.432   | 1.264   | 0.457   | 0.139  | 0.339  | 0.539  | 0.813  | 0.649  |
| 95              | 0.428  | -0.048 | 1.289  | -0.298 | 1.831   | 1.298   | 0.391   | 0.150  | 0.343  | 0.539  | 0.813  | 0.649  |
| 99              | 0.432  | 0.067  | 0.063  | -0.239 | -0.209  | 0.631   | 0.093   | 0.158  | 0.343  | 0.539  | 0.813  | 0.649  |
| 99.9            | 0.432  | 0.084  | 0.082  | -0.164 | -0.180  | 0.209   | 0.121   | 0.158  | 0.343  | 0.539  | 0.813  | 0.649  |
| <b>Sc1b-EWR</b> |        |        |        |        |         |         |         |        |        |        |        |        |
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr     | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 41.907 | 37.329 | 20.107 | 64.412 | 368.702 | 400.053 | 140.334 | 69.482 | 18.128 | 14.927 | 32.506 | 31.324 |
| 1               | 16.744 | 31.728 | 13.624 | 39.656 | 210.943 | 340.048 | 103.847 | 48.875 | 16.275 | 11.356 | 12.600 | 8.556  |
| 5               | 4.055  | -0.294 | 2.408  | 12.306 | 61.225  | 107.550 | 48.493  | 27.500 | 2.806  | 1.205  | 1.361  | 2.345  |
| 10              | 2.813  | -0.675 | 0.045  | 2.119  | 41.774  | 37.428  | 17.276  | 4.355  | -0.163 | 0.131  | 1.409  | 2.281  |
| 15              | 2.963  | -0.970 | 0.253  | 0.358  | 17.014  | -1.076  | 5.530   | -0.278 | -0.266 | 0.276  | 1.484  | 2.464  |
| 20              | 3.232  | -0.186 | 0.324  | 0.372  | 1.252   | -1.628  | 3.773   | -0.509 | -0.049 | 0.351  | 1.646  | 2.631  |
| 30              | 3.724  | 0.343  | -0.274 | -0.053 | 1.292   | 2.866   | 1.213   | -0.381 | 0.083  | 0.569  | 1.917  | 2.836  |
| 40              | 2.900  | 1.491  | 1.187  | 1.296  | 0.561   | 1.702   | 0.191   | -0.053 | 0.301  | 0.690  | 1.606  | 0.988  |
| 50              | 1.396  | 2.070  | 2.070  | 2.556  | 1.339   | 0.778   | 0.267   | 0.039  | 0.296  | 0.518  | 0.780  | 0.712  |
| 60              | 1.209  | 2.281  | 2.451  | 3.229  | 2.211   | 1.192   | 0.437   | 0.113  | 0.325  | 0.530  | 0.800  | 0.630  |
| 70              | 1.128  | 2.339  | 2.556  | 3.426  | 2.420   | 1.341   | 0.470   | 0.134  | 0.333  | 0.533  | 0.806  | 0.639  |
| 80              | 0.630  | 2.201  | 2.506  | 1.716  | 2.425   | 0.713   | 0.252   | 0.139  | 0.335  | 0.539  | 0.807  | 0.641  |
| 85              | 0.422  | 1.412  | 1.412  | 1.275  | 1.655   | 0.375   | 0.130   | 0.139  | 0.335  | 0.539  | 0.811  | 0.641  |
| 90              | 0.422  | 1.287  | 0.767  | 0.984  | 0.342   | 0.049   | 0.091   | 0.139  | 0.338  | 0.539  | 0.813  | 0.649  |
| 95              | 0.428  | 0.410  | 0.166  | 0.080  | 0.005   | 0.093   | 0.073   | 0.150  | 0.342  | 0.539  | 0.813  | 0.649  |
| 99              | 0.363  | 0.248  | 0.271  | 0.098  | 0.055   | 0.189   | 0.045   | 0.138  | 0.288  | 0.453  | 0.683  | 0.545  |
| 99.9            | 0.036  | 0.103  | 0.214  | 0.135  | 0.005   | 0.105   | 0.068   | 0.045  | 0.031  | 0.047  | 0.069  | 0.055  |
| <b>Sc2a-EWR</b> |        |        |        |        |         |         |         |        |        |        |        |        |
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr     | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 42.459 | 36.812 | 19.870 | 65.137 | 367.129 | 399.622 | 140.266 | 70.107 | 18.217 | 15.020 | 32.589 | 31.458 |
| 1               | 16.984 | 30.884 | 13.364 | 41.525 | 209.524 | 339.868 | 104.032 | 48.874 | 16.369 | 11.448 | 12.580 | 9.376  |
| 5               | 2.875  | -4.668 | 3.573  | 13.436 | 61.221  | 107.685 | 48.644  | 27.728 | 2.901  | 0.324  | 1.510  | 3.354  |
| 10              | 2.799  | -7.157 | 0.619  | 4.592  | 41.579  | 36.328  | 16.580  | 5.808  | -0.023 | 0.125  | 1.388  | 2.401  |
| 15              | 2.949  | -5.906 | -2.843 | 0.825  | 18.728  | -0.782  | 6.413   | 0.697  | -0.132 | 0.278  | 1.504  | 2.552  |
| 20              | 3.219  | -4.394 | -2.206 | -2.201 | 1.396   | -1.595  | 3.847   | -0.733 | 0.029  | 0.416  | 1.698  | 2.617  |
| 30              | 3.712  | 0.332  | -0.557 | -1.175 | 1.522   | -0.427  | 0.910   | -0.401 | 0.239  | 0.659  | 1.903  | 2.977  |
| 40              | 4.046  | 1.480  | 1.176  | 1.290  | -0.359  | -0.647  | -0.242  | -0.150 | 0.414  | 0.730  | 2.083  | 3.235  |
| 50              | 1.495  | 2.059  | 2.057  | 2.554  | 1.328   | 0.714   | 0.278   | 0.023  | 0.398  | 0.755  | 2.146  | 3.335  |
| 60              | 1.134  | 2.270  | 2.438  | 3.231  | 2.209   | 1.186   | 0.438   | 0.107  | 0.312  | 0.746  | 2.151  | 0.606  |
| 70              | 0.820  | 2.326  | 2.547  | 3.454  | 2.415   | 1.345   | 0.483   | 0.129  | 0.320  | 0.724  | 0.777  | 0.616  |
| 80              | 0.407  | 1.416  | 2.506  | 3.517  | 2.489   | 1.380   | 0.486   | 0.134  | 0.322  | 0.520  | 0.778  | 0.618  |
| 85              | 0.407  | 1.345  | 1.990  | 3.490  | 2.448   | 1.374   | 0.475   | 0.134  | 0.322  | 0.520  | 0.782  | 0.618  |
| 90              | 0.407  | 1.215  | 1.447  | 3.422  | 2.353   | 1.328   | 0.463   | 0.134  | 0.326  | 0.520  | 0.784  | 0.626  |
| 95              | 0.413  | -0.051 | 0.320  | -0.306 | 1.634   | 1.299   | 0.399   | 0.145  | 0.330  | 0.520  | 0.784  | 0.626  |
| 99              | 0.417  | 0.063  | 0.045  | -0.249 | -0.229  | 0.453   | 0.076   | 0.153  | 0.330  | 0.520  | 0.784  | 0.626  |
| 99.9            | 0.417  | 0.080  | 0.063  | -0.180 | -0.200  | 0.175   | 0.103   | 0.153  | 0.330  | 0.520  | 0.784  | 0.626  |
| <b>Sc2b-EWR</b> |        |        |        |        |         |         |         |        |        |        |        |        |
| Percentiles     | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr     | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1             | 42.461 | 36.703 | 19.870 | 65.093 | 366.821 | 399.622 | 140.266 | 70.107 | 18.217 | 15.020 | 32.589 | 31.933 |
| 1               | 16.997 | 30.865 | 13.364 | 41.083 | 209.470 | 339.868 | 104.026 | 48.874 | 16.369 | 11.448 | 12.580 | 14.121 |
| 5               | 2.855  | -0.267 | 2.278  | 13.439 | 61.212  | 107.547 | 48.629  | 27.727 | 2.901  | 0.323  | 1.331  | 3.379  |
| 10              | 2.796  | -0.676 | 0.045  | 4.294  | 41.579  | 36.390  | 17.019  | 4.498  | -0.023 | 0.097  | 1.289  | 2.259  |
| 15              | 2.946  | -0.970 | -0.045 | 0.382  | 18.683  | -0.782  | 6.412   | 0.320  | -0.132 | 0.184  | 1.405  | 2.445  |
| 20              | 3.217  | -0.186 | 0.043  | 0.372  | 1.292   | -1.636  | 3.782   | -0.444 | 0.029  | 0.310  | 1.594  | 2.609  |
| 30              | 3.707  | 0.340  | -0.274 | -0.053 | 1.586   | 2.934   | 1.425   | -0.305 | 0.241  | 0.549  | 0.913  | 2.216  |
| 40              | 1.763  | 1.488  | 1.188  | 1.294  | 0.561   | 1.398   | 0.619   | 0.157  | 0.431  | 0.627  | 0.683  | 0.980  |
| 50              | 1.185  | 2.067  | 2.071  | 2.554  | 1.339   | 0.727   | 0.234   | 0.039  | 0.388  | 0.498  | 0.750  | 0.712  |
| 60              | 1.128  | 2.279  | 2.452  | 3.226  | 2.210   | 1.189   | 0.434   | 0.107  | 0.312  | 0.511  | 0.771  | 0.606  |
| 70              | 1.024  | 2.340  | 2.559  | 3.284  | 2.416   | 1.338   | 0.396   | 0.129  | 0.320  | 0.514  | 0.777  | 0.616  |
| 80              | 0.767  | 2.335  | 2.560  | 1.347  | 1.883   | 0.640   | 0.131   | 0.134  | 0.322  | 0.520  | 0.778  | 0.618  |
| 85              | 0.591  | 2.190  | 2.004  | 1.141  | 1.426   | 0.233   | 0.100   | 0.134  | 0.322  | 0.519  | 0.782  | 0.618  |
| 90              | 0.407  | 1.230  | 0.895  | 0.636  | 0.152   | 0.023   | 0.065   | 0.133  | 0.326  | 0.519  | 0.784  | 0.626  |
| 95              | 0.413  | 0.186  | 0.227  | 0.082  | 0.005   | 0.093   | 0.039   | 0.144  | 0.330  | 0.519  | 0.783  | 0.625  |
| 99              | 0.349  | 0.247  | 0.271  | 0.077  | 0.055   | 0.228   | 0.015   | 0.133  | 0.278  | 0.436  | 0.658  | 0.525  |
| 99.9            | 0.035  | 0.099  | 0.214  | 0.133  | 0.005   | 0.283   | 0.064   | 0.044  | 0.030  | 0.045  | 0.067  | 0.053  |

**Table 37: Estimated non-compliances with EWR (Sc3) for all months at UO\_EWR09\_I**

| Sc3a-EWR    |        |        |        |        |         |         |         |        |        |        |        |        |
|-------------|--------|--------|--------|--------|---------|---------|---------|--------|--------|--------|--------|--------|
| Percentiles | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr     | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1         | 43.667 | 38.698 | 19.909 | 66.604 | 364.953 | 399.716 | 140.489 | 71.059 | 18.555 | 15.591 | 32.894 | 32.127 |
| 1           | 16.890 | 32.594 | 14.035 | 42.311 | 208.969 | 339.981 | 104.971 | 49.287 | 16.968 | 11.801 | 12.875 | 13.351 |
| 5           | 4.102  | -4.413 | 3.966  | 15.729 | 61.925  | 108.497 | 49.301  | 28.778 | 3.221  | 0.677  | 2.084  | 3.266  |
| 10          | 2.799  | -6.213 | 1.095  | 6.715  | 41.302  | 35.917  | 17.598  | 5.914  | 0.448  | 0.318  | 1.385  | 2.368  |
| 15          | 2.949  | -6.046 | -2.843 | 1.543  | 19.088  | -0.071  | 8.652   | 1.488  | 0.264  | 0.348  | 1.493  | 2.448  |
| 20          | 3.219  | -4.395 | -2.206 | -2.838 | 2.977   | -1.696  | 4.679   | -0.243 | 0.486  | 0.427  | 1.620  | 2.614  |
| 30          | 3.712  | 0.332  | -0.557 | -1.174 | -0.019  | 1.667   | 2.246   | -0.057 | 0.611  | 0.657  | 1.900  | 2.975  |
| 40          | 4.046  | 1.481  | 1.177  | 1.290  | -0.364  | 0.410   | 0.129   | 0.283  | 0.817  | 0.727  | 2.079  | 3.232  |
| 50          | 1.240  | 2.060  | 2.059  | 2.554  | 1.327   | 0.756   | 0.306   | 0.340  | 0.716  | 0.750  | 1.778  | 1.432  |
| 60          | 0.938  | 2.274  | 2.440  | 3.230  | 2.205   | 1.192   | 0.436   | 0.107  | 0.606  | 0.737  | 0.771  | 0.606  |
| 70          | 0.813  | 2.328  | 2.548  | 3.452  | 2.415   | 1.346   | 0.478   | 0.129  | 0.320  | 0.720  | 0.777  | 0.616  |
| 80          | 0.725  | 2.318  | 2.554  | 3.504  | 2.485   | 1.386   | 0.483   | 0.134  | 0.322  | 0.653  | 0.778  | 0.618  |
| 85          | 0.407  | 2.038  | 2.496  | 3.473  | 2.436   | 1.378   | 0.469   | 0.134  | 0.322  | 0.622  | 0.782  | 0.618  |
| 90          | 0.407  | 1.342  | 2.262  | 2.759  | 2.323   | 1.353   | 0.402   | 0.134  | 0.326  | 0.543  | 0.784  | 0.626  |
| 95          | 0.413  | 1.419  | 0.164  | 0.750  | -0.306  | 1.304   | 0.091   | 0.145  | 0.330  | 0.520  | 0.784  | 0.626  |
| 99          | 0.417  | 0.063  | 0.023  | -0.267 | -0.246  | 0.559   | 0.033   | 0.153  | 0.330  | 0.520  | 0.784  | 0.626  |
| 99.9        | 0.417  | 0.080  | 0.044  | -0.199 | -0.218  | 0.093   | 0.049   | 0.153  | 0.330  | 0.520  | 0.784  | 0.626  |
| Sc3b-EWR    |        |        |        |        |         |         |         |        |        |        |        |        |
| Percentiles | Oct    | Nov    | Dec    | Jan    | Feb     | Mar     | Apr     | May    | Jun    | Jul    | Aug    | Sep    |
| 0.1         | 43.668 | 38.584 | 19.909 | 66.559 | 365.031 | 399.716 | 140.488 | 71.059 | 18.555 | 15.591 | 32.894 | 32.108 |
| 1           | 16.905 | 32.574 | 14.035 | 41.854 | 208.982 | 339.981 | 104.965 | 49.287 | 16.968 | 11.801 | 12.875 | 13.166 |
| 5           | 4.112  | -0.427 | 3.962  | 15.732 | 61.925  | 108.359 | 49.302  | 28.777 | 3.221  | 0.677  | 2.084  | 2.566  |
| 10          | 2.797  | -0.676 | 0.278  | 6.708  | 41.302  | 35.933  | 18.544  | 5.097  | 0.448  | 0.318  | 1.386  | 2.258  |
| 15          | 2.948  | -1.107 | 0.323  | 0.676  | 19.078  | -0.071  | 8.652   | 1.221  | 0.264  | 0.348  | 1.410  | 2.442  |
| 20          | 3.217  | -0.186 | 0.043  | 0.372  | 2.977   | -1.432  | 3.859   | 0.008  | 0.486  | 0.427  | 1.614  | 2.608  |
| 30          | 3.711  | 0.340  | -0.058 | -0.053 | 1.891   | 3.976   | 2.246   | 0.132  | 0.611  | 0.614  | 1.749  | 2.013  |
| 40          | 3.613  | 1.488  | 1.188  | 1.297  | 0.561   | 2.177   | 0.748   | 0.326  | 0.818  | 0.709  | 0.775  | 1.263  |
| 50          | 1.305  | 2.067  | 2.070  | 2.561  | 1.340   | 1.423   | 0.308   | 0.437  | 0.715  | 0.708  | 0.750  | 0.712  |
| 60          | 1.061  | 2.279  | 2.452  | 3.231  | 2.211   | 1.263   | 0.439   | 0.332  | 0.627  | 0.695  | 0.771  | 0.606  |
| 70          | 0.860  | 2.340  | 2.560  | 3.437  | 2.421   | 1.353   | 0.478   | 0.129  | 0.321  | 0.631  | 0.777  | 0.616  |
| 80          | 0.769  | 2.339  | 2.587  | 1.738  | 2.426   | 0.927   | 0.307   | 0.134  | 0.322  | 0.520  | 0.778  | 0.618  |
| 85          | 0.579  | 2.164  | 2.407  | 1.270  | 2.074   | 0.284   | 0.148   | 0.134  | 0.322  | 0.520  | 0.782  | 0.618  |
| 90          | 0.407  | 1.472  | 0.967  | 0.984  | 0.342   | 0.049   | 0.068   | 0.134  | 0.326  | 0.520  | 0.784  | 0.626  |
| 95          | 0.413  | 1.416  | 0.245  | 0.101  | 0.004   | 0.093   | 0.038   | 0.144  | 0.330  | 0.519  | 0.783  | 0.625  |
| 99          | 0.417  | 0.247  | 0.314  | 0.096  | 0.055   | 0.181   | 0.012   | 0.152  | 0.330  | 0.519  | 0.783  | 0.625  |
| 99.9        | 0.416  | 0.099  | 0.180  | 0.135  | 0.005   | 0.055   | 0.047   | 0.152  | 0.330  | 0.519  | 0.783  | 0.625  |

## 6 GROUNDWATER SCENARIOS

Surface and groundwater are part of the hydrological cycle, with surface water run-off discharged via many surface drainage systems, and groundwater occurs in the earth's crust, i.e., deeper rock formations as the flow medium. Groundwater 'run-off' reports to the surface drainage systems as baseflows, although the flow velocity is significantly lower than the surface water component. . It has been noted that the baseflow volumes in the upper stems of the Catchment, i.e., GRU 4.0 (Kraai River) and GRU 5.1 (Blikana and Tele Rivers).

The groundwater contribution to baseflow in the Upper Orange River catchment is significant and therefore represents an important component of the groundwater balance of the catchment.

Groundwater resources are highly dependent on frequent rainwater recharge which is presented as either (i) % of MAP, or (ii) calculated as 'XX' mm per annum and is currently based on long-term average values. The result is thus a calculated value (Mm<sup>3</sup>/a) that forms the most important groundwater balance component in assessing the potential of groundwater resources (particularly aquifer systems). In areas where climate variation is present, i.e., dry spells with significant lower rainfall input, it is obvious that the annual groundwater replenishment will decrease or may in progressively drier periods, not happen at all.

Other important aspects of the groundwater balance are the baseflow component required for the ecological water requirements (EWR), and the basic human need (BHN). These values combined represent the Groundwater Reserve that needs to be protected. It is a fixed volume (groundwater reserve as  $\text{Mm}^3/\text{a}$ ) – except in the case of severe rainfall deficits where the EWR may be naturally impacted.

Groundwater use is the volume of groundwater that is removed from the groundwater systems, i.e., the various aquifer systems present in the catchment. There are many boreholes in the catchment and the water is abstracted for several different uses including:

- (i) domestic use (households and/or yards),
- (ii) stock watering,
- (iii) bulk water supplies (wellfields),
- (iv) mining (ore processing and/or dewatering),
- (v) cash crop irrigation schemes (1 to 200 hectares), and
- (vi) industries.

The overall volume abstracted annually is difficult to calculate as boreholes are widely located with many not registered in the Water Use Authorisation and Registration Management System (WARMS).

In this respect, scenario assessment for the groundwater component has been predominantly based on:

- (i) rainfall impact variation, i.e., reduction of annual rainfall depths as a departure from the long-term average annual rainfall depths, and
- (ii) water use increases due to population growth and water use increases.

## 6.1 Groundwater scenario assessment approach

The following criteria were used for the groundwater scenario assessment:

**Groundwater Scenario 0 (GW-S0): Status Quo** – this scenario represents the baseline conditions based on groundwater quality and quantity assessments over the last 50-60 years. The monitored quality [QI] and quantity [Qn] changes/ trends were used to determine this baseline. For the rural/ unimpacted areas the groundwater status was regarded as “Natural” groundwater conditions and represents a good “Baseline” reference (where applicable).

**Groundwater Scenario 1 (GW-S1) (Qn): Quantity Balances** – this scenario assessed the impact on the aquifer potential, i.e., how feasible the “allocable volumes” as per the catchment’s Reserve determination are, to serve as a protocol on resource protection by considering:

- (i) Variation in rainfall depths (climate change impacts – say over  $\frac{1}{2}$  x Sunspot Cycle (5-years); a 25% depletion.
- (ii) Basic water-use requirements at 25 L/c/d as calculated as part of the Groundwater Reserve (DWS, 2024).

- (iii) Domestic use of 175 L/c/d (due to upgraded water reticulation services) included with the National Water Act (Act 36 of 1998) Schedule 1 groundwater users and added to the other specified water users, i.e., stock watering, irrigation, mining and industries to represent the total groundwater use.
- (iv) EWR requirements included as per the Reserve determination estimations (EWR contribution is dependent on local aquifer saturation levels; thus, long-term aquifer saturation elevation depletion will minimize/ stop groundwater baseflow contribution).
- (v) Cases where alien vegetation starts to play an important role in the groundwater sustainability – found to be a significant threat in the Upper Orange River catchment.

The objective of this scenario was to assess the impact of these scenarios on the sustainability of the groundwater quantity from the *Present to Future* in those Groundwater Resource Units (GRUs) where the Reserve shows a rather low (1.0 Mm<sup>3</sup>) “Allocable” Yield(s) value (each QC should have an “Allocable Yield” limit and assurance thereof).

**Groundwater Scenario 2 (GW-S2) (QI):** *Quality Balances* – this scenario considered:

- (i) The quality status (TDS-concentration trends) should the aquifer not be “refreshed” annually by charging rainwater (this aspect is an important scenario to consider in future as per existing long-term time series trend analyses).
- (ii) Activities, such as (i) mining/ industries, that may cause land use alteration(s) and impacts on the “Aquifer Vulnerability Status”, for example, removal of topsoil enhances local (polluted) run-off driven recharge, and (ii) agricultural (irrigation additives) such as in the case of the high nitrates in the FS Kalkveld Aquifer System; and
- (iii) Testing how the “Aquifer Vulnerability Status” is impacted should one or more of the DRASTIC<sup>1</sup> components change, such as (a) recharge values, (b) depth of water level, or (c) altered soil profile, because of climate change (dry spells, wind erosion), topsoil degradation (due to mining and agricultural activities) and sewage pollution due to poor sanitation facilities and poor operation of wastewater treatment works (WWTW) – not addressed due to poor data availability. This should be a case for specific sites/ hot spots.

For each of scenarios, GW-S1 and GW-S2, the impact(s) of the following variations were tested:

- c) GW-S1(i) and GW-S1(ii) focussed on a balance between (a) depleting recharge (rainfall depths) and (b) increasing supply yields due to higher demand on the water resource – those IUAs/ GRUs that report a low “allocable yield” volume after allowance for BHN, EWR and Water Use.
- d) GW-S1(iii) assessed whether the groundwater baseflow would be able to balance the EWRs should the groundwater level elevation drop due to (a) lower rainfall recharge,

<sup>1</sup> DRASTIC: D-depth to groundwater; R-Recharge rate; A-Aquifer; S-Soil; T- Topography; I-vadose zone impact and C-aquifer’s hydraulic conductivity

- and/or (b) higher groundwater abstraction rates (those GRUs where a significant portion of the annual groundwater recharge goes to driving the baseflow required for EWR).
- e) GW-S2(i) highlighted extraordinary changes (say a quality Class Range change) over time, and should a permanent shift be declared if annual groundwater recharge does not take place (those GRUs where long-term TDS-concentrations shows that rainwater recharge [timely] improves the aquifer water quality status – what will happen with rainfall depletion).
- f) GW-S2(ii) and GW-S2(iii) assessed whether the aquifer systems are vulnerable to variations in the components of the “Aquifer Vulnerability Status” for the known (four) aquifer type classifications in SA.

## 6.2 Results and consequences

The following observations are made:

- Rainfall recharge depletion of 25% on the long-term average rainfall depths indicated that there is a notable increase in the final Stress Factor indicator. A range of SI Categories were used (like the categories that were used in the Reserve Determination Study (DWS, 2024). The shift is for example, from a Good/Fair Category (SI of 30%) to a Fair Category (SI of 40%).
- The figures for the Allocable Yield are directly linked to the groundwater recharge value, therefore, the effect of recharge reduction is directly related to this yield and as set out in Table 38 in several cases (i.e., quaternary catchments) the yield dropped to below the 1.0 Mm<sup>3</sup>/a limit (not specifically referenced) and some even below the nil value This condition is than high-lighted by the Stress Index indicator (Stress Factor then 1.00).
- Given the rainfall recharge depletion, the Baseflow values also reduced by several million cubic metres per Groundwater Resource Unit, but >1.0Mm<sup>3</sup>/a per Quaternary Catchment.
- The groundwater quality, as noted in the available long-term groundwater quality (TDS-concentrations) does not show sudden changes during years of lower rainfall input – it is therefore expected that the impact of lower rainfall will have a long-term effect on the water quality rather than sudden changes over one/two years.
- The most important component of the assessment was the specification of a Domestic water use that comes in above the basic human needs (BHN at 25L/c/d fixed), a domestic water use of 173 L/c/d were included with the other water uses (i.e., stock water, irrigation, mines and industries). Variations of this figure between 150 and 200 L/c/d did not affect the final water use figure that much, e.g., ±0.1 Mm<sup>3</sup>/a for GNU 9.2 with a Total Water Use of 40.55Mm<sup>3</sup>/a.
- The individual consequences [per GNU] are included in Table 38, however, the most severe consequence is the impact that is on the baseflow component as the result of depleting water levels in the aquifer system(s) supporting the baseflow volumes from the local aquifer system.

It is reported that a few quaternary catchments have estimated baseflow figures significantly higher than the direct rainfall recharge figures. Discussions with the ecology team suggested that the elevated baseflow figures could be related to the fact that there are several wetlands (viz., marshes, bogs or floodplain systems) in/ close to the surface water drainage channels that could feed shallow subterranean flow systems (i.e., interflow) and this flow reports to the lower river valley drainage system in addition to the natural deep aquifer discharges. Another possibility for this phenomenon could be where the estimated groundwater baseflow figures are much higher than the estimated groundwater recharge. The case of riverbank storage should also be considered in cases where alluvial beds transgress sideways from the river valley – during periods of high flooding in the river valley, these beds are recharged and act as a secondary storage facility that gradually leaks back to the river channel over time. These conditions can also lead to exceptional high baseflow estimations.

### 6.3 Conclusions

Of the potential scenario's listed and evaluated, the following ones are important for the sustainability of the groundwater systems and their support to the baseflow component, especially in the Catchment's Eastern part:

- Groundwater abstraction for irrigation on a large scale
- Groundwater abstraction for municipal [bulk] water supplies – currently becoming a significant impact due to over-abstraction due to increasing population figures that requires a water supply of much greater than BHN
- Groundwater quality at “sole water supply towns” are at significant risk(s) due to the poor wastewater treatment – although this untreated sewer water runs down the local streamlet(s), these streamlets are in many cases the areas where the local/underlying aquifer system supplying the town, are situated, and
- The consequence of polluting an aquifer are far worse than having to deal with reduction in rainfall recharge.

To conclude\*, there is a concern that the spread of alien tree species such as the mesquite tree (*Prosopis glandulosa* – native to the Americas but well adapted to southern Africa) in the catchment could impact significantly on specifically the groundwater systems. This concern is well defined as the groundwater levels in the catchment are well within the reach of the trees' rooting system and uses in the order of 40 to 55 L/tree/day (~350 mm to ~500 mm annually for a single tree, [www.ndmc.gov.ca](http://www.ndmc.gov.ca)).

**Table 38: Groundwater Scenario Testing Results (per Groundwater Resource Units)**

| GRU reference | QC reference                                  | Groundwater Scenarios                                                              |                                                                          |                                                                                                |                                                                               |                                                                        | Results on allocable yield status classification                                                                                 | Major consequence(s)                                                                                         |
|---------------|-----------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
|               |                                               | GW-S1(i)(c):<br>Aquifer Recharge -25%                                              | GW-S1(ii)(c)<br>Domestic Water Use<br>(175L/c/d)                         | GW-S2(i)(a)<br>Aquifer Water Quality<br>(mgTDS/L)                                              | GW-S2(ii)(b)<br>Aquifer quality<br>Agricultural Activities                    | GW-S2(iii)<br>Aquifer Vulnerability<br>Water quality - WWTW            |                                                                                                                                  |                                                                                                              |
| 2.0           | D21C – D21H,<br>D22A – D22L,<br>D23A – D23F.  | Groundwater recharge dropped from 360 Mm <sup>3</sup> /a to 270 Mm <sup>3</sup> /a | BHN = 0.135 Mm <sup>3</sup> /a (fixed)<br>DU = 1.119 Mm <sup>3</sup> /a. | Expected to stay at present status: C1.<br><br>(Based on the regional aquifer quality status). | No significant change noted in quality status.                                | Only localised impact possible (depending on the status of the WWTWs). | Changes noted in D21D and D21E (from Poor to Seriously Modified due to high baseflow EWR – D to D/E).                            | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 91 to 73 Mm<sup>3</sup>/a.</b>   |
| 3.0           | D23G – D23J,<br>D24A – D24L.                  | Groundwater recharge dropped from 159 Mm <sup>3</sup> /a to 120 Mm <sup>3</sup> /a | BHN = 0.039 Mm <sup>3</sup> /a (fixed)<br>DU = 0.293 Mm <sup>3</sup> /a. | Expected to stay at present status: C1.<br><br>(Based on the regional aquifer quality status). | No significant change noted in quality status.                                | Only localised impact possible (depending on the status of the WWTWs). | No significant changes noted – SI remains Fair to Natural to Good.<br><br>AYId >1.0 Mm <sup>3</sup> /a except D42A.              | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 27 to 22 Mm<sup>3</sup>/a.</b>   |
| 4.0           | D13A – D13M                                   | Groundwater recharge dropped from 277 Mm <sup>3</sup> /a to 208 Mm <sup>3</sup> /a | BHN = 0.064 Mm <sup>3</sup> /a (fixed)<br>DU = 0.492 Mm <sup>3</sup> /a. | Expected to stay at present status: C1.<br><br>(Based on the regional aquifer quality status). | No significant change noted in quality status.                                | Only localised impact possible (depending on the status of the WWTWs). | No significant changes noted – SI remains Natural/Good to Fair, except D13H goes to Poor.<br><br>AYId = -1.8 Mm <sup>3</sup> /a. | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 60 to 48 Mm<sup>3</sup>/a.</b>   |
| 5.1           | D123A – D12F,<br>D15G – G12H,<br>D18K – D18L. | Groundwater recharge dropped from 186 Mm <sup>3</sup> /a to 139 Mm <sup>3</sup> /a | BHN = 0.215 Mm <sup>3</sup> /a (fixed)<br>DU = 1.996 Mm <sup>3</sup> /a. | Expected to stay at present status: C1.<br><br>(Based on the regional aquifer quality status). | Agriculture (cultivated lands) is <10% of area – thus; no significant impact. | Critically stressed in local areas (Hot Spots developing).             | SI remains Fair to Natural to Good and<br><br>AYId (all) >1.0 Mm <sup>3</sup> /a.                                                | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 24 to 20 Mm<sup>3</sup>/a.</b>   |
| 5.2           | D14A – D14K                                   | Groundwater recharge dropped from 94 Mm <sup>3</sup> /a to 70 Mm <sup>3</sup> /a   | BHN = 0.036 Mm <sup>3</sup> /a (fixed)<br>DU = 0.296 Mm <sup>3</sup> /a. | Expected to stay at present status: C1.<br><br>(Based on the regional aquifer quality status). | Agriculture (cultivated lands) is <10% of area – thus; no significant impact. | Only localised impact possible.                                        | SI remains Fair to Natural to Good (except D14A that shift to a D/E.<br><br>AYId all <1.0 Mm <sup>3</sup> /a except D14G.        | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 24 to 19 Mm<sup>3</sup>/a.</b>   |
| 6.0           | D34A – D34G,<br>D35A – D35K.                  | Groundwater recharge dropped from 131 Mm <sup>3</sup> /a to 98 Mm <sup>3</sup> /a  | BHN = 0.04 Mm <sup>3</sup> /a (fixed)<br>DU = 0.303 Mm <sup>3</sup> /a.  | Expected to stay at present status: C2.<br><br>(Based on the regional aquifer quality status). | Stock farming merely, no significant impact.                                  | Only localised impact possible.                                        | SI remains Good to Fair.<br><br>AYId all >1.0 Mm <sup>3</sup> /a except D35A, D53B, and D35E & -F.                               | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 13 to 11 Mm<sup>3</sup>/a.</b>   |
| 7.1           | D32E – D32K.                                  | Groundwater recharge dropped from 64 Mm <sup>3</sup> /a to 48 Mm <sup>3</sup> /a   | BHN = 0.150 Mm <sup>3</sup> /a (fixed)<br>DU = 0.120 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br><br>(Based on the regional aquifer quality status). | Stock farming merely, no significant impact.                                  | Only localised impact possible.                                        | SI remains Natural/Good to Fair.<br><br>AYId remains >1.0 Mm <sup>3</sup> /a.                                                    | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 4.2 to 3.4 Mm<sup>3</sup>/a.</b> |
| 7.2           | D32A – D32D                                   | Groundwater recharge dropped from 33 Mm <sup>3</sup> /a to 25 Mm <sup>3</sup> /a.  | BHN = 0.008 Mm <sup>3</sup> /a (fixed)<br>DU = 0.056 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br><br>(Based on the regional aquifer quality status). | Stock farming merely, no significant impact.                                  | Only localised impact possible.                                        | SI remains Natural/Good to Fair.<br><br>AYId remains >1.0 Mm <sup>3</sup> /a.                                                    | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 2.2 to 2.0 Mm<sup>3</sup>/a.</b> |
| 8.1           | D31A – D31E and D33A.                         | Groundwater recharge dropped from 55 Mm <sup>3</sup> /a to 41 Mm <sup>3</sup> /a   | BHN = 0.013 Mm <sup>3</sup> /a (fixed)<br>DU = 0.089 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br><br>(Based on the regional aquifer quality status). | Stock farming merely, no significant impact.                                  | Only localised impact possible.                                        | SI remains Natural/Good to Fair.<br><br>AYId remains >1.0 Mm <sup>3</sup> /a.                                                    | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 5.5 to 4.4 Mm<sup>3</sup>/a.</b> |
| 8.2           | D31B,<br>D33B – D33G                          | Groundwater recharge dropped from 88 Mm <sup>3</sup> /a to 66 Mm <sup>3</sup> /a   | BHN = 0.022 Mm <sup>3</sup> /a (fixed)<br>DU = 0.159 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br><br>(Based on the regional aquifer quality status). | Stock farming merely, no significant impact.                                  | Only localised impact possible.                                        | SI remains Natural/Good to Fair.<br><br>AYId remains >1.0 Mm <sup>3</sup> /a.                                                    | Local water levels may drop a few metres.<br><br><b>Baseflow decreases from 1.9 to 1.5 Mm<sup>3</sup>/a.</b> |

| GRU reference | QC reference                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Groundwater Scenarios                                                              |                                                                          |                                                                                                                                                                                             |                                                                                                                                                                                                               |                                                                                                                                  | Results on allocable yield status classification                                                                                                                                                                                                                        | Major consequence(s)                                                                                                                                                                                                                                                          |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | GW-S1(i)(c):<br>Aquifer Recharge -25%                                              | GW-S1(ii)(c)<br>Domestic Water Use<br>(175L/c/d)                         | GW-S2(i)(a)<br>Aquifer Water Quality<br>(mgTDS/L)                                                                                                                                           | GW-S2(ii)(b)<br>Aquifer quality<br>Agricultural Activities                                                                                                                                                    | GW-S2(iii)<br>Aquifer Vulnerability<br>Water quality - WWTW                                                                      |                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                               |
| 8.3           | D33H – D33K                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Groundwater recharge dropped from 21 Mm <sup>3</sup> /a to 16 Mm <sup>3</sup> /a   | BHN = 0.010 Mm <sup>3</sup> /a (fixed)<br>DU = 0.064 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br>(Based on the regional aquifer quality status).                                                                                                  | Stock farming merely, although overgrazing could lead to serious land reform conditions (bad lands).                                                                                                          | Only localised impact possible.                                                                                                  | SI remains Natural/Good to Fair.<br>AYld remains >1.0 Mm <sup>3</sup> /a.                                                                                                                                                                                               | Vulnerability of soil cover due to significant erosion after long-periods of over-grazing – permanent impact.<br><b>Baseflow decreases from 0.6 to 0.5 Mm<sup>3</sup>/a.</b>                                                                                                  |
| 9.1           | C52A – C52F                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Groundwater recharge dropped from 107 Mm <sup>3</sup> /a to 81 Mm <sup>3</sup> /a  | BHN = 0.080 Mm <sup>3</sup> /a (fixed)<br>DU = 1.594 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br>(Based on the regional aquifer quality status).                                                                                                  | Small high-tech farming units that may impact on the GW Yield and Quality over time.<br>Water quality deterioration due to fertilizers (NO <sub>3</sub> ).<br>Monitoring required to quantify ITO WRC & RQOs. | Visible evidence of extreme sewage impacts on local spruits (Bloemspruit, Renosterspruit and upper section of the Modder River). | SI remains Good to Fair except C52A and C52F (Fair to Poor) due to high Water Use figures (GW irrigation).<br>AYld remains >1.0 Mm <sup>3</sup> /a.                                                                                                                     | Small high-tech farming units that may impact on the GW Yield and Quality over time.<br>Water quality deterioration due to fertilizers (NO <sub>3</sub> ).<br>Monitoring required to quantify ITO WRC & RQOs.<br><b>Baseflow decreases from 11.6 to 9.3 Mm<sup>3</sup>/a.</b> |
| 9.2           | C52G and C52H                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Groundwater recharge dropped from 58 Mm <sup>3</sup> /a to 44 Mm <sup>3</sup> /a   | BHN = 0.040 Mm <sup>3</sup> /a (fixed)<br>DU = 0.345 Mm <sup>3</sup> /a. | Expected to stay at present status: C2, but locally there is proof of decreasing to C3 status due to large irrigation water circulation.<br>(Based on the regional aquifer quality status). | Small high-tech farming units that may impact on the GW Yield and Quality over time.<br>Water quality deterioration due to fertilizers (NO <sub>3</sub> ).<br>Monitoring required to quantify ITO WRC & RQOs. | Only localised impact possible.                                                                                                  | SI at Seriously Modified Seriously – should irrigation volumes increase The SI will be at Critically Modified.<br>AYld remains <1.0 Mm <sup>3</sup> /a for C52H.                                                                                                        | Small high-tech farming units that may impact on the GW Yield and Quality over time.<br>Water quality deterioration due to fertilizers (NO <sub>3</sub> ).<br>Monitoring required to quantify ITO WRC & RQOs.<br><b>Baseflow decreases from 1.8 to 1.4 Mm<sup>3</sup>/a.</b>  |
| 10.1          | C51A – C51J                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Groundwater recharge dropped from 162 Mm <sup>3</sup> /a to 122 Mm <sup>3</sup> /a | BHN = 0.070 Mm <sup>3</sup> /a (fixed)<br>DU = 0.495 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br>(Based on the regional aquifer quality status).                                                                                                  | Stock farming merely, no significant impact.                                                                                                                                                                  | Only localised impact possible.                                                                                                  | SI changes from Good/Fair to Fair/Poor.<br>AYld remains >1.0 Mm <sup>3</sup> /a.                                                                                                                                                                                        | Local water levels may drop a few metres.<br><b>Baseflow decreases from 20 to 16 Mm<sup>3</sup>/a.</b>                                                                                                                                                                        |
| 10.2          | C51K and C52J – C52L.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Groundwater recharge dropped from 181 Mm <sup>3</sup> /a to 135 Mm <sup>3</sup> /a | BHN = 0.120 Mm <sup>3</sup> /a (fixed)<br>DU = 1.049 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br>(Based on the regional aquifer quality status).                                                                                                  | High-tech farming units that may impact on the GW Yield and Quality over time.<br>Water quality deterioration due to fertilizers (NO <sub>3</sub> ).<br>Monitoring required to quantify ITO WRC & RQOs.       | Only localised impact possible.                                                                                                  | SI remains from Good to Good/Fair, but C52J and C52K changes from Seriously Modified Critically Modified due to the high GW irrigation if not reduced by at least 25%.<br>AYld remains >1.0 Mm <sup>3</sup> /a except C52J that's changing to - 2.7 Mm <sup>3</sup> /a. | Local water levels may drop significantly that will impact on the Aquifer Vulnerability.<br><b>Baseflow decreases from 1.6 to 1.3 Mm<sup>3</sup>/a.</b>                                                                                                                       |
| 10.3          | C51L and C51M                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Groundwater recharge dropped from 31 Mm <sup>3</sup> /a to 24 Mm <sup>3</sup> /a   | BHN = 0.020 Mm <sup>3</sup> /a (fixed)<br>DU = 0.113 Mm <sup>3</sup> /a. | Expected to stay at present status: C2.<br>(Based on the regional aquifer quality status).                                                                                                  | Stock farming merely, no significant impact.                                                                                                                                                                  | Only localised impact possible.                                                                                                  | SI remains at Natural/Good status.<br>AYld remains >1.0 Mm <sup>3</sup> /a.                                                                                                                                                                                             | <b>Baseflow decreases from 0.84 to 0.67 Mm<sup>3</sup>/a.</b>                                                                                                                                                                                                                 |
| <b>Notes:</b> | <ul style="list-style-type: none"> <li>• DU = Domestic Use calculated at 200 litres/ capita/ day (L/c/d) (as per Res Determination); GW: groundwater; AYld – Allocable Yield; SI=Stress Index</li> <li>• Short-term implies &lt;2-years; Medium-term implies 2-5-years; Long-term implies 5-10-years and Historic-Term implies &gt;10-years.</li> <li>• Water Quality C1 implies Ideal to Good (C10 to C1); Water Quality C2 implies Marginal (C2, TDS 450 to 1000 mg/L), and Water Quality C3 implies Poor to Unacceptable (C10 to C1)</li> </ul> |                                                                                    |                                                                          |                                                                                                                                                                                             |                                                                                                                                                                                                               |                                                                                                                                  |                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                               |

## 7 ECOLOGICAL CONSEQUENCES

### 7.1 Ecological Consequences Approach

The scenario analysis serves as the foundation for evaluating the ecological consequences discussed in the subsequent sections. This process is aimed at appraising the effects of the chosen flow scenarios on ecological categories by anticipating both the drivers and responses in each scenario. These findings, in turn, provide insights that guide the ultimate determination of the ecological category. This will subsequently be used for the determination of the water resources classes within each of the delineated IUA in this study. Please refer to the subsequent sections for further detail in the approach.

The process for assessing the ecological consequences for the primary identified scenarios was undertaken through a series of chronological steps as follows:

- The operational scenarios were modelled, and a time series was provided for each scenario at each river EWR site. These scenarios encompassed present day conditions, as well as future projections for medium term (2040) and long term (2060). The hydrological changes associated with each of the identified scenarios as modelled were used as the primary driver of change. The scenario flows were assessed in terms of how the changes in hydrology for the various scenarios will impact on the level of stress being experienced in the system and the state of the various response variables. To aid in the interpretation of the impacts due to hydrological changes, seasonal distribution and flow duration graphs were prepared for the operational scenarios.

#### ***Biotic component***

- Seasonal modelling of the biotic consequences for all scenarios, encompassing fish and macroinvertebrates, was undertaken using the Fish Invertebrate Flow Habitat Assessment Model (FIFHA). This model, developed by Dr. N. Kleynhans and C. Thirion of the Department of Water and Sanitation's Resource Quality Information Services (RQIS) in 2016, adheres to Eco-categorisation principles, Ecological Category formulation (Kleynhans and Louw, 2007), and the specification of EWR, specifically pertaining to instream flows. The FIFHA model incorporates the following parameters:
  - Discharge,
  - Average width and depth,
  - Different flow-depth velocity classes for fish and inverts,
  - Different biotope / substrate,
  - Hydrology (Natural, Present day, and Baseflows)
  - Various scenario flows,
  - Ecological Categories (PES, REC),
  - Fish (flow dependent species), and
  - Macroinvertebrates (sensitive and flow dependent/ habitat dependent taxon).

- Hydrology inputs (all in cumecs, m<sup>3</sup>/s) include natural monthly hydrology data, entered in grey cells from January to December, along with the percentiles at which the maximum natural baseflow occurs, the EWR site name, site coordinates, and the REMP site code; this data is then fed into the FIFHA model. Scenario hydrology, for which provisions are made for multiple scenarios, is entered separately and is pasted into the appropriate sheets. In terms of the ecological inputs, a month from both the dry and wet seasons is selected for analysis, and the percentile representing the natural baseflow for each respective month is determined. An appropriate rheophilic species/taxon (those that have a high preference for fast flow), is selected for both fish and macroinvertebrates for the chosen month. Furthermore, the percentiles for maintaining the dry and wet season, as well as the dry and wet season drought conditions, are selected based on the EWR results.
- The outputs of the model provide the baseflows for each percentile, including natural flows, present-day conditions and REC (i.e., A-D), are provided according to the selected indicator species, taxa, or guild. A summary of the results for both fish and invertebrates during the dry and wet seasons is presented. Additionally, the assessment of observed flows, in terms of their exceedance of the recommended flows for the REC, is indicated.
- Importantly, it should be noted that the FIFHA model has certain limitations. The FIFHA model was in fact developed to enable rapid monitoring of water velocities and levels related to critical habitats and instream biota requirements using HABFLO and hydrology. It is useful for dry seasons, but for wet seasons, proper baseflow separation is required (of which is problematic using monthly flows).

The FIFHA model does not consider possible facilitation of non-native species which may have similar flow-related requirements as native species. Consequently, increases in habitat suitability for native species may result in increased suitability for non-native species, thereby facilitating their further establishment and competition with the indigenous species.

Nevertheless, FIFHA was specifically prescribed in the Terms of Reference for this study and was consequently employed for modelling the scenarios. At certain locations, such as the Upper Orange, Caledon River, the FIFHA model did not yield accurate results due to the limitations described (e.g. habitat). As a result, the team reverted to fundamental principles and incorporated additional metrics into their interpretations (MIRAI and FRAI), based on available data and expert knowledge integration. This included increased flows, siltation, erosion, incision, and/or limited habitat availability. Thus, the FIFHA was used as a ‘stop-gap’ approach.

In situations where rheophilic macroinvertebrate taxa, such as Perlidae, were absent due to the lack of their preferred habitat at these sites, alternative indicator taxa were used. These alternative indicators may not be as sensitive because of the available habitats and/or their other preferences (e.g. water quality). When it comes to fish, there are no true rheophilic species and only semi-rheophilic fish species was used in the FIFHA model for this catchment. This approach may not always provide the same level of accuracy in assessing the biotic consequences of the scenarios. Therefore, the interpretations are

based on the expertise and knowledge of specialists who consider the current characteristics and impacts on the systems, as well as their understanding of the potential consequences resulting from the scenarios.

Additionally, in interpreting the suitability percentage index (suitability of flows) for fish and macroinvertebrates from the FIFHA, it was noted that the PES for fish and macroinvertebrate communities reflects community-level responses. In contrast, the scenarios assessed within FIFHA are based on responses of individual indicator taxa rather than communities, making direct comparisons inappropriate and therefore the index will serve as a guide.

Furthermore, in this context, the assessment of anticipated changes in water quality resulting from the implementation of various scenarios considered existing impacts and insights derived from diatom results, macroinvertebrates, and/or other nutrient data on hand. The water quality perspective was an integral part of the consequence assessment, especially for scenario 7.

- Scenarios at each EWR site from a biotic perspective were ranked based on the degree to which the scenarios would meet the EWR for the REC.
- The following was further taken cognisant of when evaluating the preferred scenario:
  - Ecological significance of the EWR sites:
    - The significance of an EWR site is directly proportional to the values of PES and/or EIS; in other words, the higher the PES and/or EIS, the greater the ecological importance of the EWR site (DWS, 2014).
    - Consideration is given to the conservation importance of a site. Consequently, if an EWR site is situated within a conservation area of notable significance, it will be designated as a pivotal EWR site due to its ecological importance (DWS, 2014).
    - The extent of the river reach encompassed by the EWR sites is also a factor in determining their importance. Specifically, the greater the length of the represented river reach, the higher the level of significance attributed to the potential impacts within that scenario (DWS, 2014); and
    - The crucial factor determining the ranking of EWR sites in the ecosystem is their relative position and influence on simulated operations. This involves considering factors such as the location (upstream or downstream) in relation to WWTW or other developments, as well as the nature and extent of their influences on the EWR site. The hierarchy of these sites depends on their significance in the modelling context, which determines the primary driver EWR site for "releases" within the model. These key sites can either be the most downstream or have a higher REC (or PES) compared to others, resulting in a greater flow requirement and, consequently, higher ecological importance (DWS, 2014).
  - Geomorphological and riparian vegetation responses were also considered.

- Overall, the categories for the biotic component per scenario were assessed as to whether the scenario will be met.
  - If the scenario fell short of the REC by a half a category, it was orange colour-coded; and
  - If the scenario fell short of the REC by a full category or more, it was red colour-coded, signaling potential system failure from a biotic perspective, as the flows did not meet the requirements of the selected indicator species or taxa, compromising habitat suitability.

## **7.2 Ecological Consequences**

Table 39 to Table 47 set out the ecological consequences per IUA, highlighting the category changes per scenario evaluated.

**Table 39: IUA 1: Golden Gate - Ecological Consequences**

| IUA1: Golden Gate                                                              | Sc1a | Sc1b | Sc1b.1 | Sc2a | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------------------------------------------------------------------|------|------|--------|------|------|--------|------|------|------|--------|--------|---------|--------|--------|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UO_EWR01_R (Little Caledon)_Wet/Dry: Mar/July_Indicators: BAEN/Perlidae</b> |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>EWR REC: B/C</b>                                                            |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Fish Wet                                                                       | A/B  | A/B  |        |      |      |        |      |      |      |        |        |         |        |        | No proposed developments. | Flows under present day conditions (Scenario 1a) for the selected indicator species/taxon during the wetter months were noted to support critical habitats at levels reflective of natural flows and exceeded those specified for the REC. However, present day flows were insufficient for meeting the REC during drier months, instead showing a significant reduction in habitat suitability for the selected indicator species/taxon. This is primarily owing to some of the critical habitat being completely exposed and flow requirements not meeting the needs for Perlidae (selected macroinvertebrate indicator species). For the fish, a connectivity for spawning migrations is needed and the spawning habitat must be available (no embedded). Implementing the EWR in the present scenario (Scenario 1b) improves the system by ensuring flows during the drier months better and match the habitat needs of macroinvertebrates with specific flow preferences. Although, the flow requirements for BAEN in the dry periods are still not met, likely owing to connectivity and water quality impacting on the recruitment of fish. Overall, implementing the EWR is recommended to ensure flows remain adequate and ecological balance is maintained. |
| Fish Dry                                                                       | C/D  | C    |        |      |      |        |      |      |      |        |        |         |        |        |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Inverts Wet                                                                    | A/B  | A/B  |        |      |      |        |      |      |      |        |        |         |        |        |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Inverts Dry                                                                    | C    | B/C  |        |      |      |        |      |      |      |        |        |         |        |        |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

**Table 40: IUA 2: Caledon/ Leeu River – Ecological Consequences**

| IUA2: Leeu/ Caledon River                                                     | Sc1a | Sc1b | Sc1b.1 | Sc2a | Sc2b | Sc2.1b | Sc3a                     | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------------|------|------|--------|------|------|--------|--------------------------|------|------|--------|--------|---------|--------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UO_EWR01_I (Middle Caledon)_Wet/Dry: Feb/Jul_Indicators_ BAEN/Caenidae</b> |      |      |        |      |      |        |                          |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>EWR REC: D</b>                                                             |      |      |        |      |      |        |                          |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Fish Wet                                                                      | A    | A    |        | A    | A    |        |                          |      |      |        |        |         |        |        | Scenario flows, whether or not the EWR is implemented, generally align with the flow preferences of the indicator species/taxon. However, the biota shows a stronger positive response when EWR is implemented. The proposed weirs reduce instream continuity and cause instream modifications, particularly affecting fish and impeding flow. Despite these impacts, the flows remain sufficient to meet the overall REC of a D. It is crucial to highlight that water quality is the primary driver in this reach, coupled with limited habitat availability. Fine silts passing through the system remain a concern, as they clog the gills of both fish and macroinvertebrates. Additionally, the proposed weirs may trap coarse materials like gravel, which are vital habitats for biotic communities. |
| Fish Dry                                                                      | D    | C    |        | D    | C    | N/A    | Flow data similar to Sc2 |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Inverts Wet                                                                   | A    | A    |        | A    | A    |        |                          |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Inverts Dry                                                                   | B/C  | A/B  |        | B/C  | A/B  |        |                          |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

**Table 41: IUA 3: Caledon River – Ecological Consequences**

| IUA3: Caledon River                                                                      | Sc1a | Sc1b | Sc1b.1 | Sc2a | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
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| <b>UO_EWR04_I (Lower Caledon)_Wet/Dry: Mar/Jul_Indicators_ BAEN/ Hydropsychidae 2spp</b> |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>REC: C/D</b>                                                                          |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Fish Wet                                                                                 | C    | B    |        | C    |      | B      | C/D  | C    |      |        |        |         |        |        | Scenario flows, whether the EWR is implemented or not, generally align with the flow preferences of the indicator species/taxon. However, the biota shows a stronger positive response when EWR is implemented. The proposed weirs reduce instream continuity and cause instream modifications, particularly affecting fish (migration and embedded spawning habitat) and impeding flow. Despite these impacts, the flows remain sufficient to meet the overall REC of a C/D. Scenario 2b, remains better than Scenario 3b. Both Scenario 3b and 3c, the drought flows during the wet season from approximately the 80% percentile is when the biotic community will negatively respond to the flows as they have an ecological category of a D, while during the dry periods, they respond positively to the drought flows. It is crucial to highlight that water quality is the primary driver in this reach, coupled with limited habitat availability. Fine silts passing through the system remain a concern, as they clog the gills of both fish and macroinvertebrates. Additionally, the proposed weirs may trap coarse materials like gravel, which are vital habitats for biotic communities. |
| Fish Dry                                                                                 | C    | A    |        | C    |      | A      | C/D  | A    |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Inverts Wet                                                                              | B/C  | B    |        | C    |      | B      | D    | D    |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Inverts Dry                                                                              | C    | B/C  |        | C/D  |      | B/C    | A    | B/C  |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

**Table 42: IUA 4: Kraai River – Ecological Consequences**

| IUA4: Kraai River                                                                | Sc1a | Sc1b | Sc1b.1 | Sc2a | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------------------------|------|------|--------|------|------|--------|------|------|------|--------|--------|---------|--------|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UO_EWR08_I (Lower Kraai)_Wet/Dry: Mar/September_Indicators: BAEN/Perlidae</b> |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>REC: B/C</b>                                                                  |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Fish Wet                                                                         | B    | A    |        |      |      |        |      |      |      |        |        |         | C      | A      | Flows under present-day conditions (Scenario 1a) during wetter months support critical habitats for the selected indicator species/taxon at levels consistent with natural flows and exceed those required for the REC of a B/C. However, during drier months, present-day flows fall short of achieving the REC of a B/C, leading to a significant reduction in habitat suitability. This is primarily due to very low drought flows, which cause critical habitats to become completely exposed for flow-dependent species/taxon. Implementing the EWR under the current scenario (Scenario 1b) improves conditions by providing flows in both seasons that better align with the habitat needs of biota with specific flow preferences. If the Boskraai Dam is constructed in the future without implementing the EWR, flow requirements during both seasons will not be met for fish or macroinvertebrates, raising serious ecological concerns. To ensure adequate flows and maintain ecological balance under either scenario (present or future), implementing the EWR is strongly recommended. If this is not feasible and trade-offs are required, an Alien Invasive Plant (AIP) eradication programme should be prioritised. Extensive AIP infestations along the Kraai's riparian zone currently reduce baseflows. Over time, eradication efforts could help restore some baseflows, potentially improving flow and thus biotic responses. |
| Fish Dry                                                                         | C/D  | B    |        |      |      |        |      |      |      |        |        |         | F      | A/B    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Inverts Wet                                                                      | B    | A/B  |        |      |      | N/A    |      |      |      |        |        |         | C      | A      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Inverts Dry                                                                      | C/D  | B    |        |      |      |        |      |      |      |        |        |         | F      | A/B    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

**Table 43: IUA 5: Upper Orange River – Ecological Consequences**

| IUA5: Upper Orange River                                                            | Sc1a | Sc1b | Sc1b.1 | Sc2a | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------------|------|------|--------|------|------|--------|------|------|------|--------|--------|---------|--------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UO_EWR03_I (Upper Orange)_Wet/Dry: Feb/July_Indicators: BAEN/Leptophlebiidae</b> |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>REC: D</b>                                                                       |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Fish Wet                                                                            | A    | A    |        | A/B  |      | A/B    | A/B  | A/B  | A/B  | A/B    | A/B    | A/B     | N/A    |        | Scenario flows, with or without EWR implementation, generally align with the indicator biota flow preferences, even under future dam proposals. Increased flows in months like February contribute to habitat scouring and sediment mobilisation. However, as highlighted by the limitations of FIFHA, the model does not account for poor habitat availability and water quality, which are the primary non-flow drivers of ecological conditions at this Upper Orange EWR site. These factors were therefore considered when interpreting the FIFHA results. Although the FIFHA indicates adequate flows for the indicator species/taxon, ecological conditions are likely to remain constrained if the proposed upstream dams (e.g., Verbeeldingskraal, Pohlihal, and Makhaleng) are constructed. These dams will trap more sediment, particularly coarse material such as gravel, which is critical for biotic habitats. Fine sediments will continue to pass through the system, increasing turbidity, sediment deposition, and embedding of available rocky habitats. These changes clog the gills of biota, restrict riparian zones, encourage the spread of AIP, and degrade biotic responses. This underscores the importance of addressing non-flow drivers, such as improving water quality, to support ecological health effectively. |
| Fish Dry                                                                            | A    | A    |        | A    |      | A      | A    | A    | A    | A      | A      | A       |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Inverts Wet                                                                         | A    | A    |        | A/B  |      | A/B    | A/B  | A/B  | A/B  | A/B    | A/B    | A/B     |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Inverts Dry                                                                         | A    | A    |        | A    |      | A      | A/B  | A/B  | A    | A      | A      | A/B     |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>UO_EWR02_I (Sterkspruit)_Wet/Dry: Mar/July_Indicators: BAEN/Perlidae</b>         |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>REC: C/D</b>                                                                     |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Fish Wet                                                                            | D    | D    | N/A    | D    | D    |        |      |      |      |        |        |         |        |        | Flows under present-day (Scenario 1) and future (Scenario 2) conditions, with or without EWR implementation, are insufficient for fish and macroinvertebrates during the dry season and for fish during the wet season, primarily due to limited releases from Jozana's Hoek Dam. These deficits negatively impact critical habitats despite the presence of suitable biotopes. Indicator fish species respond to Scenario 1b and 2b flows with a rating of "D," falling short of the REC of a C/D. The flows compromise fish migration and spawning during the critical summer high-flow period. In addition to the flow requirements not being met, both fish and macroinvertebrate health are predominantly influenced by water quality (non-flow driver). The PES of the fish and macroinvertebrate community was rated as D/E (largely to critically modified) and "D" (largely modified) respectively, indicating the significant impact of this non-flow driver on their ecological state. Overall, priority should focus on maintaining suitable conditions during March to support spawning rather than addressing low-flow periods e.g. July.                                                                                                                                                                                           |
| Fish Dry                                                                            | F    | F    |        | F    | F    |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Inverts Wet                                                                         | C    | C    |        | C    | C    |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Inverts Dry                                                                         | D    | D    |        | D    | D    |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

**Table 44: IUA7: Seekoei River - Ecological Consequences**

| IUA7: Seekoei                                                                          | Sc1a | Sc1b | Sc1b.1 | Sc2a                           | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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| <b>UO_EWR05_I_Seekoei)_Wet/Dry: Mar/July_Indicators: BAEN/Leptophlebiidae (REC: C)</b> |      |      |        |                                |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>REC: C</b>                                                                          |      |      |        |                                |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Fish Wet                                                                               | C    | C    | N/A    | N/A (no proposed developments) |      |        |      |      |      |        |        |         |        |        | <p>Scenario flows, with or without EWR implementation, generally align with the flow preferences of the biota. However, biota respond more favourably when the EWR is implemented. Since no changes to the main drivers are proposed, the macroinvertebrate and fish communities are unlikely to change in the absence of developments.</p> <p>Notably, deficits in the system during March (from the 15% to the 90% exceedance levels) result in insufficient flow to meet the EWR. However, as the system is ephemeral and such deficits are expected.</p> |
| Fish Dry                                                                               | B    | A    |        |                                |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Inverts Wet                                                                            | C    | B/C  |        |                                |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Inverts Dry                                                                            | C    | B/C  |        |                                |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

**Table 45: IUA8: Vanderkloof Dam – Ecological Consequences**

| IUA8: Vanderkloof Dam                                                                | Sc1a | Sc1b | Sc1b.1 | Sc2a | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
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| <b>UO_EWR10_I (Lower Orange)_Wet/Dry: Feb/July_Indicators: BAEN/ Leptophlebiidae</b> |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>REC: C</b>                                                                        |      |      |        |      |      |        |      |      |      |        |        |         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Fish Wet                                                                             | A    | A    | A      | A    | A/B  | A      | A/B  | A/B  | B    | A/B    | A/B    | B       | N/A    |        | <p>Scenario flows, with or without EWR implementation, generally align with the flow preferences of indicator biota, even under future dam proposals. Increased flows during months like February play a key role in habitat scouring and sediment mobilisation. While the FIFHA indicates adequate flows for the indicator species/taxon, ecological conditions are likely to remain constrained if proposed upstream dams (e.g., Verbeeldingskraal, Pohliali, and Makhaleng) are constructed. These dams will trap coarse sediment, such as gravel, which is crucial for biotic habitats, while fine sediments will continue to increase turbidity, sediment deposition, and the embedding of rocky habitats. These changes adversely impact biota by clogging gills (physiological stress impacting on reproduction), narrowing riparian zones, promoting alien invasive plants, and degrading ecological responses. Addressing non-flow drivers, such as improving water quality, is therefore critical in maintaining ecological health. In addition to the above, to protect geomorphology and riparian vegetation, it is essential to implement the floods specified in the Reserve determination study. Failure to do so would have detrimental effects on these ecological components and thus may have a knock-on effect on the biotic component.</p> <p><i>Although the scenario flows at this EWR site near Marksdrift are meeting the REC of a Category C. There is a concern regarding the limited bigger floods of approximately 155 and 550m<sup>3</sup>/s (October to April) that have been removed. This will have a major impact on the geomorphological and riparian vegetation components of the system, which will have a knock-on effect on the instream biota (ecological trade-off). The lack of large floods will be insufficient to effectively scour habitats, mobilise sediments, and transport gravel and reset marginal vegetation, which are critical processes for maintaining ecosystem health. While the results from the FIFHA indicate that the flow requirements for the indicator species or taxa are being met, it is important to acknowledge that the reduced freshet may not fully support key ecological functions. Therefore, careful consideration must be given to the potential impacts of this lower-than-ideal freshet on habitat maintenance and overall river system dynamics.</i></p> |
| Fish Dry                                                                             | A    | A    | A      | A    | A    | A      | A    | A    | A    | A      | A      | A       |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Inverts Wet                                                                          | A    | A    | A      | A    | A/B  | A      | A/B  | A    | A/B  | A/B    | A      | A/B     |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Inverts Dry                                                                          | A    | A    | A      | A    | A    | A      | A    | A    | A    | A      | A      | A       |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

**Table 46: IUA 9: Upper Modder River - Ecological Consequences**

| IUA9: Modder River                                                                        | Sc1a | Sc1b | Sc1b.1 | Sc2a | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1 | Sc3.2a | Sc3.2b | Discussion |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
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| <b>UO_EWR07_I (Middle Modder)_Wet/Dry: Mar/July_Indicators: BAEN/ Hydropsychidae 2spp</b> |      |      |        |      |      |        |      |      |      |        |        |         |        |        |            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>REC: C</b>                                                                             |      |      |        |      |      |        |      |      |      |        |        |         |        |        |            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Fish Wet                                                                                  | A    | A    |        | A    | A    | N/A    |      |      |      |        |        |         |        |        |            | Scenario flows, with or without EWR implementation, generally align with the flow preferences of the biota. In fact, flows are higher owing to releases from upstream WWTW. However, it is important to note that flow is not the primary driver in this system; water quality is the dominant factor influencing ecological health. This critical aspect is not accounted for in the FIFHA model, which focuses primarily on flow metrics. The poor water quality in the system has a significant impact on biota, affecting their ability to thrive and altering ecological conditions. These impacts include reduced habitat suitability, physiological stress on species, and the potential for long-term degradation of biotic communities. Addressing water quality issues is therefore essential to improve the ecological state of the system, even where flows are deemed adequate. |
| Fish Dry                                                                                  | -    | -    |        | -    | -    |        |      |      |      |        |        |         |        |        |            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Inverts Wet                                                                               | A/B  | A/B  |        | A    | A    |        |      |      |      |        |        |         |        |        |            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Inverts Dry                                                                               | A    | A    |        | A    | A    |        |      |      |      |        |        |         |        |        |            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

**Table 47: IUA10: Modder/ Riet River - Ecological Consequences**

| IUA8: Modder/ Riet                                                                     | Sc1a | Sc1b | Sc1b.1 | Sc2a                                    | Sc2b | Sc2.1b | Sc3a | Sc3b | S3b1 | Sc3.1a | Sc3.1b | Sc3.1b1                                                                                                     | Sc3.2a | Sc3.2b | Discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------|------|------|--------|-----------------------------------------|------|--------|------|------|------|--------|--------|-------------------------------------------------------------------------------------------------------------|--------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UO_EWR06_I (Upper Riet)_Wet/Dry: Mar/July_Indicators: BAEN/ Hydropsychidae 2spp</b> |      |      |        |                                         |      |        |      |      |      |        |        |                                                                                                             |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>REC: C</b>                                                                          |      |      |        |                                         |      |        |      |      |      |        |        |                                                                                                             |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Fish Wet                                                                               | C    | C    |        | No difference in flows compared to Sc 1 |      |        |      | N/A  |      |        |        | Scenario flows, with or without EWR implementation, generally align with the flow preferences of the biota. |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Fish Dry                                                                               | A    | A    |        |                                         |      |        |      |      |      |        |        |                                                                                                             |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Inverts Wet                                                                            | C    | C    |        |                                         |      |        |      |      |      |        |        |                                                                                                             |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Inverts Dry                                                                            | A/B  | A/B  |        |                                         |      |        |      |      |      |        |        |                                                                                                             |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>UO_EWR09_I (Lower Riet)_Wet/Dry: Mar/July_Indicators: BAEN/ Hydropsychidae 2spp</b> |      |      |        |                                         |      |        |      |      |      |        |        |                                                                                                             |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>REC: B/C</b>                                                                        |      |      |        |                                         |      |        |      |      |      |        |        |                                                                                                             |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Fish Wet                                                                               | C    | C    |        | C                                       | C    |        | C    | C    | C    |        | A      | C                                                                                                           | N/A    |        | Flows under present-day (Scenario 1) with or without the EWR implemented, do not meet the flow requirements for the specified indicator species/taxon during the wet season (March). The biota's responses in these scenarios fall between categories C's and D's, which do not meet the overall REC of a B/C. However, during the dry season, the indicator biota responds positively to the available flows, indicating that conditions are more favourable during this period. The negative responses observed during the wet season are of particular concern, as they directly affect the migration and spawning movements of the indicator fish species. The lack of adequate flow cues during this critical period prevents these species from accessing suitable habitats for spawning (physiological responses). Under Scenarios 2 and 3, there is only a slight improvement in biota responses, but they still do not meet the REC of B/C, with most results falling into the C category during the wet season. However, dry season results remain adequate. As a result, there will be a minor ecological trade-off during wet periods, though this impact would be reduced if the TEC were adjusted to a C category. Maintaining overall habitat suitability at this site is crucial, as the upper reaches serve as key refugia for fish species. This will support the long-term ecological health of the system. |
| Fish Dry                                                                               | A    | A    |        | A                                       | A    |        | A    | A    | A    |        | A      | A                                                                                                           |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Inverts Wet                                                                            | C/D  | C/D  |        | D                                       | D    |        | C    | C    | C    |        | A      | C/D                                                                                                         |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Inverts Dry                                                                            | A    | A    |        | A                                       | A    |        | A    | A    | A    |        | A      | A                                                                                                           |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

|        |                                           |
|--------|-------------------------------------------|
| Orange | Half a category lower than the REC        |
| Red    | Full category or more, lower than the REC |

## 8 WATER QUALITY SCENARIOS

The Orange River system is a vital water resource that supports agricultural, industrial and municipal needs. Understanding the overall pollution loads using Total Dissolved Solids (TDS) as a critical indicator is essential for sustainable water resource management. This chapter sets out the results of the study that was done to evaluate the relative impact of various users on water quality under different development scenarios, ensuing informed decision-making for future water management strategies.

### 8.1 Methodology

The methodology outlines the process for assessing TDS loads, metals and nutrients in the Orange River system, over the hydrological years from October 2012 to January 2024, as data were available. The approach included data collection, evaluation and analysis, followed by an interpretation to evaluate sources and impacts on water quality.

The approach taken needed to ensure that the loads estimated can be assessed within all the IUAs where possible, and to align with the location of key EWR sites that were used for the hydrological and ecological assessment.

#### 8.1.1 Data Sources

The following datasets were used for pollutant load estimation:

- Water quality: processed data from the Status Quo Report, Report Number: RDM/WMA13/00/CON/CLA/0224 for the Upper Orange River catchment, as supplied by the DWS – National Water Quality Monitoring Program. Additional secondary data was obtained from the Northern Cape Provincial Operation – Upington (Directorate: Orange Proto CMA). For the latter dataset, only one monitoring station is situated within the Upper Orange River main stem (site “01 – Orange River at Marksdrift”) (IUA 8), and
- River flows (instream): Observed daily flows from DWS Hydrological Services website

#### Data gaps and challenges

The data shows general gaps for the period February 2020 to February 2023, and this is consistent for most of the sites.

#### 8.1.2 Selection of Monitoring Sites

##### ***Water quality monitoring stations***

The criteria for the selection of water quality monitoring sites involved first evaluating the spatial alignment of the EWR site in relation to the National Hydrological sites which typically includes the measurement of both flow and water quality (e.g., C5H003 aligned with UO\_EWR07\_I). The rationale was that if EWR site alignment was achieved, then a representation of load calculation would be achieved in each IUA. If alignment was not obtained, the regional water quality information, such as that supplied by the Northern Cape Provincial Operation, was used to assess

the water quality and align the monitoring points with an appropriate nearby flow gauging station (weir).

### **Flow gauging stations**

All active flow measurement gauging stations within the Orange River system, including the Modder-Riet rivers, and which included data within the target date range were selected for data evaluation. The Vaal River system contribution of flow was assessed by evaluating data from gauging stations upstream of the confluence of the Vaal River with Modder-Riet River and the Vaal River flowing through the town of Douglas.

A map showing the locations of the various flow gauging stations and water quality monitoring stations is shown in Figure 22 for the Upper Orange River catchment.

### **8.1.3 Data processing and load calculations**

Flow and water quality data was processed, cleaned and analysed.

#### **Water Quality Parameters**

The following water quality parameters were evaluated as the main constituents of concern for the Orange River system:

- Salts: Total Dissolved Solids (TDS) and sulphates (SO<sub>4</sub>)
- Nutrients: Nitrate-nitrogen (NO<sub>3</sub>-N) and Orthophosphate (PO<sub>4</sub>-P)
- Heavy metals: Aluminium (Al), Iron (Fe) and Manganese (Mn), and
- Solids: Total Suspended Solids (TSS)

TDS was used as the indicator parameter to characterise the system's load primarily due to its use as an indicator of overall water quality, ease of measurement and its high correlation to Electrical Conductivity (EC). The latter relationship was used to increase the number of missing data points where there was an EC value without a corresponding TDS value. While TDS and EC ratio is highly dependent on the type of water, its relationship in natural water is usually defined by an TDS/ EC ratio range of 5.5 to 7.5 (where TDS and EC are measured in mg/l and mS/m, respectively). As a result, 6.5 was used to calculate missing TDS values where EC was available, which increased the number of samples at certain sites to increase the confidence of TDS load calculations and statistics. Applying this conversion factor to missing TDS values with a measured EC value increased sample size numbers for the assessed datasets on average by 74%.

In terms of nutrient data, orthophosphate data records were sufficient to draw statistical inferences for the Upper Orange River catchment where most samples number were more than 30. As a result, TDS and PO<sub>4</sub> were selected for the load evaluation of the entire Orange River System at a 95<sup>th</sup> and 50<sup>th</sup> percentile, respectively. The remaining water quality parameters were only used for a localised assessment and inference to discuss water quality hotspots.

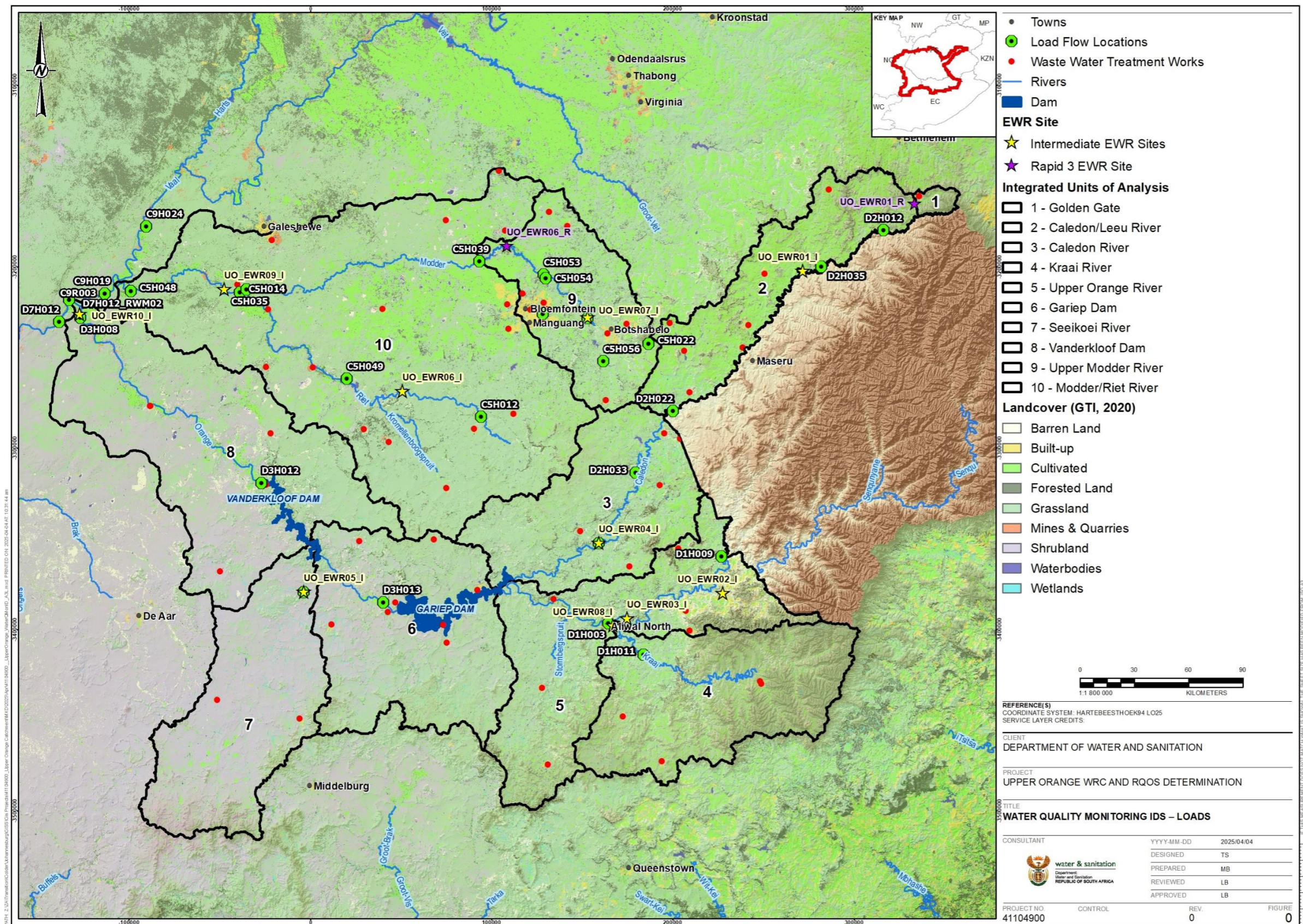


Figure 22: Water quality monitoring and flow stations for load assessment in the Upper Orange

## **Flow data**

The DWS flow gauging weirs were used as a basis for all observed daily flow data. Stations with reliable data within the period 2012 to 2023 hydrological years were selected and assessed for data quality. As with all pollution load assessment studies, the availability of flow gauging weirs, which tend to be fewer when compared to water quality monitoring stations, is the limiting factor.

For nineteen (19) water quality monitoring sites that are managed by the Northern Cape Provincial Operation (from Marksdrift to the Orange River mouth), the selected nearby flow gauging station data (i.e. D7H012) which aligned with the Regional Water Monitoring (RWM) site was duplicated and tagged with the RWM site identification number (i.e. 02-Orange River @ Douglas Confluence), resulting in a flow file (D7H012\_RWM02) which could be used to calculate the estimated load.

## **Load calculations**

To calculate the various loads within the system, the following formula was used:

$$\text{Parameter Load} = \text{Flow Rate (m}^3/\text{s)} \times \text{Parameter Concentration (mg/l)} \times 86.4$$

Where 86.4 converts the results to **kg/day**.

Once the results were obtained, they were subjected to trend analysis, statistical assessment and spatial GIS mapping for the final selection of monitoring points.

## **8.2 Results of analysis**

### **8.2.1 River Network Load Assessment**

The load assessment carried out for the Orange River network was visualised using a river network diagram to enable an overview of the relative load contribution per IUA. The loads visualised represent the 95<sup>th</sup> and 50<sup>th</sup> percentile values for TDS (Figure 5) and PO<sub>4</sub> (Figure 6), respectively from upstream to downstream along the river. The network further shows the number of samples from which these statistics have been derived.

Figure 23 and Figure 24 show the complete the statistics for the load assessment for the Upper and Lower Orange, respectively.

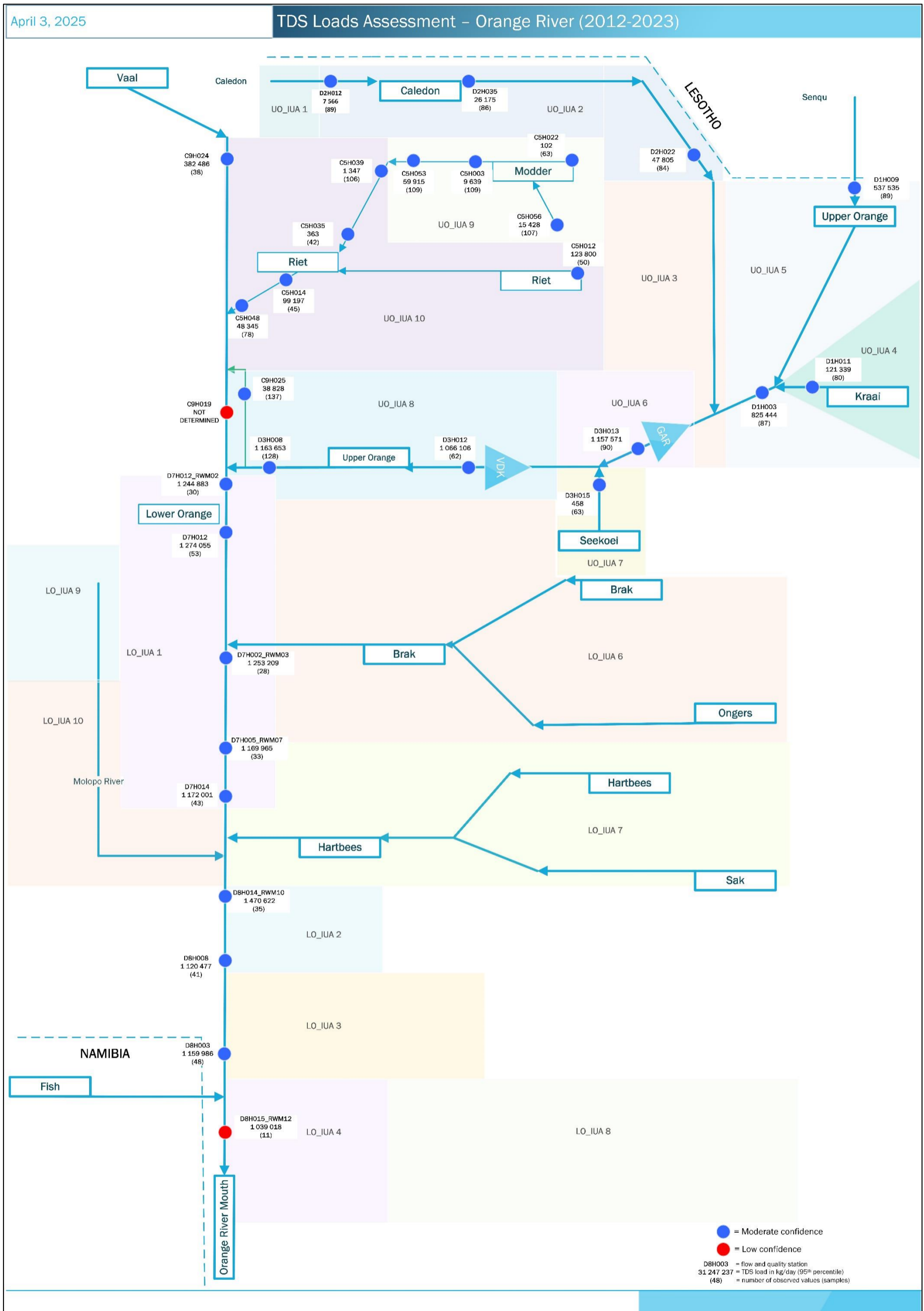


Figure 23: Orange River network showing assessed points for TDS load assessment

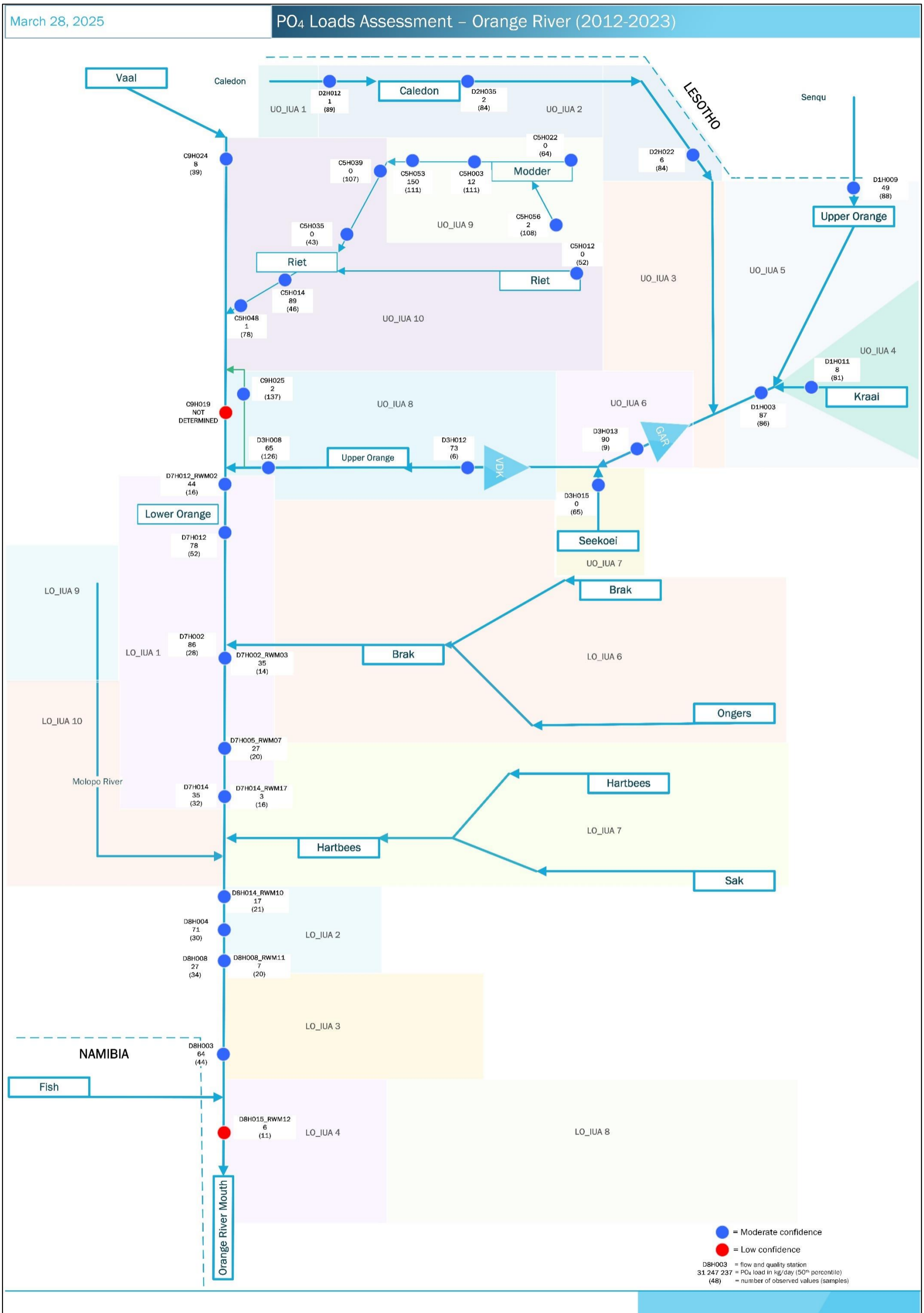


Figure 24: Orange River network showing assessed points for Orthophosphate load assessment

**Table 48: Load assessment results for the Upper Orange River**

| Station ID | Description                                                                      | Associated Selected EWR Site Name   | Station ID - EWR Distance | IUA      | Statistic        | Al (kg/day) | Fe (kg/day)    | Mn (kg/day)    | NO3-N (kg/day) | PO4-P (kg/day) | SO4 (kg/day) | TDS (DMS) (kg/day) | TDS (EC-Conv.) (kg/day) |
|------------|----------------------------------------------------------------------------------|-------------------------------------|---------------------------|----------|------------------|-------------|----------------|----------------|----------------|----------------|--------------|--------------------|-------------------------|
| D2H012     | D2H012 CALEDONSPPOORT 190 THE POPLARS 199 AT THE POPLARS ON LITTLE CALEDON RIVER | UO_EWR01_R                          | 41km DS                   | UO_IUA 1 | <i>n Samples</i> | 5           | 5              | 5              | <b>No Data</b> | <b>89</b>      | <b>87</b>    | <b>60</b>          | <b>89</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 11          | 3              | 3              |                | 3              | 1 350        | 17 647             | 16 472                  |
|            |                                                                                  |                                     |                           |          | 95th percentile  | 36          | 6              | 6              |                | 12             | 6 053        | 68 509             | 65 654                  |
|            |                                                                                  |                                     |                           |          | 50th percentile  | 3           | 3              | 3              |                | 1              | 474          | 7 556              | 7 566                   |
|            |                                                                                  |                                     |                           |          | Std. Dev.        | 18          | 3              | 3              |                | 7              | 2 194        | 25 578             | 23 080                  |
| D2H035     | D2H035Q01 CALEDON RIVER AT FICKSBURG/ FICKSBURG BRIDGE                           | UO_EWR01_I                          | 21km US                   | UO_IUA 2 | <i>n Samples</i> | 4           | 4              | 4              | <b>No Data</b> | <b>88</b>      | <b>87</b>    | <b>62</b>          | <b>86</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 4           | 8              | 2              |                | 23             | 12 399       | 137 328            | 132 807                 |
|            |                                                                                  |                                     |                           |          | 95th percentile  | 11          | 25             | 5              |                | 80             | 61 447       | 708 701            | 560 143                 |
|            |                                                                                  |                                     |                           |          | 50th percentile  | 2           | 2              | 2              |                | 2              | 1 852        | 21 342             | 26 179                  |
|            |                                                                                  |                                     |                           |          | Std. Dev.        | 6           | 14             | 3              |                | 66             | 23 648       | 268 677            | 240 680                 |
| D2H022     | D2H022Q01 CALEDON RIVER AT WILGEDRAAI/HOBHOUSE                                   | None                                | -                         | UO_IUA 2 | <i>n Samples</i> | 3           | 3              | 3              | <b>No Data</b> | <b>84</b>      | <b>83</b>    | <b>56</b>          | <b>84</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 2           | 1              | 1              |                | 41             | 18 855       | 225 341            | 223 984                 |
|            |                                                                                  |                                     |                           |          | 95th percentile  | 3           | 2              | 2              |                | 159            | 86 176       | 1 133 425          | 1 126 110               |
|            |                                                                                  |                                     |                           |          | 50th percentile  | 2           | 1              | 0              |                | 6              | 4 767        | 42 947             | 47 805                  |
|            |                                                                                  |                                     |                           |          | Std. Dev.        | 1           | 1              | 1              |                | 112            | 36 001       | 427 956            | 402 383                 |
| D1H009     | D1H009Q01 ORANGE RIVER AT ORANJEDRAAI                                            | None                                | -                         | UO_IUA 5 | <i>n Samples</i> | 3           | 3              | 3              | <b>No Data</b> | <b>88</b>      | <b>86</b>    | <b>63</b>          | <b>86</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 108         | 102            | 92             |                | 309            | 60 826       | 1 003 581          | 979 710                 |
|            |                                                                                  |                                     |                           |          | 95th percentile  | 245         | 244            | 242            |                | 744            | 201 575      | 3 675 066          | 3 665 580               |
|            |                                                                                  |                                     |                           |          | 50th percentile  | 33          | 29             | 5              |                | 49             | 31 261       | 544 124            | 537 535                 |
|            |                                                                                  |                                     |                           |          | Std. Dev.        | 138         | 144            | 152            |                | 1 293          | 84 329       | 1 460 091          | 1 365 704               |
| D1H011     | D1H011Q01 KRAAI RIVER AT ROODEWAL                                                | UO_EWR08_I                          | 41km US                   | UO_IUA 4 | <i>n Samples</i> | 4           | 4              | 4              | <b>No Data</b> | <b>81</b>      | <b>79</b>    | <b>58</b>          | <b>80</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 79          | 80             | 73             |                | 83             | 15 017       | 302 011            | 310 083                 |
|            |                                                                                  |                                     |                           |          | 95th percentile  | 220         | 220            | 220            |                | 460            | 87 267       | 1 362 020          | 1 337 240               |
|            |                                                                                  |                                     |                           |          | 50th percentile  | 28          | 32             | 21             |                | 8              | 4 850        | 121 339            | 121 339                 |
|            |                                                                                  |                                     |                           |          | Std. Dev.        | 116         | 115            | 120            |                | 206            | 26 792       | 556 352            | 531 499                 |
| D1H003     | D1H003Q01 ORANGE RIVER AT ALIWAL NORTH                                           | UO_EWR03_I                          | 13km DS                   | UO_IUA 5 | <i>n Samples</i> | 2           | <b>No Data</b> | <b>No Data</b> | <b>No Data</b> | <b>86</b>      | <b>87</b>    | <b>62</b>          | <b>87</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 137         |                |                |                | 376            | 90 360       | 1 637 368          | 1 554 188               |
|            |                                                                                  |                                     |                           |          | 95th percentile  | 140         |                |                |                | 1 463          | 309 519      | 5 686 357          | 5 334 284               |
|            |                                                                                  |                                     |                           |          | 50th percentile  | 137         |                |                |                | 87             | 43 587       | 814 852            | 825 444                 |
|            |                                                                                  |                                     |                           |          | Std. Dev.        | 6           |                |                |                | 983            | 146 354      | 2 726 278          | 2 421 309               |
| D3H013     | D3H013Q01 ROODEPOORT ON ORANGE RIVER                                             | Site added below Gariep Dam for FMP | 27km US                   | UO_IUA 6 | <i>n Samples</i> | 3           | 3              | 3              | <b>No Data</b> | <b>91</b>      | <b>88</b>    | <b>64</b>          | <b>90</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 285         | 240            | 14             |                | 323            | 176 960      | 2 407 771          | 2 244 078               |
|            |                                                                                  |                                     |                           |          | 95th percentile  | 689         | 585            | 30             |                | 1 600          | 489 945      | 9 805 564          | 8 679 068               |
|            |                                                                                  |                                     |                           |          | 50th percentile  | 53          | 52             | 8              |                | 90             | 64 584       | 1 184 895          | 1 157 571               |
|            |                                                                                  |                                     |                           |          | Std. Dev.        | 411         | 350            | 17             |                | 745            | 572 743      | 4 636 307          | 4 048 095               |
| D3H015     | D3H015Q01 SEEKOEI RIVER AT DE EERSTE POORT                                       | UO_EWR05_I                          | 0km                       | UO_IUA 7 | <i>n Samples</i> | 2           | 2              | 2              | <b>No Data</b> | <b>65</b>      | <b>64</b>    | <b>39</b>          | <b>63</b>               |
|            |                                                                                  |                                     |                           |          | Average          | 1           | 1              | 1              |                | 1              | 718          | 12 110             | 9 231                   |

| Station ID | Description                                                    | Associated Selected EWR Site Name | Station ID - EWR Distance | IUA      | Statistic        | Al (kg/day) | Fe (kg/day)    | Mn (kg/day)    | NO3-N (kg/day) | PO4-P (kg/day) | SO4 (kg/day) | TDS (DMS) (kg/day) | TDS (EC-Conv.) (kg/day) |           |            |
|------------|----------------------------------------------------------------|-----------------------------------|---------------------------|----------|------------------|-------------|----------------|----------------|----------------|----------------|--------------|--------------------|-------------------------|-----------|------------|
|            |                                                                |                                   |                           |          | 95th percentile  | 1           | 1              | 1              |                | 2              | 3 389        | 47 701             | 45 560                  |           |            |
|            |                                                                |                                   |                           |          | 50th percentile  | 1           | 1              | 1              |                | 0              | 37           | 415                | 458                     |           |            |
|            |                                                                |                                   |                           |          | Std. Dev.        | 0           | 1              | 1              |                | 1              | 1 898        | 29 291             | 24 013                  |           |            |
| D3H012     | D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003) | EWR01 - Hopetown                  | 110km US                  | UO_IUA 8 | <i>n Samples</i> | 1           | <b>No Data</b> | <b>No Data</b> | <b>No Data</b> |                | <b>61</b>    | <b>61</b>          | <b>36</b>               | <b>62</b> |            |
|            |                                                                |                                   |                           |          | Average          | 173         |                |                |                |                | 324          | 69 229             | 1 247 962               | 1 193 758 |            |
|            |                                                                |                                   |                           |          | 95th percentile  | 173         |                |                |                |                | 2 246        | 111 822            | 2 227 768               | 2 100 720 |            |
|            |                                                                |                                   |                           |          | 50th percentile  | 173         |                |                |                |                | 73           | 61 510             | 1 153 191               | 1 066 106 |            |
|            |                                                                |                                   |                           |          | Std. Dev.        |             |                |                |                |                | 734          | 48 999             | 817 371                 | 751 407   |            |
| D3H008     | D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER                        | UO_EWR10_I                        | 2km US                    | UO_IUA 8 | <i>n Samples</i> | 16          | 16             | 16             | 2              | <b>126</b>     | <b>125</b>   | <b>83</b>          | <b>128</b>              |           |            |
|            |                                                                |                                   |                           |          | Average          | 548         | 657            | 22             | 2 855          | 173            | 117 694      | 1 335 772          | 1 460 613               |           |            |
|            |                                                                |                                   |                           |          | 95th percentile  | 2 392       | 2 521          | 54             | 4 027          | 657            | 248 238      | 2 446 650          | 3 460 473               |           |            |
|            |                                                                |                                   |                           |          | 50th percentile  | 49          | 192            | 12             | 2 855          | 65             | 78 476       | 1 164 060          | 1 163 653               |           |            |
|            |                                                                |                                   |                           |          | Std. Dev.        | 1 670       | 1 565          | 17             | 1 841          | 403            | 190 425      | 658 956            | 997 902                 |           |            |
| C5H022     | C5H022Q01 KGABANYANE RIVER AT BEDFORD UP STREAM GROOTHOEK D    | None                              | -                         | UO_IUA 9 | <i>n Samples</i> |             | <b>No Data</b> | <b>No Data</b> | <b>No Data</b> | <b>No Data</b> | <b>64</b>    | <b>63</b>          | <b>46</b>               | <b>63</b> |            |
|            |                                                                |                                   |                           |          | Average          |             |                |                |                |                | 0            | 6                  | 217                     | 203       |            |
|            |                                                                |                                   |                           |          | 95th percentile  |             |                |                |                |                | 0            | 23                 | 719                     | 679       |            |
|            |                                                                |                                   |                           |          | 50th percentile  |             |                |                |                |                | 0            | 2                  | 50                      | 102       |            |
|            |                                                                |                                   |                           |          | Std. Dev.        |             |                |                |                |                | 1            | 15                 | 605                     | 522       |            |
| C5H056     | C5H056 DIEPWATER 227 - ON MODDERRIVIER                         | None                              | -                         | UO_IUA 9 | <i>n Samples</i> | 28          | <b>No Data</b> | <b>No Data</b> |                |                | 25           | <b>108</b>         | <b>106</b>              | <b>56</b> | <b>107</b> |
|            |                                                                |                                   |                           |          | Average          | 73          |                |                |                |                | 77           | 26                 | 3 053                   | 16 849    | 21 850     |
|            |                                                                |                                   |                           |          | 95th percentile  | 340         |                |                |                |                | 270          | 97                 | 7 352                   | 33 079    | 56 727     |
|            |                                                                |                                   |                           |          | 50th percentile  | 7           |                |                |                |                | 37           | 2                  | 1 179                   | 15 221    | 15 428     |
|            |                                                                |                                   |                           |          | Std. Dev.        | 155         |                |                |                |                | 91           | 70                 | 11 280                  | 18 738    | 29 362     |
| C5H003     | C5H003Q01 AT LIKATLONG / SANNASPOS ON MODDER RIVER             | UO_EWR07_I                        | 0km                       | UO_IUA 9 | <i>n Samples</i> | <b>33</b>   | <b>33</b>      | <b>33</b>      | <b>30</b>      | <b>111</b>     | <b>109</b>   | <b>52</b>          | <b>109</b>              |           |            |
|            |                                                                |                                   |                           |          | Average          | 240         | 82             | 4              | 114            | 61             | 2 457        | 41 001             | 31 964                  |           |            |
|            |                                                                |                                   |                           |          | 95th percentile  | 453         | 265            | 20             | 387            | 208            | 9 122        | 130 317            | 127 904                 |           |            |
|            |                                                                |                                   |                           |          | 50th percentile  | 3           | 2              | 1              | 40             | 12             | 885          | 10 826             | 9 639                   |           |            |
|            |                                                                |                                   |                           |          | Std. Dev.        | 1 135       | 321            | 8              | 243            | 178            | 5 778        | 96 764             | 79 832                  |           |            |
| C5H007     | C5H007Q01 AT SHANNON VALLEY ON RENOSTERSPRUIT                  | None                              | -                         | UO_IUA 9 | <i>n Samples</i> | 4           | 4              | 4              | <b>No Data</b> | <b>89</b>      | <b>88</b>    | <b>57</b>          | <b>89</b>               |           |            |
|            |                                                                |                                   |                           |          | Average          | 1           | 1              | 1              |                | 64             | 1 470        | 17 366             | 14 982                  |           |            |
|            |                                                                |                                   |                           |          | 95th percentile  | 1           | 1              | 1              |                | 143            | 3 812        | 41 794             | 30 251                  |           |            |
|            |                                                                |                                   |                           |          | 50th percentile  | 1           | 1              | 1              |                | 54             | 933          | 10 609             | 10 094                  |           |            |
|            |                                                                |                                   |                           |          | Std. Dev.        | 0           | 0              | 0              |                | 47             | 1 957        | 25 519             | 21 035                  |           |            |
| C5H054     | C5H054Q01 AT BISHOPS GLEN ON RENOSTERSPRUIT                    | None                              | -                         | UO_IUA 9 | <i>n Samples</i> | 2           | 2              | 2              | <b>No Data</b> | <b>88</b>      | <b>87</b>    | <b>59</b>          | <b>86</b>               |           |            |
|            |                                                                |                                   |                           |          | Average          | 6           | 2              | 1              |                | 118            | 3 583        | 35 521             | 36 028                  |           |            |
|            |                                                                |                                   |                           |          | 95th percentile  | 12          | 4              | 2              |                | 375            | 11 656       | 117 244            | 112 006                 |           |            |
|            |                                                                |                                   |                           |          | 50th percentile  | 6           | 2              | 1              |                | 86             | 2 977        | 28 379             | 30 510                  |           |            |
|            |                                                                |                                   |                           |          | Std. Dev.        | 8           | 3              | 1              |                | 117            | 3 803        | 40 718             | 36 870                  |           |            |

| Station ID | Description                                                                                         | Associated Selected EWR Site Name | Station ID - EWR Distance | IUA       | Statistic        | Al (kg/day) | Fe (kg/day)    | Mn (kg/day)    | NO3-N (kg/day) | PO4-P (kg/day) | SO4 (kg/day) | TDS (DMS) (kg/day) | TDS (EC-Conv.) (kg/day) |           |
|------------|-----------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------|-----------|------------------|-------------|----------------|----------------|----------------|----------------|--------------|--------------------|-------------------------|-----------|
| C5H053     | C5H053Q01 CYPRESS 89 - AT GLEN ON MODDER RIVER                                                      | None                              | -                         | UO_IUA 9  | <i>n Samples</i> | 26          | <b>No Data</b> | <b>No Data</b> | 26             | <b>111</b>     | <b>109</b>   | <b>62</b>          | <b>109</b>              |           |
|            |                                                                                                     |                                   |                           |           | Average          | 135         |                |                | 911            | 237            | 9 338        | 149 115            | 107 447                 |           |
|            |                                                                                                     |                                   |                           |           | 95th percentile  | 624         |                |                | 2 593          | 752            | 31 070       | 538 457            | 430 918                 |           |
|            |                                                                                                     |                                   |                           |           | 50th percentile  | 11          |                |                | 911            | 150            | 6 022        | 65 321             | 59 915                  |           |
|            |                                                                                                     |                                   |                           |           | Std. Dev.        | 343         |                |                | 858            | 325            | 13 391       | 235 752            | 184 341                 |           |
| C5H039     | C5H039Q01 KRUGERSDRIFT DAM ON MODDER RIVER: DOWNSTREAM WEIR                                         | None                              | -                         | UO_IUA 10 | <i>n Samples</i> | 1           | <b>No Data</b> | <b>No Data</b> | <b>No Data</b> | <b>107</b>     | <b>106</b>   | <b>69</b>          | <b>106</b>              |           |
|            |                                                                                                     |                                   |                           |           | Average          | 35          |                |                |                | 35             | 7 864        | 94 914             | 87 099                  |           |
|            |                                                                                                     |                                   |                           |           | 95th percentile  | 35          |                |                |                | 126            | 51 592       | 680 584            | 665 857                 |           |
|            |                                                                                                     |                                   |                           |           | 50th percentile  | 35          |                |                |                | 0              | 98           | 2 384              | 1 347                   |           |
|            |                                                                                                     |                                   |                           |           | Std. Dev.        |             |                |                |                | 156            | 22 828       | 243 828            | 224 941                 |           |
| C5H035     | C5H035Q01 DOORNS 131 - TWEERIVIER 129 - @ MODDERRIVIER DOWNSTREAM NICO SMITH BRIDGE ON MODDER RIVER | None                              | -                         | UO_IUA 10 | <i>n Samples</i> | <b>34</b>   | <b>34</b>      | <b>34</b>      | <b>30</b>      | <b>43</b>      | <b>43</b>    | 9                  | <b>42</b>               |           |
|            |                                                                                                     |                                   |                           |           | Average          | 5           | 4              | 2              | 49             | 26             | 3 436        | 6 699              | 45 368                  |           |
|            |                                                                                                     |                                   |                           |           | 95th percentile  | 33          | 21             | 5              | 190            | 110            | 14 615       | 30 030             | 232 561                 |           |
|            |                                                                                                     |                                   |                           |           | 50th percentile  | 0           | 0              | 0              | 1              | 0              | 57           | 176                | 363                     |           |
|            |                                                                                                     |                                   |                           |           | Std. Dev.        | 11          | 11             | 10             | 196            | 84             | 11 147       | 13 150             | 161 353                 |           |
| C5H012     | C5H012Q01 RIET RIVER AT KROMDRAAI/RIETWATER                                                         | UO_EWR06_I                        | 58km US                   | UO_IUA 10 | <i>n Samples</i> | 3           | 3              | 3              | 1              | <b>52</b>      | <b>50</b>    | <b>31</b>          | <b>50</b>               |           |
|            |                                                                                                     |                                   |                           |           | Average          | 2           | 6              | 2              | 13             | 9              | 2 005        | 39 444             | 31 693                  |           |
|            |                                                                                                     |                                   |                           |           | 95th percentile  | 3           | 8              | 3              | 13             | 52             | 8 355        | 145 804            | 123 800                 |           |
|            |                                                                                                     |                                   |                           |           | 50th percentile  | 3           | 6              | 3              | 13             | 0              | 277          | 0                  | 2 857                   |           |
|            |                                                                                                     |                                   |                           |           | Std. Dev.        | 1           | 2              | 2              |                | 22             | 3 911        | 88 671             | 72 257                  |           |
| C5H014     | C5H014 RICHIE KLIPDRIFT 109 - @ U/S SIDE OF WEIR ON RIET RIVER                                      | UO_EWR09_I                        | 12km US                   | UO_IUA 10 | <i>n Samples</i> | <b>32</b>   | <b>32</b>      | <b>32</b>      | 29             | <b>46</b>      | <b>46</b>    | 13                 | <b>45</b>               |           |
|            |                                                                                                     |                                   |                           |           | Average          | 40          | 28             | 18             | 249            | 131            | 22 383       | 79 007             | 139 829                 |           |
|            |                                                                                                     |                                   |                           |           | 95th percentile  | 133         | 92             | 38             | 1 151          | 390            | 59 882       | 185 830            | 412 124                 |           |
|            |                                                                                                     |                                   |                           |           | 50th percentile  | 23          | 16             | 13             | 84             | 89             | 15 923       | 56 121             | 99 197                  |           |
|            |                                                                                                     |                                   |                           |           | Std. Dev.        | 47          | 30             | 20             | 525            | 155            | 24 183       | 63 619             | 156 164                 |           |
| C5H048     | C5H048Q01 AT ZOUTPANSDRIFT ON RIET RIVER                                                            | UO_EWR09_I                        | 73km DS                   | UO_IUA 10 | <i>n Samples</i> | <b>40</b>   | <b>40</b>      | <b>40</b>      | 26             | <b>78</b>      | <b>78</b>    | <b>32</b>          | <b>78</b>               |           |
|            |                                                                                                     |                                   |                           |           | Average          | 26          | 5              | 4              | 44             | 28             | 13 965       | 57 942             | 76 292                  |           |
|            |                                                                                                     |                                   |                           |           | 95th percentile  | 52          | 23             | 19             | 169            | 90             | 40 373       | 186 368            | 242 746                 |           |
|            |                                                                                                     |                                   |                           |           | 50th percentile  | 2           | 1              | 1              | 16             | 1              | 9 209        | 31 224             | 48 345                  |           |
|            |                                                                                                     |                                   |                           |           | Std. Dev.        | 111         | 9              | 7              | 106            | 94             | 15 226       | 64 940             | 91 219                  |           |
| C9H024     | Vaal River @ Schmidtsdrif                                                                           | None                              | -                         | VAAL      | <i>n Samples</i> |             |                |                |                | <b>39</b>      | <b>38</b>    | 20                 | <b>38</b>               |           |
|            |                                                                                                     |                                   |                           |           | Average          |             |                |                |                |                | 372          | 263 484            | 647 206                 | 1 400 454 |
|            |                                                                                                     |                                   |                           |           | 95th percentile  |             |                |                |                |                | 2 595        | 785 182            | 988 778                 | 6 286 767 |
|            |                                                                                                     |                                   |                           |           | 50th percentile  |             |                |                |                |                | 8            | 91 250             | 444 061                 | 382 486   |
|            |                                                                                                     |                                   |                           |           | Std. Dev.        |             |                |                |                |                | 1 185        | 711 338            | 952 956                 | 3 534 729 |
| C9H025     | C9H025Q01 ST CLAIR 148 DOUGLAS - ON ORANGE-VAAL TRANSFER CANAL                                      | None                              | -                         | VAAL      | <i>n Samples</i> | 2           | 2              | 2              | 2              | <b>137</b>     | <b>135</b>   | <b>89</b>          | <b>137</b>              |           |
|            |                                                                                                     |                                   |                           |           | Average          | 3           | 6              | 0              | 151            | 5              | 3 391        | 50 462             | 46 953                  |           |
|            |                                                                                                     |                                   |                           |           | 95th percentile  | 5           | 9              | 0              | 157            | 12             | 7 966        | 118 337            | 93 416                  |           |

| Station ID | Description | Associated Selected EWR Site Name | Station ID - EWR Distance | IUA | Statistic       | Al (kg/day) | Fe (kg/day) | Mn (kg/day) | NO3-N (kg/day) | PO4-P (kg/day) | SO4 (kg/day) | TDS (DMS) (kg/day) | TDS (EC-Conv.) (kg/day) |
|------------|-------------|-----------------------------------|---------------------------|-----|-----------------|-------------|-------------|-------------|----------------|----------------|--------------|--------------------|-------------------------|
|            |             |                                   |                           |     | 50th percentile | 3           | 6           | 0           | 151            | 2              | 2 861        | 39 933             | 38 828                  |
|            |             |                                   |                           |     | Std. Dev.       | 3           | 6           | 0           | 9              | 16             | 2 646        | 32 449             | 28 925                  |

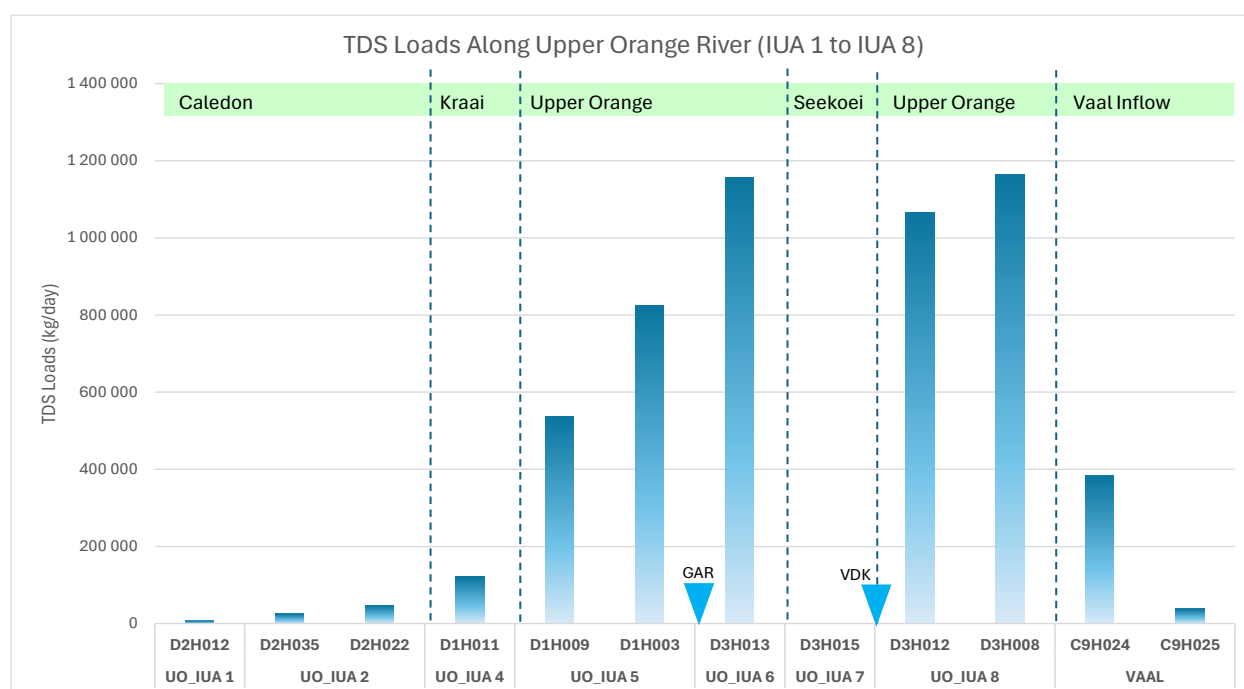
***Bold italics sample numbers*** – Sufficient data to deduce long term statistics and thus usable for regulatory planning

## 8.2.2 Spatial Distribution of Pollutant Loads

### Salts - Total Dissolved Solids (TDS) (Upper Orange)

The longitudinal contribution of TDS loads within the Caledon and Upper Orange River catchments is characterized by an exponential increase from IUA1 to IUA5 with Gariep Dam (denoted GAR in Figure 25) acting as a sink followed by a similar trend to Vanderkloof Dam within IUA6 and IUA8. IUA 7. Seekoei River is a dry catchment so the contribution to load is negligible.

With a large catchment area encompassing the majority of Lesotho, it is not surprising that site D1H009 (inflow into IUA5) exhibits high daily TDS loads of approximately 540 000 kg/day, which increases to about 830 000 kg/day due to the contribution of load from IUA4 of 120 000 kg/day. Owing to return flows from extensive irrigation and agricultural practices captured by Gariep Dam, releasing these flows tends to introduce elevated loads downstream of Gariep Dam of approximately 1 160 000 kg/day at D3H013 for downstream supply and irrigation. Similarly, it is expected that Vanderkloof Dam, following various water use activities and irrigation would act as a sink, but due to a comparably less area of cultivation compared to upstream of Gariep Dam, would release relatively lower TDS loads, as observed at D3H012, of approximately 1 070 000 kg/day. These loads increase marginally to 1 160 000 kg/day when moving further downstream to Marksdrift weir (D3H008). IUA7 contributes a negligible amount of TDS load of 458 kg/day. Being a catchment with relatively low flow, and cultivation practices occurring generally in the upper reaches of the catchment, this is expected.



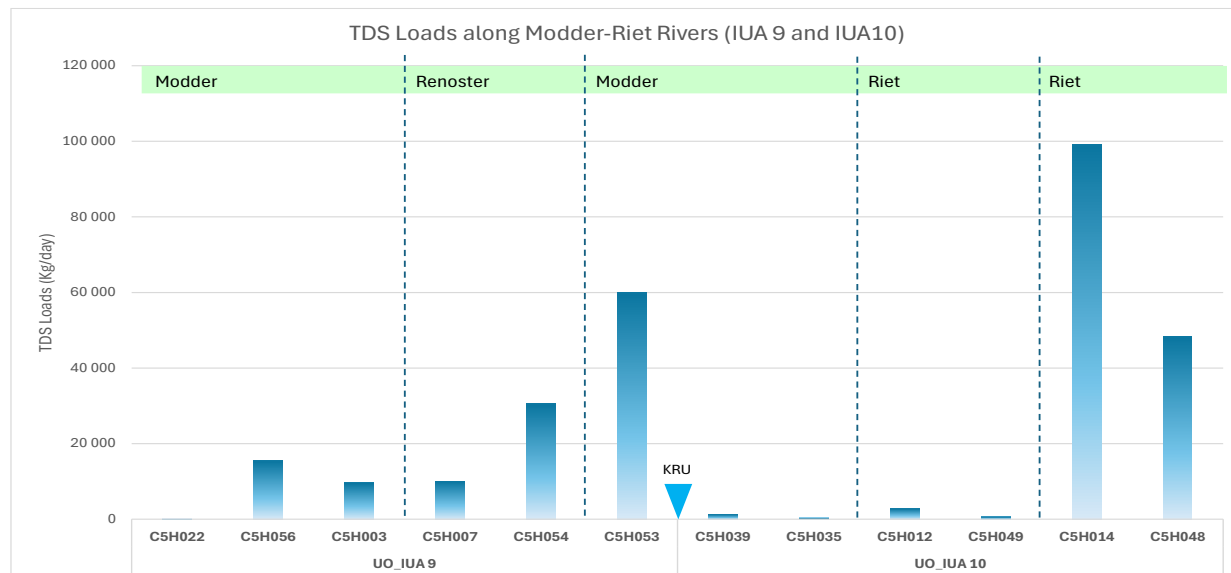
**Figure 25: Longitudinal distribution of median TDS loads along the Upper Orange River from upstream to downstream**

The longitudinal contribution of TDS loads within the Modder-Riet River system is characterised by extensive loads emanating from the Renosterspruit and Klein Modder River

in IUA9 and an inferred increase in TDS load from the Riet River upstream of the confluence with Modder River due to a lack of data.

Although both sites lie in the upper reaches of the catchment, the relatively high TDS load at C5H056 (15 400 kg/day) when compared to C5H022 (100 kg/day) is primarily due to the Caledon-Modder (Novo) Transfer Scheme which transfers water from Knellpoort Dam to Rustfontein Dam in the upper reaches of the Modder River basin to supply the growing demand in the Bloemfontein area. Based on the slight reduction in loads observed at C5H003, some of this load (about 5 800 kg/day) is supplied to Botshabelo and Thaba Nchu. TDS is then further added to the system from the urban areas of Bloemfontein due to urban runoff, cultivation practices and WWTW discharges to about 30 000 kg/day observed at C5H054 along the Renosterspruit. This load is then doubled because of the combination with the Modder TDS load from upstream due to subsistence farming downstream of C5H003.

It is likely that water abstractions along the Modder River for irrigation and domestic purposes account for the observed reduction of TDS loads observed at C5H039 (1 350 kg/day) from Krugersdrift Dam. The TDS loads are further reduced along the Modder River as observed at C5H035 (about 360 kg/day) due to releases which cascade down via a series of weirs which allow abstraction of water for irrigation. Although the data does not explicitly show this, there appears to be a high amount of TDS load inflow from the Riet River adding approximately 100 000 kg/day onto the system as observed at station C5H014. The latter may be due to irrigation return flows, the WWTW discharges throughout the catchment, and the presence of mining activities such as the diamond mining at Jagersfontein.



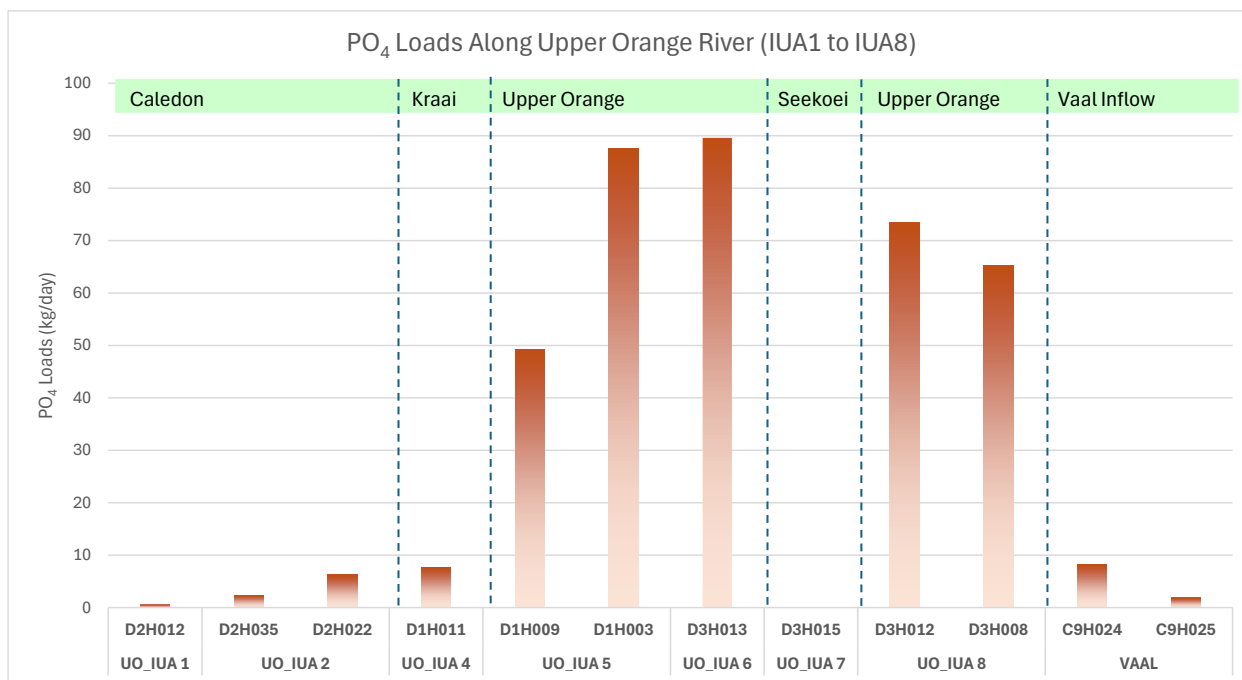
**Figure 26: Longitudinal distribution of median TDS loads along the Modder and Riet Rivers from upstream to downstream**

**Nutrients – Orthophosphate (Upper Orange)**

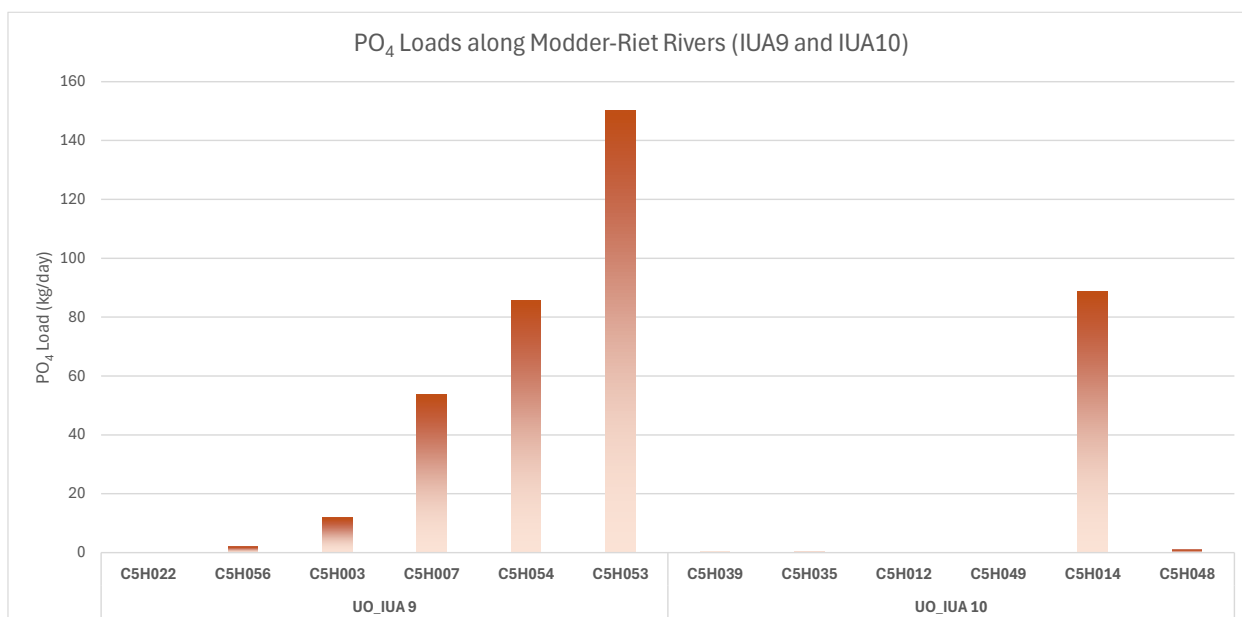
Orthophosphate (PO<sub>4</sub>) was used selected for the evaluation of relative nutrient contribution and loading into the Orange River system as it is an indicator for more long-term nutrient enrichment and eutrophication. As a result, PO<sub>4</sub> was used as a good indicator for wastewater

treatment works impacts within all IUAs. It is important to note that  $PO_4$  as an indicator is only useful as a local indicator as it is unstable in rivers over time and space. High levels and the order of magnitude can point to a long-term nutrient pollution problem making it crucial for catchment planning.

The distribution of  $PO_4$  within the Upper Orange River is shown in Figure 27.



**Figure 27: Longitudinal distribution of orthophosphate loads along the Upper Orange River from upstream to downstream (IUA1 to IUA8)**



**Figure 28: Longitudinal distribution of Orthophosphate loads along Modder and Riet Rivers from upstream to downstream (IUA9 to IUA10)**

### 8.2.3 Key Pollution Sources and Contributions

As part of the Status Quo assessment, Report number RDM/WMA13/00/CON/CLA/0224, the relevant DWS Green Drop (GD) Reports for the Free State, Eastern Cape and Northern Cape (DWS, 2022) were reviewed to obtain an assessment of the status of wastewater services in the Eastern Cape, Northern Cape and Free State Provinces which fall within the Upper Orange River catchment. The Green Drop audit scores indicate poor performance by almost all wastewater treatment works in the catchment, with low Green Drop scores and high cumulative risk rating (CRR).

The CRR relates to a rating of the hydraulic design capacity of the treatment plant in ML/day, operational flow as percentage (%) of the installed design capacity, the number of non-compliant effluent quality parameters at point of discharge to receiving water body and number of technical skills gaps (supervision, operation, maintenance) in terms of Reg 2834 and Draft Reg 813, and is calculated as follows:

Risk is calculated for each system using a formula:  $CRR = (A \times B) + C + D$ , where:

*A = Hydraulic design capacity of the treatment plant in megalitres per day (ML/d)*

*B = Operational flow as % of the installed design capacity*

*C = Number of non-compliant effluent quality parameters at point of discharge to receiving water body*

*D = Number of technical skills gaps (supervision, operation, maintenance) in terms of Reg. 2834 & Draft Reg. 813.*

**Table 49: Scenarios for increasing water quality based on current land use and associated impacts in the Upper Orange River system**

| IUA | Station ID | Description                                                                    | Associated Selected EWR Site Name | Station ID - EWR Distance | Land Use Description and Impacts                                                                                                                                                                                                                                                                                                                                                                           | Scenarios for improving water quality                                                                                                                                                                                        |
|-----|------------|--------------------------------------------------------------------------------|-----------------------------------|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | D2H012     | D2H012 CALEDONSPORT 190 THE POPLARS 199 AT THE POPLARS ON LITTLE CALEDON RIVER | UO_EWR01_R                        | 41km DS                   | <ul style="list-style-type: none"> <li>• Town of Clarens with the Clarens wastewater treatment works (WWTW) and Water Supply System (WSS) (901kL/d) with abstractions from the small Caledon and tunnel</li> <li>• Agriculture in lower catchment of the quaternary catchment; small game farms; may be limited abstraction from the Caledon for subsistence agriculture;</li> </ul>                       | The site experiences relatively low TDS with a low Cumulative Risk Rating (CRR). Maintenance or improvement of the GD score is recommended                                                                                   |
| 2   | D2H035     | D2H035Q01 CALEDON RIVER AT FICKSBURG/ FICKSBURG BRIDGE                         | UO_EWR01_I                        | 21km US                   | <ul style="list-style-type: none"> <li>• Extensive agriculture including dryland cultivation and irrigation (crops and livestock farming)</li> <li>• Tourism</li> <li>• Towns and associated WWTWs and WTWs                             <ul style="list-style-type: none"> <li>o Ficksburg</li> <li>o Fouriesburg</li> <li>o Clocolan</li> <li>o Ladybrand, and</li> <li>o Hobhouse</li> </ul> </li> </ul> | There is an order of magnitude increase in TDS load at Ficksburg (D2H35) which doubles at the IUA outlet (D2H022) due to irrigation return flows.                                                                            |
|     | D2H022     | D2H022Q01 CALEDON RIVER AT WILGEDRAAI/HOB HOUSE                                | None                              | -                         |                                                                                                                                                                                                                                                                                                                                                                                                            | Two-fold increase in PO <sub>4</sub> between Ficksburg and IUA outlet. All WWTW have High CRR, and nutrient load can be improved by addressing low GD scores such as improving treatment efficiencies and/or upgrading WWTW. |

| IUA | Station ID | Description                                                                                        | Associated Selected EWR Site Name | Station ID - EWR Distance | Land Use Description and Impacts                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Scenarios for improving water quality                                                                                                                               |
|-----|------------|----------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3   | D2H033     | D2H033<br>WELBEDACHT 285<br>- @ GAUGING<br>WEIR ON<br>CALEDON RIVER<br>D/S OF<br>WELBEDACHTDA<br>M | UO_EWR04_I                        | 66km US                   | <ul style="list-style-type: none"> <li>• Main towns and associated WWTWs and WTWs                             <ul style="list-style-type: none"> <li>o Vanstadensrus</li> <li>o Wepener on Sandveld River, and</li> <li>o Smithfield on Skulpspruit (tributary)</li> </ul> </li> <li>• Caledon Nature Reserve around the Welbedacht Dam and Tussen-die-Riviere Nature Reserve in the lower reaches of the Caledon River</li> <li>• Irrigated agriculture dominates along the main river and tributaries.</li> <li>• There are also transfers from Caledon River, e.g. to Modder from the Welbedacht Dam, through Rietspruit.</li> <li>• Welbedacht Water Treatment Works</li> </ul> | Salt and Nutrient load inference to loads is low due to limited data. However, there is a known impact of suspended solids and sediment build-up at Welbedacht Dam. |
| 4   | D1H011     | D1H011Q01 KRAAI<br>RIVER AT<br>ROODEWAL                                                            | UO_EWR08_I                        | 41km US                   | <ul style="list-style-type: none"> <li>• Scattered rural settlements</li> <li>• Cultivation (irrigated and dry land crops) and predominantly subsistence farming</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | WWTW have moderate to high CRR and nutrient load can be improved by addressing low GD scores such as improving treatment efficiencies and/or upgrading WWTW.        |
| 5   | D1H009     | D1H009Q01<br>ORANGE RIVER AT<br>ORANJEDRAAI                                                        | None                              | -                         | <ul style="list-style-type: none"> <li>• Extensive subsistence agriculture (cultivation with limited irrigation, and</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Inflow TDS and PO4 daily loads from Lesotho form the basis of improvement into the IUA and are                                                                      |

| IUA | Station ID | Description                                   | Associated Selected EWR Site Name   | Station ID - EWR Distance | Land Use Description and Impacts                                                                                                                                                                                                                                                                                                                                                                                                                 | Scenarios for improving water quality                                                                                                                                                                                             |
|-----|------------|-----------------------------------------------|-------------------------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     | D1H003     | D1H003Q01<br>ORANGE RIVER AT ALIWAL NORTH     | UO_EWR03_I                          | 13km DS                   | extensive livestock grazing) in the upper portions<br><ul style="list-style-type: none"> <li>• Irrigation along the river in the middle to lower portions</li> <li>• Sand mining (on main stem)</li> <li>• Towns and associated WWTWs and WTWs <ul style="list-style-type: none"> <li>o Zastron</li> <li>o Maletswai (Aliwal North)</li> <li>o Burgersdorp</li> <li>o Witkop</li> <li>o Stormberg, and</li> <li>o Molteno</li> </ul> </li> </ul> | relatively elevated. Nutrient loads increase within the IUA and reduction                                                                                                                                                         |
| 6   | D3H013     | D3H013Q01<br>ROODEPOORT ON ORANGE RIVER       | Site added below Gariep Dam for FMP | 27km US                   | <ul style="list-style-type: none"> <li>• Gariep Dam (Orange-Fish transfer and hydropower)</li> <li>• Gariep Nature Reserve</li> <li>• Doornkloof Provincial Nature Reserve</li> <li>• Livestock grazing</li> <li>• Irrigation below the dam</li> <li>• Village of Oviston with WWTW and WTW</li> </ul>                                                                                                                                           | Gariep Dam acts as a pollution sink for both TDS and PO <sub>4</sub> , thus TDS is released predominantly from the dam. However, the nutrient pollution can be addressed by lining oxidation ponds at Gariep Dam and Norvalspont. |
| 7   | D3H015     | D3H015Q01<br>SEEKOEI RIVER AT DE EERSTE POORT | UO_EWR05_I                          | 0km                       | <ul style="list-style-type: none"> <li>• Main activity is livestock farming mainly with sheep for wool and meat.</li> <li>• Rural and livestock agriculture</li> <li>• Main towns of Hanover and Noupport and associated WWTWs and WTWs</li> </ul>                                                                                                                                                                                               | Although the WWTW (Hanover and Noupport) in this IUA have low GD score and high CRR, their contribution to the overall system load is low.<br><br>Plans should be geared towards improving plant efficiency,                      |

| IUA | Station ID | Description                                                    | Associated Selected EWR Site Name | Station ID - EWR Distance | Land Use Description and Impacts                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Scenarios for improving water quality                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----|------------|----------------------------------------------------------------|-----------------------------------|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                                |                                   |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | especially Hanover as it is the larger of the two WWTW.                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 8   | D3H012     | D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003) | EWR01 Hopetown                    | - 110km US                | <ul style="list-style-type: none"> <li>• Vanderkloof Dam (transfer to Riet River catchment and hydropower)</li> <li>• Extensive Irrigation downstream and at the outlet of the IUA</li> <li>• Hopetown and associated WWTW and WTW</li> </ul>                                                                                                                                                                                                                                                                                      | <p>There data shows a net increase in TDS loads between D4H012 and the IUA outlet (D3H008) and a slight reduction in nutrient loads (PO<sub>4</sub>), owing to the extensive irrigation return flows up- and downstream of Hopetown and relatively small WWTWs.</p> <p>Nonetheless, plans should be geared towards improving WWTW plant efficiency.</p>                                                                                                                                         |
|     | D3H008     | D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER                        | UO_EWR10_I                        | 2km US                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 9   | C5H022     | C5H022Q01 KGABANYANE RIVER AT BEDFORD UP STREAM GROOTHOEK D    | None                              | -                         | <ul style="list-style-type: none"> <li>• Mangaung Metropolitan Municipality - urban Area (Towns)</li> <li>• Mangaung Metropolitan Municipality WWTWs                             <ul style="list-style-type: none"> <li>o Bloemspruit</li> <li>o Bainsvlei</li> <li>o Welvaart</li> <li>o Northern Works</li> <li>o Bloemindustria</li> <li>o Suid-oostelike</li> <li>o Vanstadensrus, and</li> <li>o Botshabelo</li> </ul> </li> <li>• Mangaung Metropolitan Municipality is supplied with water from a bulk supplier,</li> </ul> | <p>The major concern based on the data is extensive nutrient load contribution from the Klein Modder (Thaba Nchu and Botshabelo) and Renosterspruit and Bloemspruit (Bloemfontein). WWTW impacting these systems have moderate to low GD scores with moderate to high CRR and unless treatment efficiencies are addressed, PO<sub>4</sub> loads (over 150 kg/day) at C5H053 will continue to increase. NO<sub>3</sub> loads are comparably elevated.</p> <p>TDS loads are marginal upstream</p> |
|     | C5H056     | C5H056 DIEPWATER 227 - ON MODDERRIVIER                         | None                              | -                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|     | C5H003     | C5H003Q01 AT LIKATLONG / SANNASPOS ON MODDER RIVER             | UO_EWR07_I                        | 0km                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

| IUA | Station ID | Description                                                                                         | Associated Selected EWR Site Name | Station ID - EWR Distance | Land Use Description and Impacts                                                                                                                                                                                                                                         | Scenarios for improving water quality                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----|------------|-----------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     | C5H007     | C5H007Q01 AT SHANNON VALLEY ON RENOSTERSPRUIT                                                       | None                              | -                         | Bloem Water, and<br>• Vanstadensrus, and Soutpan (Krugersdrift) WTWs<br>• Agricultural areas (dryland, and some irrigation, in the lower portions of the Modder catchment around Krugersdrift Dam<br>• Extensive subsistence agriculture in the upper reaches of the IUA | of C5H053 on Modder along Renoster and increase about four-fold at C5H053 towards the IUA outlet implying a significant addition of loads from Modder and associated tributaries due to subsistence agriculture.                                                                                                                                                                                                                          |
|     | C5H054     | C5H054Q01 AT BISHOPS GLEN ON RENOSTERSPRUIT                                                         | None                              | -                         |                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|     | C5H053     | C5H053Q01 CYPRESS 89 - AT GLEN ON MODDER RIVER                                                      | None                              | -                         |                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 10  | C5H039     | C5H039Q01 KRUGERSDRIFT DAM ON MODDER RIVER: DOWNSTREAM WEIR                                         | None                              | -                         | Irrigation agriculture along the Riet River and diamond mine at Koffiefontein                                                                                                                                                                                            | The results show a TDS load contribution from IUA9 recovery along the Modder River from C5H039 (downstream of Krugersdrift Dam) to the confluence with the Riet (C5H035). This is likely owing to a well-established riparian zone and farming practices along this 152km river reach. This phenomenon is echoed by the observation of very low nutrient load contribution and the associated lack of WWTWs besides Petrusburg. This WWTW |
|     | C5H035     | C5H035Q01 DOORNS 131 - TWEERIVIER 129 - @ MODDERRIVIER DOWNSTREAM NICO SMITH BRIDGE ON MODDER RIVER | None                              | -                         |                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                           |

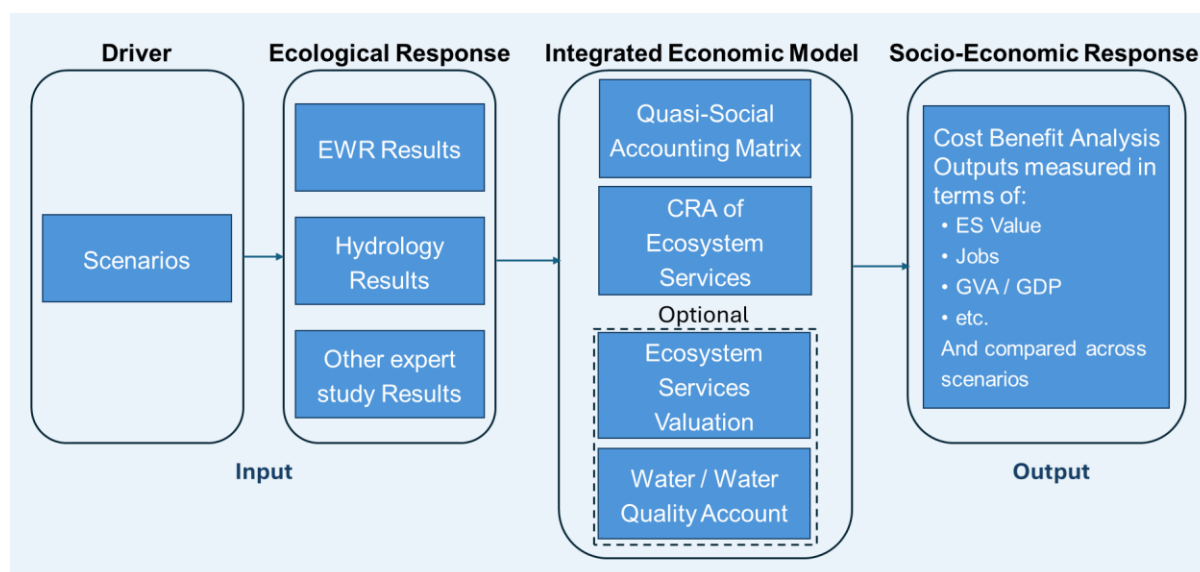
| IUA | Station ID | Description                                                    | Associated Selected EWR Site Name | Station ID - EWR Distance | Land Use Description and Impacts | Scenarios for improving water quality                                                                                                                                                                                                                                                                                                                                                               |
|-----|------------|----------------------------------------------------------------|-----------------------------------|---------------------------|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     | C5H012     | C5H012Q01 RIET RIVER AT KROMDRAAI/RIET WATER                   | UO_EWR06_I                        | 58km US                   |                                  | is also well managed with a low CRR of 47 and moderate GD score of 61, among the highest within the Upper Orange.                                                                                                                                                                                                                                                                                   |
|     | C5H014     | C5H014 RICHIE KLIPDRIFT 109 - @ U/S SIDE OF WEIR ON RIET RIVER | UO_EWR09_I                        | 12km US                   |                                  | Continued monitoring and efficient land use practices should be maintained along this river reach.                                                                                                                                                                                                                                                                                                  |
|     | C5H048     | C5H048Q01 AT ZOUTPANSDRIFT ON RIET RIVER                       | UO_EWR09_I                        | 73km DS                   |                                  | The Riet River inflow adds an equivalent load observed at C5H035, resulting in a 95th percentile daily TDS load of over 400 000 kg/day. The Riet River, in contrast, brings additional nutrient loads, which is observed at C5H014 (89 kg/day), likely due to immediate upstream WWTWs (Jacobsdal, Oppermansgronde and Koffiefontein), all of which have low GD scores coupled with very high CRRs. |

Notes: GD: Greed Drop; CRR: Critical Risk Rating; WWTW: Wastewater Treatment Works

## 9 SOCIO-ECONOMIC CONSEQUENCES

### 9.1 Socio-economic approach

The socio-economic approach for assessing the ecological and socio-economic consequences for the identified scenarios was undertaken by conducting a Comparative Ecological Risk Assessment (CERA), an economic analysis and a water quality analysis (only IUAs which had problems, where there was a change in ecological category and for which data was available) to evaluate the socio-economic impact of exogenous changes to the Upper Orange River catchments' economy resulting from the implementation of the water management scenarios. The approach is illustrated in Figure 29 and each analysis approach is set out in detail in the sections that follow.



**Figure 29: Approach to assessing the ecological and socio-economic consequences for the identified scenarios in the Upper Orange River catchment**

### 9.2 Comparative Ecological Risk Assessment (CERA)

The assessment of water resource scenarios provided insights into the impact of the scenarios on the ecological assets and associated ecosystem services towards evaluating trade-offs against varying water resource scenarios. The approach identifies the ecosystem services at risk within each of the IUAs to support informed allocation of water resource management classes per IUA.

The process involves undertaking a Comparative Risk Assessment (CRA) per IUA looking at the likelihood and consequences of impact to beneficiaries. The resulting output is a prioritised list of Ecosystem Services that are spatially aggregated across the WMA.

The CRA process involves defining the following linkages in the chain of causality:

- **Environmental hazard:** The environmental hazard is the environmental stressor which drives change. The hazard is identified as the input which initiates the chain of causality and is determined through the changes initiated through varying scenarios. Examples in this case include decreased surface water flow through over abstraction from rivers.

Note that the environmental hazard would vary between ecological infrastructure and across scenarios.

- **Environmental effect statement:** The environmental effect statement describes the physical impacts that the environmental hazard has on specific ecological infrastructure. In line with the example above, this would describe that decreased surface water flow would modify natural flows processes and restrict primary productivity within the channel and riparian areas.
- **Risk rating of ecosystem services.** The risk to the flow of ecosystem services is assessed in terms of the likelihood and consequences of impact by the identified environmental effect on the specific ecological infrastructure providing the service. The process is further detailed below:

Ecosystem risk is the function of the likelihood and consequence of a scenario to which Ecological Infrastructure (EI) is exposed.

Thus: **Risk = f (likelihood, consequence) of environmental effect on EI.**

For each scenario-EI-ES combination, two questions are asked:

Firstly, 'What is the likelihood that this ecosystem service, provided by the specific ecological infrastructure, will be affected under this scenario? This speaks to impacts that the scenario would have on the ability to provide the ecosystem service.

Secondly, 'What would be the consequences of this scenario in this ecological infrastructure to the delivery of this ecosystem service?' This speaks to the socio-economic consequences and therefore links directly to the relevant beneficiaries within the IUA.

The likelihood of an impact is the change in possibility that a specific scenario will have an impact on the EI and therefore the benefits received. The likelihood rating framework can be seen in Table 50. The consequence of the scenario is the change in the service from the environmental effect of the scenario on the exposed EI. A consequence rating framework can be seen in Table 51. Likelihood and consequence categories are chosen for each ES. It is important that the certainty is recorded to ensure transparency of the level of confidence in categories chosen. Risks are then automatically ranked according to risk levels. A description of each risk is given (Risk Statement) which includes the underlying chain of causality between environmental effect and its consequence to ensure transparency of the ranking process (Table 52).

**Table 50: Qualitative and quantitative classes of likelihood of impacts (environmental effect, or resultant change in the flow of an ecosystem service) of a scenario having an ecological consequence to a service from EI. Adapted from the classification adopted by the IPCC (2007)**

| Likelihood rating | Assessed probability of occurrence | Description                                                           |
|-------------------|------------------------------------|-----------------------------------------------------------------------|
| Almost certain    | > 90%                              | Extremely or very likely, or virtually certain. Is expected to occur. |

| Likelihood rating  | Assessed probability of occurrence | Description                                 |
|--------------------|------------------------------------|---------------------------------------------|
| Likely             | > 66%                              | Will probably occur                         |
| Possible           | > 50%                              | Might occur; more likely than not           |
| Unlikely           | < 50%                              | May occur                                   |
| Very unlikely      | < 10%                              | Could occur                                 |
| Extremely unlikely | < 5%                               | May occur only in exceptional circumstances |

**Table 51: Qualitative measures of consequence to ecosystem services arising from impacts linked to scenarios. Adapted from the classification adopted by the IPCC (2007)**

| Consequence rating | Level of consequence | Environmental effect                                                                                          |
|--------------------|----------------------|---------------------------------------------------------------------------------------------------------------|
| Severe             | 1                    | Substantial permanent loss of environmental service, requiring mitigation or offset.                          |
| Major              | 2                    | Major effect on the EI or service, that will require several years to recover, and substantial mitigation.    |
| Moderate           | 3                    | Serious effect on the EI or service, that will take a few years to recover, but with no or little mitigation. |
| Minor              | 4                    | Discernible effect on the EI or service, but with rapid recovery, not requiring mitigation.                   |
| Insignificant      | 5                    | A negligible effect on the EI or service.                                                                     |

**Table 52: Levels of risk, assessed as the product of likelihood and consequence in the event of an environmental effect on EI. Adapted from the classification adopted by the IPCC (2007)**

| Likelihood Rating  | Consequence Rating |        |          |         |         |
|--------------------|--------------------|--------|----------|---------|---------|
|                    | Insignificant      | Minor  | Moderate | Major   | Severe  |
| Almost certain     | Low                | Medium | High     | Extreme | Extreme |
| Likely             | Low                | Medium | High     | Extreme | Extreme |
| Possible           | Low                | Medium | High     | High    | Extreme |
| Unlikely           | Low                | Low    | Medium   | High    | Extreme |
| Very unlikely      | Low                | Low    | Low      | High    | Extreme |
| Extremely unlikely | Low                | Low    | Low      | Medium  | High    |

The output of the CRA process is an aggregated risk assessment for each of the scenario-EI-ES combinations for each IUA. Not all these combinations are valuable, and the results are used to prioritise the key ecosystem services at risk across the IUAs.

The output is thus a prioritised list of risks, with diagnostic and causal descriptions for each priority risk. High and extreme risks are classed as priority risks. These risks and their relative

weight (High risk = 3, Extreme risk = 4) are summed for each scenario to allow for a comparison of cumulative risks between scenarios. The beneficiaries of the identified ES will be at the greatest risk due to a specific scenario.

### **Hazards identified during the CRA process**

The environmental hazards identified during the CRA process are provided here. While each hazard is specific to ecological infrastructure, hazards may share impacts across different EI and are thus summarised to avoid repetition within the results sections for each IUA.

#### **Hazards:**

**Impacts on water flow:** Alterations in terms of rate and volume of water within the catchments in the study area are driven by various land-use and management activities which include:

- Abstraction of surface water by agriculture, industrial processes and domestic use
- Abstraction of groundwater for domestic use and agricultural use
- Storage of water in dams impacting waterways and wetlands
- Timed releases of water from dams
- Reduced base flows into estuaries resulting in altered hydrological processes due to over abstraction upstream

**Impacts on water quality:** the alterations of water quality within the study area are driven by point source and diffuse sources of inputs and contaminants from various activities including the following:

- Point and diffuse source nutrient contaminants from dysfunctional WWTW, sewerage effluent and livestock agricultural run-off
- Sedimentation and turbidity resulting from improper land use including livestock trampling and overgrazing
- Increased agricultural run-off and return flows particularly from formal irrigation schemes

**Non-flow impacts:** these are those impacts that are not related to water resource flow scenarios. These impacts include land transformation from alien invasive plants and land transformation related to unsustainable land uses, overgrazing, trampling, vegetation removal, sand mining activities (in some IUAs) leading to erosion and sedimentation.

The results of the CRA process and only those services at high or extreme risk are presented in more detail. It is further to be noted that the risk assessment undertaken here was based on expert analysis from specific work sessions conducted with subject specialists and desktop data available and therefore the scale of impact has not been assessed.

### **9.3 Economic Trade-off Analysis**

An Upper Orange River catchment Quasi-Social Accounting Matrix (QSAM) was developed with the aim of quantifying the size of the Upper Orange River catchment economy. The QSAM module was initially developed from the Supply and Use tables published by Statistics South

Africa in June 2024 for the year 2021. The QSAM may be used to evaluate the socio-economic impact of exogenous changes to the Upper Orange River catchment economy.

The macro-economic indicators estimated in the QSAM model for the catchment are Gross Value Added (GVA) and Compensation to Employees as described in Table 53.

**Table 53: Macro-economic indicators estimated in the economic model**

| Indicator                 | Unit           | Description                                                                                            |
|---------------------------|----------------|--------------------------------------------------------------------------------------------------------|
| Gross Value Added (GVA)   | Rand, Millions | Economic productivity metric measuring the contribution of Upper Orange River catchment to the economy |
| Compensation to Employees | Rand, Millions | Component of the Gross Domestic Product (GDP) measuring the change in total salaries paid              |

The methodology followed to build the QSAM for the Upper Orange River catchment is illustrated in Figure 30.

The major economic sectors of the Upper Orange River catchment were identified using the economic data reported by National Treasury for each of the Local Municipalities that lie within the catchment.

The Upper Orange River catchment GVA was determined per sector based on the National Treasury economic data. The Upper Orange catchment Supply and Use tables were developed by proportioning of the National Supply and Use Tables based on the National Treasury published economic data for the municipalities within the catchment area. To do this, an economic table was compiled from the National Treasury data, where the sector categories of were as follows:

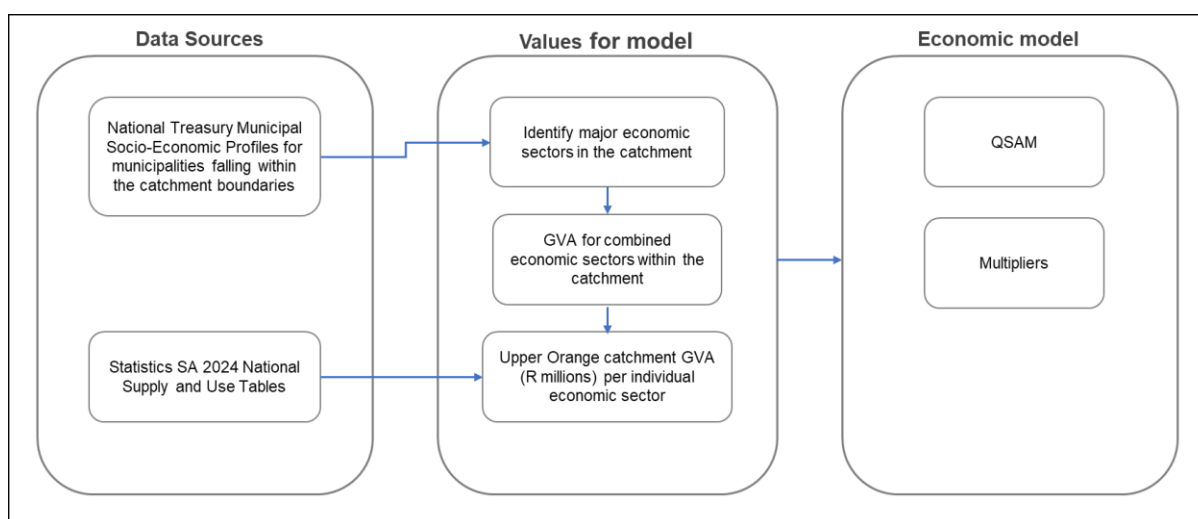
- Agriculture, forestry and fishing
- Mining
- Manufacturing
- Electricity & water
- Construction
- Wholesale & retail trade; catering and accommodation
- Transport & communication
- Financial services
- General government, and
- Community, social and personal services

The National Supply and Use Tables' categories were then summarised to fit these categories above. An example is shown below using Agriculture and Mining sectors:

|                                                                                                                                                                                                                                                                     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Agriculture, forestry and fishing</b>                                                                                                                                                                                                                            |
| Agriculture                                                                                                                                                                                                                                                         |
| Forestry                                                                                                                                                                                                                                                            |
| Fishing                                                                                                                                                                                                                                                             |
| <b>Mining</b>                                                                                                                                                                                                                                                       |
| Mining of coal and lignite                                                                                                                                                                                                                                          |
| Extraction of crude, petroleum and natural gas                                                                                                                                                                                                                      |
| Mining of gold and uranium ore                                                                                                                                                                                                                                      |
| Iron ore mining; chrome mining; copper mining; manganese mining; platinum mining; other metal ore mining                                                                                                                                                            |
| Dimension stone; Limestone and lime works; Other stone quarrying; Diamond mining; Chemical and fertiliser minerals, phosphates and other; Extraction and evaporation of salt; Other mining and quarrying n.e.c. (stones, asbestos and other minerals and materials) |
| Service activities incidental to mining of minerals                                                                                                                                                                                                                 |

The Upper Orange GVA values for each sector were then split based on the national proportions of the individual sector categories to the combined sector. Using the National Supply and Use tables, each value’s proportion to the National GVA was calculated and used to split the Upper Orange GVA to complete the tables. Once the Supply and Use tables were complete, they were then used to construct the Upper Orange QSAM. Finally, the multipliers were derived from the Upper Orange QSAM.

The aim of the QSAM is to combine the suppliers and consumers of economic products in a single matrix (table of interacting economic sectors) to determine the magnitude of the macro-economic indicators.



**Figure 30: Schematic representation of the methodology used for the economic model development**

The QSAM model was used to evaluate the socio-economic impact of exogenous changes to the Upper Orange River catchment economy resulting from the implementation of the different

water resource scenarios described in Chapter 3. The data inputs into the QSAM included the change in domestic, mining and industrial use water flows for each scenario (received from the hydrological modelling team) and these are used to measure the impact and economic consequences of these changes. The macro-economic indicator of Gross Value Added (GVA) is used as a measure of the potential economic trade-offs for each IUA and scenario and the compensation to employees may be used to estimate the impact on jobs. Stats SA Agricultural survey report and the Stats SA Quarterly employment Statistics report were used to determine the total average salaries value for the agriculture and non-agriculture overall sectors to estimate the impact on jobs based on the compensation to employees' value from the QSAM scenario runs.

The impact and economic consequences related to the change in agricultural water flows for each scenario was estimated based on the estimated potential gain or loss of hectares (ha) of irrigation agriculture resulting from the change in water flows and the resultant estimate of the economic consequences to the GDP and jobs per IUA. The data values for the estimate of the potential revenue per hectare is derived from studies on other irrigation areas in South Africa that have been undertaken by the specialist (Prime Africa). This data was then used in the QSAM model to derive the final impacts of irrigation flow changes to the economy of the Upper Orange River catchment.

In IUAs with significant changes in urban flows (domestic, mining and industrial sectors), the impact and economic consequences was estimated based on the specific industry sectors which would be impacted by the potential reduced water.

#### **9.4 Water Quality Model**

The Water Quality Model (WQM) quantifies the total cost of water quality remediation (to recommended standards) for various scenarios. The quantification of this cost is based on the change in water load at an EWR site due to a change in ecological category. The load quantifies the water yield utilizing specific water quality indicators (Phosphate, Total Dissolved Solids). The treatment cost of the water quality yield back to recommended standards is then determined based on costs for current best practice and industry-specific water quality remediation techniques.

##### *Water Quality Model Considerations*

The cost of water pollution is estimated by estimating the water quality externality benefits enjoyed by polluting industries. This is accomplished by considering the following parameters when producing the model:

- Water quality indicators representing the pollution associated with these activities
- Water treatment technologies required for the reduction of these identified pollutants and the costs associated with each; and
- Target water quality objectives for the identified pollutants.

These parameters were collated into a model that demonstrates the relationships between ecological state and the resulting water quality yield within an IUA. These results are thus used to estimating the cost of treating water to RQO requirements.

## Inputs

### Step 1

Concentrations of water quality indicators must be allocated to the range of ecological categories forming the first input into the model. The water quality indicators key to the model include (DWS, 2003):

- Total inorganic nitrogen (TIN) representing nutrient pollution from partially treated or untreated sewerage discharge and from agricultural practices
- Soluble reactive phosphorous (SRP), representing ortho-phosphates ( $PO_4^{3-}$ ), used to assess nutrient pollution from sewerage discharge and agricultural activities; and
- Total Dissolved Solids (TDS) to represent the salinity changes due to the Wastewater Treatment Works (WWTWs).

Concentrations of these water quality indicators must be allocated to the various ecological categories using known literature, tacit expert knowledge and the results of the EWR studies to this point. An example of the results of the ranges can be seen in Table 54.

**Table 54: Example of water quality indicator concentration allocation per ecological category**

|     | A     | B     | C     | D     | E    |
|-----|-------|-------|-------|-------|------|
|     | mg/L  | mg/L  | mg/L  | mg/L  | mg/L |
| TIN | 0.25  | 0.75  | 2     | 4     | 6    |
| SRP | 0.005 | 0.015 | 0.025 | 0.125 | 0.3  |
| TDS | 200   | 293   | 520   | 780   | >780 |

### Step 2:

The next step is to input the measure of the impacts on water quality due to changing scenarios. At this point the variation in ecological category must be drawn from the Scenario Tool. The final input is the mean annual runoff (MAR) for selected EWR sites. This is necessary to calculate the load and yield per EWR site. An example of this input is provided in Table 55.

**Table 55: Example of scenario input for the Water Quality Model**

| EWR Site | Ecological Category/ Scenario |                                 | MAR per scenario (k/a) |
|----------|-------------------------------|---------------------------------|------------------------|
|          | Current State                 | Recommended Ecological Category |                        |
| 1        | D                             | D                               | 184,520,000            |
| 2        | C                             | B                               | 81,540,000             |
| 3        | C                             | B                               | 175,500,000            |
| 4        | D                             | D                               | 500,630,000            |
| 5        | D                             | D                               | 570,980,000            |

| EWR Site | Ecological Category/ Scenario |                                 | MAR per scenario (k/a) |
|----------|-------------------------------|---------------------------------|------------------------|
|          | Current State                 | Recommended Ecological Category |                        |
| 6        | C                             | D                               | 60,300,000             |
| 7        | D                             | D                               | 726,520,000            |
| 8        | C                             | B                               | 813,040,000            |

### Outputs

Once the inputs are in place the model will calculate the treatment costs to return system to the recommended ecological category. This will be presented in (R million/ year) and represents the water quality externality benefits enjoyed by various industries. An example of this output is presented in Table 56.

**Table 56: Example of outputs of the water quality model representing R millions per year to return a system to its recommended ecological category**

| EWR site  | Water Quality Parameter | Concentration (mg/L) |             | Main Stem: Load from Source (kg/year) | Load Calculated | Recommended load (kg/a) | Treatment Load Reduction (kg/a) |
|-----------|-------------------------|----------------------|-------------|---------------------------------------|-----------------|-------------------------|---------------------------------|
|           |                         | Current              | Recommended |                                       |                 |                         |                                 |
| UO_EWR XX | PO <sub>4</sub>         | 0.05                 | 0.025       | 9,545                                 | 9,545           | 4,773                   | 4,773                           |
|           | TDS                     | 806.4                | 520         | 153,941,760                           | 153,941,760     | 99,268,000              | 54,673,760                      |

## 9.5 IUA 1: Golden Gate - Scenarios and Consequences

### 9.5.1 Economic Trade-off Analysis

In IUA 1 there are no changes in the volumes of water supplied within the IUA with the implementation of the EWR flows and there are no resulting economic trade-offs for the present day, medium term or long-term scenarios.

### 9.5.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 1 (Golden Gate) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 57 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at a risk in the IUA.

#### **Environmental effect statement for IUA 1:**

- Waterways (Rivers and Riparian Ecosystems)

Present-day flows are insufficient to meet the REC during the drier months, resulting in a significant reduction in habitat suitability for the selected indicator species/taxon. This is primarily due to the complete exposure of critical habitats and the failure of flows to meet the ecological requirements of *Perlidae*, the selected macroinvertebrate indicator species.

For fish populations, longitudinal connectivity is essential to support spawning migrations, and suitable spawning habitats must be available. These habitats must be free of sediment embedding to maintain their functionality for reproductive success.

**Table 57: CERA outcome - risks to associated ecosystem services in IUA 1**

| Environmental Hazard | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                   | Likelihood | Consequence   | Risk |
|----------------------|---------------------------|-------------------------------|-----------------------------------------|------------|---------------|------|
| Reduced flow         | Waterways                 | Habitats for species          | Fish and invertebrates                  | Likely     | Moderate      | High |
| Reduced flow         | Waterways                 | Fresh Water (Natural Sources) | No water, supply deficit to water users | Unlikely   | Insignificant | Low  |
| Poor Water quality   | Waterways                 | Habitats for species          | Fish and invertebrates                  | Possible   | Moderate      | High |

## 9.6 IUA 2: Caledon/ Leeu River - Scenarios and Consequences

### 9.6.1 Economic Trade-off Analysis

In IUA 2 there are very small changes in the volumes of water supplied within the IUA with the implementation of the EWR flows for both urban (domestic/mine) and irrigation users, however these would not result in any significant economic trade-offs in the present day, medium term or long-term scenarios.

The small deficits (ranges from 0.179 Mm<sup>3</sup>/a deficit in present day to 0.186 Mm<sup>3</sup>/a deficit in the long-term scenario 3) in supply across the IUA for irrigation may be managed through reduction in the assurance of irrigation water demand.

The urban deficits are small with the most impact being seen in the long term, with a deficit of 0.47 Mm<sup>3</sup>/a which could be managed by the agro-processing industries in the IUA that could reduce their water use for processing, or by means of water conservation/ demand management (WC/DM) through measures such as reducing of leakages and increased water use efficiency in the municipal areas.

### 9.6.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 2 (Caledon/ Leeu River) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 58 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

#### **Environmental effect statement for IUA 2:**

- Waterways (Rivers and Riparian Ecosystems)

Scenario flows, with or without EWR implemented, generally align with the flow preferences of the indicator species or taxa. However, biotic communities exhibit a noticeably stronger positive response when EWRs are applied, indicating the ecological value of targeted flow management.

Water quality in this reach is significantly influenced by discharges from WWTWs and runoff from the surrounding urban area. As a result, water quality emerges as the primary driver of ecological condition, compounded by limited habitat availability. The continuous passage of fine silts through the system remains a concern, as these particles can clog the gills of both fish and macroinvertebrates, impairing respiration and overall health. Furthermore, the construction of proposed weirs may trap coarse sediment such as gravel, which serves as critical habitat for various aquatic organisms, potentially reducing habitat diversity and resilience.

- Wetlands

In IUA 2, the Brandwater floodplain and the Rantsho wetland complex are the two priority wetlands. While the floodplain appears to be no longer activated via floodwaters, the maintenance of the lateral flood-out zones is critical for providing ecosystem services such as biodiversity maintenance and grazing for livestock. It is uncommon to find such extensive and hydrologically well-maintained flood-out zones in a floodplain context (DWS, 2023). The Rantsho wetland complex, still relatively intact, encompasses a high geomorphological diversity and an unusual geomorphic setting (DWS, 2023). Impacts to these wetlands are mainly from reduced flows associated with damming and abstraction.

**Table 58: CERA outcome - risks to associated ecosystem services in IUA 2**

| Environmental Hazard | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                             | Likelihood | Consequence   | Risk   |
|----------------------|---------------------------|-------------------------------|---------------------------------------------------|------------|---------------|--------|
| Reduced flow         | Waterways                 | Habitats for species          | Fish and invertebrates                            | Unlikely   | Minor         | Low    |
| Reduced flow         | Waterways                 | Fresh Water (Natural Sources) | Insignificant water supply deficit to water users | Unlikely   | Insignificant | Low    |
| Poor Water quality   | Waterways                 | Habitats for species          | Fish and invertebrates                            | Likely     | Moderate      | High   |
| Reduced flows        | Wetlands                  | Fresh Water (Natural Sources) | Downstream water users and wetland habitat        | Possible   | Minor         | Medium |

## 9.7 IUA 3: Caledon River - Scenarios and Consequences

### 9.7.1 Economic Trade-off Analysis

The results of the economic analysis of the effect of the change in water flows for each of the different scenarios for IUA 3, are provided in Table 59. For each scenario the impact of implementing EWR flows is evaluated and the consequent effect on the economy is determined because of the change in flows.

This IUA has economic impacts that result from the changes in irrigation supply flows as there are no urban (domestic /mine) flow deficits for this IUA. When the EWR is implemented, there will be an impact on the agricultural sector with less water available for irrigation and thus potentially fewer hectares that can be planted to irrigation agriculture across the IUA with associated economic trade-offs. In this IUA the potential reduced hectares are approximately 1,030 ha in the present day, 1,067ha in the medium term and 1,080 ha in the long term.

**Table 59: Economic consequences resulting from the EWR impact in each of the analysed scenarios in IUA 3 Caledon**

| Scenario                        | Flow impact and socio-economic consequences |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                        |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
|---------------------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|-------------|--------|------|--------|------|
| Present day Scenario 1          |                                             | <p>In IUA 3 there are no urban (domestic/mine) user flow supply deficits. The irrigation supply flows decrease from 19.1 million m<sup>3</sup>/annum without EWR to 10.6 Mm<sup>3</sup>/a with the EWR in the present-day scenario resulting in a deficit of 8.5 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million R/a</td> <td>-418</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-616</td> </tr> </tbody> </table>      | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million R/a | -418   | Jobs | Number | -616 |
| Macro-economic impacts          |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                        |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
| Economy                         | Indicator                                   | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Economic Effect        |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
| Upper Orange River catchment    | GDP                                         | Million R/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | -418                   |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
|                                 | Jobs                                        | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -616                   |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
| Medium-term (2040) Scenario 2   |                                             | <p>In the medium term the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 19.07 Mm<sup>3</sup>/a without EWR to 10.05 Mm<sup>3</sup>/a, with allocation to the EWR, a deficit of 9.02 Mm<sup>3</sup>/a. This is illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million R/a</td> <td>-444.8</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-655</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million R/a | -444.8 | Jobs | Number | -655 |
| Macro-economic impacts          |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                        |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
| Economy                         | Indicator                                   | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Economic Effect        |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
| Upper Orange River catchment    | GDP                                         | Million R/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | -444.8                 |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
|                                 | Jobs                                        | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -655                   |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |
| Medium-term (2040) Scenario 2.1 |                                             | <p>In the alternative medium-term scenario, there are no impacts to the domestic/mine users and the impact is for the irrigation users. The irrigation supply flows decrease from 19.07 Mm<sup>3</sup>/a without EWR to 10.02 Mm<sup>3</sup>/a /annum with allocation to the EWR, a deficit of 9.04 Mm<sup>3</sup>/a. This is illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p>                                                                                                                                                                                                                                                                                                                                            |                        |  |  |  |         |           |      |                 |                              |     |             |        |      |        |      |

| Scenario                             | Flow impact and socio-economic consequences                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|--------|------|--------|------|
|                                      | <p>Domestic/Mine</p> <p>Irrigation</p> <p>Ecosystem Services</p> <p>Ecosystem service risk mitigated</p> <p>-60% -40% -20% 0% 20% 40% 60% 80% 100%</p> | <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-444.7</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-655</td> </tr> </tbody> </table>                                                                                                                                                                                                                                                                                                                                                                                                           | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -444.7 | Jobs | Number | -655 |
| Macro-economic impacts               |                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                              | Indicator                                                                                                                                              | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment         | GDP                                                                                                                                                    | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -444.7                 |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                                      | Jobs                                                                                                                                                   | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -655                   |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| <p>Long-Term (2060) Scenario 3</p>   | <p>Domestic/Mine</p> <p>Irrigation</p> <p>Ecosystem Services</p> <p>Ecosystem service risk mitigated</p> <p>-60% -40% -20% 0% 20% 40% 60% 80% 100%</p> | <p>In the long term the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 19.06 million m<sup>3</sup>/annum without EWR to 9.84 Mm<sup>3</sup>/a, with allocation to the EWR, a deficit of 9.21 Mm<sup>3</sup>/a. This is illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-454</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-656</td> </tr> </tbody> </table>            | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -454   | Jobs | Number | -656 |
| Macro-economic impacts               |                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                              | Indicator                                                                                                                                              | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment         | GDP                                                                                                                                                    | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -454                   |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                                      | Jobs                                                                                                                                                   | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -656                   |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| <p>Long-Term (2060) Scenario 3.1</p> | <p>Domestic/Mine</p> <p>Irrigation</p> <p>Ecosystem Services</p> <p>Ecosystem service risk mitigated</p> <p>-60% -40% -20% 0% 20% 40% 60% 80% 100%</p> | <p>In this alternate long-term scenario, the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 19.03 Mm<sup>3</sup>/a without EWR to 9.75 Mm<sup>3</sup>/a with allocation to the EWR, a deficit of 9.28 Mm<sup>3</sup>/a. This is illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-457.7</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-674</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -457.7 | Jobs | Number | -674 |
| Macro-economic impacts               |                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                              | Indicator                                                                                                                                              | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment         | GDP                                                                                                                                                    | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -457.7                 |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                                      | Jobs                                                                                                                                                   | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -674                   |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| <p>Long term (2060) Scenario 3.3</p> | <p>Domestic/Mine</p> <p>Irrigation</p> <p>Ecosystem Services</p> <p>Ecosystem service risk mitigated</p> <p>-60% -40% -20% 0% 20% 40% 60% 80% 100%</p> | <p>In this third long term scenario the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 19.05 Mm<sup>3</sup>/a without EWR to 9.87 Mm<sup>3</sup>/a, with allocation to the EWR, a deficit of 9.19 Mm<sup>3</sup>/a. This is illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p>                                                                                                                                                                                                                                                                                                                                                                                         |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |

| Scenario | Flow impact and socio-economic consequences |                              |           |                |                 |
|----------|---------------------------------------------|------------------------------|-----------|----------------|-----------------|
|          |                                             | Macro-economic impacts       |           |                |                 |
|          |                                             | Economy                      | Indicator | Unit           | Economic Effect |
|          |                                             | Upper Orange River catchment | GDP       | Million Rand/a | -453            |
|          |                                             |                              | Jobs      | Number         | -667            |

### 9.7.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 3 (Caledon River) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 60 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

#### **Environmental effect statement for IUA 3:**

- Waterways (Rivers and Riparian Ecosystems)

Scenario flows, with or without EWRs implemented, generally align with the flow preferences of the indicator species or taxa. However, biotic communities show a noticeably stronger positive response when EWRs are applied, indicating the ecological value of targeted flow management. However, irrigation supply is negatively impacted when EWRs are implemented.

Water quality is the primary driver in this reach, coupled with limited habitat availability. Fine silts passing through the system remain a concern, as they clog the gills of both fish and macroinvertebrates. Additionally, the proposed weirs may trap coarse materials such as gravel, which serve as vital habitats for biotic communities.

- Wetlands

There is one priority wetland complex in IUA 3, the Valley Bottom Sandspruit wetland. The key impact to the wetland is related to water quality and high nutrient loads from the WWTW and urban areas. Given that the entire runoff from Wepener town and the discharge from the town's WWTW pass through this still reasonably intact wetland before entering the Caledon River, its importance in terms water quality enhancement is likely to be high.

**Table 60: CERA outcome - risks to associated ecosystem services in IUA 3**

| Environmental Hazard | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                                           | Likelihood | Consequence | Risk |
|----------------------|---------------------------|-------------------------------|-----------------------------------------------------------------|------------|-------------|------|
| Reduced flow         | Waterways                 | Habitats for species          | Fish and invertebrates                                          | Unlikely   | Minor       | Low  |
| Reduced flow         | Waterways                 | Fresh Water (Natural Sources) | The implications of implementing EWRs results in a decrease for | Likely     | Moderate    | High |

| Environmental Hazard                        | Ecological Infrastructure | Ecosystem Service at Risk             | Beneficiaries at Risk                                       | Likelihood | Consequence | Risk   |
|---------------------------------------------|---------------------------|---------------------------------------|-------------------------------------------------------------|------------|-------------|--------|
|                                             |                           |                                       | irrigation supply flows (8.5 million m <sup>3</sup> /annum) |            |             |        |
| Poor water quality (sediment and nutrients) | Waterways                 | Habitats for species                  | Fish and invertebrates                                      | Likely     | Moderate    | High   |
| High nutrients                              | Wetlands                  | Habitat for species                   | Wetland fauna and flora                                     | Possible   | Minor       | Medium |
| High nutrients                              | Wetlands                  | Water purification & waste management | Downstream water users                                      | Possible   | Minor       | Medium |

## 9.8 IUA 4 – Kraai River - Scenarios and Consequences

### 9.8.1 Economic Trade-off Analysis

The results of the economic analysis of the effect of the change in water flows for each of the different scenarios for IUA 4 are provided in Table 61. For each scenario the impact of implementing EWR flows is evaluated and the consequent effect on the economy is determined due the change in flows.

In this IUA there are no economic impacts to the domestic/mine users with the allocation of the EWR. Implementing the EWR in this IUA will have an impact on the irrigation sector. The impacts to the agricultural economy because of potential supply deficits to irrigation users is seen in the present day, medium- and long-term scenarios. When the EWR is implemented, there will be an impact on the agricultural sector with less water available for irrigation and thus potentially fewer hectares that can be planted to irrigation agriculture across the IUA with associated economic trade-offs. In this IUA the potential reduced hectares are approximately 573 ha in the present day: between 591 and 624 ha in the medium term and between 600 and 611 ha in the long term.

**Table 61: Economic consequences resulting from the EWR impact in each of the analysed scenarios in IUA 4 Kraai River**

| Scenario               | Flow impact and socio-economic consequences |                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Present day Scenario 1 |                                             | <p>In IUA 4 Kraai River there are no impacts from urban (domestic/mine) user flows. The irrigation supply flows decrease from 40.35 Mm<sup>3</sup>/a without EWR to 34.63 Mm<sup>3</sup>/a with the EWR in the present-day scenario resulting in a deficit of 5.72 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> |

| Scenario                        | Flow impact and socio-economic consequences                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                 |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|---------------------------------|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|--------|------|--------|------|
|                                 |                                                                                                               | <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-241.7</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-356</td> </tr> </tbody> </table>                                                                                                                                                                                                                                                                                                                                                                                                                         |                 | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -241.7 | Jobs | Number | -356 |
| Macro-economic impacts          |                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                 |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                         | Indicator                                                                                                     | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Economic Effect |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment    | GDP                                                                                                           | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | -241.7          |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                                 | Jobs                                                                                                          | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -356            |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Medium term (2040) Scenario 2   | <p>Domestic/Mine: 0%<br/>Irrigation: -6.02%<br/>Ecosystem Services: 0% (Ecosystem service risk mitigated)</p> | <p>In the medium term the impact from the implementation of the EWR is only for the irrigation users. The irrigation supply flows decrease from 40.28 Mm<sup>3</sup>/a without EWR to 34.27 Mm<sup>3</sup>/a, with allocation to the EWR. This is a deficit of 6.02 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-254.3</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-374</td> </tr> </tbody> </table>                                |                 | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -254.3 | Jobs | Number | -374 |
| Macro-economic impacts          |                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                 |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                         | Indicator                                                                                                     | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Economic Effect |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment    | GDP                                                                                                           | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | -254.3          |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                                 | Jobs                                                                                                          | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -374            |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Medium term (2040) Scenario 2.1 | <p>Domestic/Mine: 0%<br/>Irrigation: -5.9%<br/>Ecosystem Services: 0% (Ecosystem service risk mitigated)</p>  | <p>In this alternative medium-term scenario, there are no impacts to the domestic/mine users and the impact is for the irrigation users. The irrigation supply flows decrease from 40.28 Mm<sup>3</sup>/a without EWR to 34.39 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 5.9 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-249</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-367</td> </tr> </tbody> </table> |                 | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -249   | Jobs | Number | -367 |
| Macro-economic impacts          |                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                 |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                         | Indicator                                                                                                     | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Economic Effect |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment    | GDP                                                                                                           | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | -249            |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                                 | Jobs                                                                                                          | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -367            |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Long Term (2060) Scenario 3     | <p>Domestic/Mine: 0%<br/>Irrigation: -5.99%<br/>Ecosystem Services: 0% (Ecosystem service risk mitigated)</p> | <p>In the long term the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 40.41 Mm<sup>3</sup>/a without EWR to 34.42 Mm<sup>3</sup>/a, with allocation to the EWR. This is a deficit of 5.99 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td>Upper Orange</td> <td>GDP</td> <td>Million Rand/a</td> <td>-253</td> </tr> </tbody> </table>                                                                                                                     |                 | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange                 | GDP | Million Rand/a | -253   |      |        |      |
| Macro-economic impacts          |                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                 |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                         | Indicator                                                                                                     | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Economic Effect |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange                    | GDP                                                                                                           | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | -253            |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |

| Scenario                      | Flow impact and socio-economic consequences |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                 |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|-------------------------------|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|--------|------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|--------|------|--------|------|
|                               |                                             | River catchment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Jobs            | Number | -373 |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Long Term (2060) Scenario 3.1 |                                             | <p>In the first alternate long-term scenario the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 40.31 Mm<sup>3</sup>/a without EWR to 34.21 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 6.1 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-257.9</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-380</td> </tr> </tbody> </table>   |                 |        |      | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -257.9 | Jobs | Number | -380 |
| Macro-economic impacts        |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                 |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                       | Indicator                                   | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Economic Effect |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment  | GDP                                         | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -257.9          |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                               | Jobs                                        | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -380            |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Long term (2060) Scenario 3.2 |                                             | <p>In the second alternate long-term scenario the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 40.32 Mm<sup>3</sup>/a without EWR to 31.42 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 8.89 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-375.9</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-553</td> </tr> </tbody> </table> |                 |        |      | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -375.9 | Jobs | Number | -553 |
| Macro-economic impacts        |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                 |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                       | Indicator                                   | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Economic Effect |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment  | GDP                                         | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -375.9          |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                               | Jobs                                        | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -553            |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Long term (2060) Scenario 3.3 |                                             | <p>In the second alternate long-term scenario the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 40.41 Mm<sup>3</sup>/a without EWR to 34.46 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 5.95 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-251</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-370</td> </tr> </tbody> </table>   |                 |        |      | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -251   | Jobs | Number | -370 |
| Macro-economic impacts        |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                 |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Economy                       | Indicator                                   | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Economic Effect |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
| Upper Orange River catchment  | GDP                                         | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -251            |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |
|                               | Jobs                                        | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -370            |        |      |                        |  |  |  |         |           |      |                 |                              |     |                |        |      |        |      |

### 9.8.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 4 (Kraai River) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects

such as climate change or land transformation. Table 62 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

**Environmental effect statement for IUA 4:**

- Waterways (Rivers and Riparian Ecosystems)

During the drier months, present-day flows fall short of achieving the REC of B/C, resulting in a significant reduction in habitat suitability. This is primarily due to extremely low drought flows, which lead to the complete exposure of critical habitats for flow-dependent species/taxon. Irrigation supply is negatively impacted when EWRs are implemented.

Extensive infestations of AIPs along the Kraai River’s riparian zone currently contribute to reduced baseflows. Over time, eradication efforts could help restore some of these baseflows, potentially improving flow conditions and supporting more favourable biotic responses. Additionally, agricultural practices such as cultivation and heavy grazing further impact the system, contributing to land degradation and hydrological stress.

- Wetlands

IUA 4 includes five priority wetland complexes. These include Wolvespruit Headwaters wetlands, Barkley Pass wetland complex, Tiffendell Seep complex, Klein Wildespruit wetland complex and Otto du Plessis Pass wetland. The wetlands in this IUA are important water source areas, with some containing peat and are important from a water supply, carbon sequestration and biodiversity maintenance perspective. The main impacts are from agricultural practices of cultivation and livestock grazing and trampling. Under climate change a further impact may potentially be from reduced groundwater recharge resulting in reduced flows.

**Table 62: CERA outcome - risks to associated ecosystem services in IUA 4**

| Environmental Hazard                        | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                                                                                                       | Likelihood | Consequence | Risk    |
|---------------------------------------------|---------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------|-------------|---------|
| Reduced flow                                | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                      | likely     | Major       | Extreme |
| Reduced flow                                | Waterways                 | Fresh Water (Natural Sources) | The implications of implementing EWRs results in a decrease for irrigation supply flows (5.7 million m <sup>3</sup> /annum) | Likely     | Moderate    | High    |
| Poor water quality (sediment and nutrients) | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                      | Likely     | moderate    | High    |
| Climate Change                              | Wetlands                  | Fresh Water (Natural Sources) | Downstream water users and wetland habitat                                                                                  | Possible   | Moderate    | High    |
| Land transformation                         | Wetlands                  | Habitat for species           | Fauna and flora                                                                                                             | Possible   | Minor       | Medium  |

## 9.9 IUA 5: Upper Orange River - Scenarios and Consequences

### 9.9.1 Economic Trade-off Analysis

The results of the economic analysis of the effect of the change in water flows for each of the different scenarios for IUA 5 flows and the consequent effect on the economy determined as a result of the change in flows are set out in Table 63.

In this IUA there are no significant flow deficits for the domestic/mine users and implementation of the EWR in this IUA will only have an impact on the irrigation sector. The impacts to the agricultural economy because of potential supply deficits to irrigation users is seen only in the present-day scenario. In the medium term and long-term scenarios there are very small changes in supply volumes, with EWR allocation, for irrigation users. These changes in supply volumes represent less than 1% of the total supply volume across the IUA without the implementation of EWR and would not result in any significant economic impacts. These small reduction in supply volumes could be managed through reduction in the assurance of demand for the irrigation users. In the present day when the EWR is implemented, there will be an impact on the agricultural sector with less water available for irrigation and thus potentially fewer hectares that can be planted to irrigation agriculture across the IUA with associated economic trade-offs. The potential reduced hectares across the IUA are 434 ha.

**Table 63: Economic consequences resulting from the EWR impact in each of the analysed scenarios in IUA 5 Upper Orange**

| Scenario               | Flow impact and socio-economic consequences |           |                                                                                                                                                                                                                                                                                                                                                                                         |                 |
|------------------------|---------------------------------------------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Present day Scenario 1 |                                             |           | <p>In IUA 5 Upper Orange there are no impacts from urban (domestic/mine) user flows. The irrigation supply flows decrease from 205.4 Mm<sup>3</sup>/a without EWR to 201.7 Mm<sup>3</sup>/a with the EWR in the present-day scenario resulting in a deficit of 3.7 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> |                 |
|                        | <p>Macro-economic impacts</p>               |           |                                                                                                                                                                                                                                                                                                                                                                                         |                 |
|                        | Economy                                     | Indicator | Unit                                                                                                                                                                                                                                                                                                                                                                                    | Economic Effect |
|                        | Upper Orange River Catchment                | GDP       | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                          | -183            |
|                        |                                             | Jobs      | Number                                                                                                                                                                                                                                                                                                                                                                                  | -269            |

### 9.9.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 5 (Upper Orange River) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 64 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

**Environmental effect statement for IUA 5:**

- Waterways (Rivers and Riparian Ecosystems)

Scenario flows, with or without EWR implementation, generally align with the indicator biota flow preferences, even under future dam proposals. Irrigation supply is negatively impacted when EWRs are implemented.

Ecological conditions are likely to remain constrained if the proposed upstream dams (e.g., Verbeelingskraal, Pohliholi, and Makhaleng) are constructed. These dams will trap more sediment, particularly coarse material such as gravel, which is critical for biotic habitats. Fine sediments will continue to pass through the system, increasing turbidity, sediment deposition, and embedding of available rocky habitats. These changes clog the gills of biota, restrict riparian zones, encourage the spread of AIP, and degrade biotic responses.

- Wetlands

IUA 5 priority wetland is the Maletswai Wetland Complex. The wetland complex comprises two main wetlands, with the eastern of these wetlands being the larger and more permanent. In the upper portions of the eastern wetland is a thermal spring rich in minerals and salts. The name of the wetland (and of the town itself) means “a place of salt” in Sesotho. Through the Aliwal North Spa, the springs have been developed into thermal pools, which attract many visitors seeking relaxation and/or health benefits and have high economic value for the town. Although moderately disturbed, the wetland complex still contains extensive intact areas and is likely to have a high importance in terms of water quality enhancement, particularly given that much of the runoff from Maletswai (Aliwal North) town passes through this wetland complex before entering the Orange River. The main impact is from water quality and high nutrient loads.

**Table 64: CERA outcome - risks to associated ecosystem services in IUA 5**

| Environmental Hazard              | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                                                                                                       | Likelihood | Consequence   | Risk   |
|-----------------------------------|---------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------|---------------|--------|
| Reduced flow                      | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                      | Unlikely   | Insignificant | Low    |
| Reduced flow                      | Waterways                 | Fresh Water (Natural Sources) | The implications of implementing EWRs results in a decrease for irrigation supply flows (3.7 million m <sup>3</sup> /annum) | Likely     | Moderate      | High   |
| Non-flow: sediment, nutrient, AIP | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                      | Likely     | Major         | High   |
| High nutrients                    | Wetlands                  | Fresh Water (Natural Sources) | Downstream water users                                                                                                      | Possible   | Minor         | Medium |

## 9.10 IUA 6: Gariep Dam - Scenarios and Consequences

### 9.10.1 Economic Trade-off Analysis

In IUA 6 there are very small to no changes in the volumes of water supplied within the IUA with the implementation of the EWR flows for both urban (domestic/mine) and irrigation users and would not result in any significant economic trade-offs in the present day, medium term or long-term scenarios. The small deficits in supply across the IUA for irrigation may be managed through reduction in the assurance of irrigation water demand.

### 9.10.2 Comparative Ecological Risk Assessment

There was no ecological infrastructure or associated ecosystem services that were found to be at risk within this IUA.

## 9.11 IUA 7: Seekoei River - Scenarios and Consequences

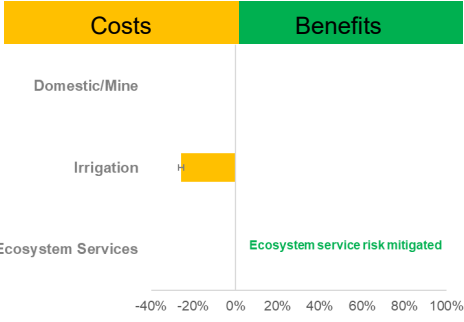
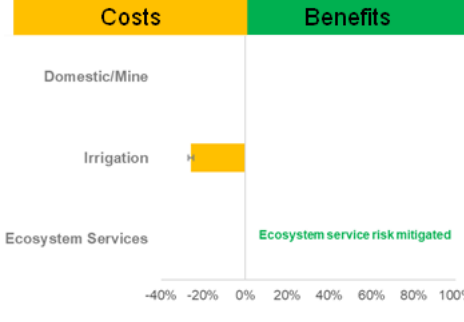
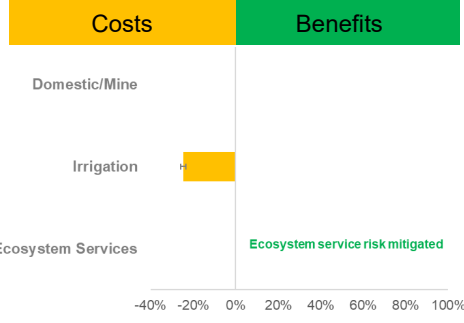
### 9.11.1 Economic Trade-off Analysis

The results of the economic analysis of the effect of the change in water flows for each of the different scenarios for IUA 7 Seekoei River flows is evaluated and the consequent effect on the economy is determined because of the change in flows (Table 65).

In this IUA there are no reported flows for domestic/ mining users. The implementation of the EWR in this IUA will only have an impact on the irrigation users. The impacts to the agricultural economy because of these potential supply deficits to irrigation users is seen in the present day, medium term and long-term scenarios. Across these scenarios, with the implementation of the EWR, there will be an impact on the agricultural sector with less water available for irrigation and thus potentially fewer hectares (approximately 34 ha) that can be planted to irrigation agriculture across the IUA with associated economic trade-offs.

**Table 65: Economic consequences resulting from the EWR impact in each of the analysed scenarios in IUA 7: Seekoei River**

| Scenario                     | Flow impact and socio-economic consequences |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |  |  |  |         |           |      |                 |                              |     |                |     |      |        |     |
|------------------------------|---------------------------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|-----|------|--------|-----|
| Present day Scenario 1       |                                             |                | <p>In IUA 7 River there are no impacts from urban (domestic/mine) user flows. The irrigation supply flows decrease from 1.34 Mm<sup>3</sup>/a without EWR to 1.01 Mm<sup>3</sup>/a with allocation to the EWR. in the present-day scenario resulting in a deficit of 0.33 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-14</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-21</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -14 | Jobs | Number | -21 |
|                              | Macro-economic impacts                      |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |  |  |  |         |           |      |                 |                              |     |                |     |      |        |     |
| Economy                      | Indicator                                   | Unit           | Economic Effect                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |  |  |  |         |           |      |                 |                              |     |                |     |      |        |     |
| Upper Orange River catchment | GDP                                         | Million Rand/a | -14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                        |  |  |  |         |           |      |                 |                              |     |                |     |      |        |     |
|                              | Jobs                                        | Number         | -21                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                        |  |  |  |         |           |      |                 |                              |     |                |     |      |        |     |
|                              |                                             |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |  |  |  |         |           |      |                 |                              |     |                |     |      |        |     |

| Scenario                              | Flow impact and socio-economic consequences                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|---------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|-------|------|--------|-----|
| Medium term (2040) Scenario 2         |    | <p>In the medium-term scenario, the impact from the implementation of the EWR is also only for the irrigation users. The irrigation supply flows decrease from 1.34 Mm<sup>3</sup>/a without EWR to 1.02 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 0.33 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-13.8</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-20</td> </tr> </tbody> </table>                                                                                                                   | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -13.8 | Jobs | Number | -20 |
| Macro-economic impacts                |                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                               | Indicator                                                                           | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River catchment          | GDP                                                                                 | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -13.8                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                                       | Jobs                                                                                | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -20                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Medium term (2040) Scenario 2 estuary |   | <p>In this alternative medium term scenario, the impact from the implementation of the EWR is only for the irrigation users and gave the same effective result as the first medium term scenario. The irrigation supply flows decrease from 1.34 million m<sup>3</sup>/annum without EWR to 1.017 million m<sup>3</sup>/annum with allocation to the EWR. This is a deficit of 0.327 million m<sup>3</sup>/annum as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-13.8</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-20</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -13.8 | Jobs | Number | -20 |
| Macro-economic impacts                |                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                               | Indicator                                                                           | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River catchment          | GDP                                                                                 | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -13.8                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                                       | Jobs                                                                                | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -20                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Medium term (2040) Scenario 2.1       |  | <p>In this alternative medium-term scenario, there are no impacts to the domestic/mine users and the impact is for the irrigation users. The irrigation supply flows decrease from 1.34 Mm<sup>3</sup>/a without EWR to 1.02 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 0.33 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-13.9</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-20</td> </tr> </tbody> </table>                                                                                             | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -13.9 | Jobs | Number | -20 |
| Macro-economic impacts                |                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                               | Indicator                                                                           | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River catchment          | GDP                                                                                 | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -13.9                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                                       | Jobs                                                                                | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | -20                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |

| Scenario                      | Flow impact and socio-economic consequences                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|-------|------|--------|-----|
| Long Term (2060) Scenario 3   | <p>The chart shows Domestic/Mine and Ecosystem Services as benefits (0% to 100%). Irrigation is a cost (-20% to 0%). Ecosystem service risk is mitigated.</p> | <p>In the long term the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 1.35 Mm<sup>3</sup>/a without EWR to 1.01 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 0.33 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-14</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-21</td> </tr> </tbody> </table>                                | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -14   | Jobs | Number | -21 |
| Macro-economic impacts        |                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                       | Indicator                                                                                                                                                     | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River catchment  | GDP                                                                                                                                                           | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -14                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                               | Jobs                                                                                                                                                          | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | -21                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Long Term (2060) Scenario 3.1 | <p>The chart shows Domestic/Mine and Ecosystem Services as benefits (0% to 100%). Irrigation is a cost (-20% to 0%). Ecosystem service risk is mitigated.</p> | <p>In the first alternate long-term scenario the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 1.35 Mm<sup>3</sup>/a without EWR to 1.0 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 0.35 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-14.7</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-22</td> </tr> </tbody> </table>    | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -14.7 | Jobs | Number | -22 |
| Macro-economic impacts        |                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                       | Indicator                                                                                                                                                     | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River catchment  | GDP                                                                                                                                                           | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -14.7                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                               | Jobs                                                                                                                                                          | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | -22                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Long Term (2060) Scenario 3.3 | <p>The chart shows Domestic/Mine and Ecosystem Services as benefits (0% to 100%). Irrigation is a cost (-20% to 0%). Ecosystem service risk is mitigated.</p> | <p>In this second alternate long-term scenario, the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 1.35 Mm<sup>3</sup>/a without EWR to 1.01 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 0.33 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-14.</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-21</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -14.  | Jobs | Number | -21 |
| Macro-economic impacts        |                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                       | Indicator                                                                                                                                                     | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River catchment  | GDP                                                                                                                                                           | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -14.                   |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                               | Jobs                                                                                                                                                          | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | -21                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |

### 9.11.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 7 (Seekoei River) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 66 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

Environmental effect statement for IUA 7:

- Waterways (Rivers and Riparian Ecosystems)

Scenario flows, with or without EWR implementation, generally align with the flow preferences of the biota. However, biota respond more favourably when the EWR is implemented.

- Groundwater

Currently and into the future with rainfall depletion there are no quaternary catchments that are over abstracted or at risks from over abstraction. The main problem is immediate and a local one (Hot Spots) due to poor waste and wastewater management at most of the small towns like Hanover and other smaller villages affecting the water quality of the groundwater. Future rainfall depletion (climate impacted) may lead to increases in the stress Indices of the quaternary catchments in this IUA. Any future over abstraction will also lead to deterioration of water quality conditions.

- Wetlands

There is only one priority wetland in IUA 7, the Gordonville wetland complex. The wetland complex comprises somewhat degraded natural vegetation which may likely be due to sustained heavy grazing. There is both natural incision and erosion in the area and the surrounding land uses include natural and cultivated areas.

**Table 66: CERA outcome - risks to associated ecosystem services in IUA 7**

| Environmental Hazard                                                | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                                                                                                        | Likelihood | Consequence   | Risk   |
|---------------------------------------------------------------------|---------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------|------------|---------------|--------|
| Reduced flow                                                        | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                       | Unlikely   | Insignificant | Low    |
| Reduced flow                                                        | Waterways                 | Fresh Water (Natural Sources) | The implications of implementing EWRs results in a decrease for irrigation supply flows (0.33 million m <sup>3</sup> /annum) | Likely     | Minor         | Medium |
| Poor water quality                                                  | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                       | Unlikely   | Insignificant | Low    |
| Increased nutrients inflow from surface water into shallow aquifers | Aquifer                   | Fresh Water (Natural Sources) | Domestic groundwater users                                                                                                   | Unlikely   | Moderate      | Medium |

| Environmental Hazard | Ecological Infrastructure | Ecosystem Service at Risk        | Beneficiaries at Risk              | Likelihood | Consequence | Risk |
|----------------------|---------------------------|----------------------------------|------------------------------------|------------|-------------|------|
| Land transformation  | Wetlands                  | Erosion control / soil stability | Farmers and downstream water users | Possible   | Moderate    | High |

## 9.12 IUA 8: Vanderkloof Dam - Scenarios and Consequences

### 9.12.1 Economic Trade-off Analysis

The results of the economic analysis of the effect of the change in water flows for each of the different scenarios for IUA 8 flows is evaluated and the consequent effect on the economy is determined as a result of the change in flows (Table 67).

In IUA 8 there are very small and insignificant changes to the supply volumes of water within the IUA with the implementation of the EWR flows for urban (domestic/mine) users. There are changes to irrigation supply volumes, albeit small in relation to the total supply volumes within the IUA in the present-day scenario and in the first medium term scenario. When the EWR is implemented, there will be an impact on the agricultural sector with less water available for irrigation and thus potentially fewer hectares that can be planted to irrigation agriculture across the IUA with associated economic trade-offs. In this IUA this reduction is between 247 and 383 ha across these scenarios.

**Table 67: Economic consequences resulting from the EWR impact in each of the analysed scenarios in IUA 8 Vanderkloof Dam**

| Scenario                     | Flow impact and socio-economic consequences |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                        |  |  |  |         |           |      |                 |                              |     |                |      |      |        |      |
|------------------------------|---------------------------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|------|------|--------|------|
| Present day Scenario 1       |                                             |                | <p>In IUA 8 Vanderkloof Dam there are no impacts from urban (domestic/mine) user flows. The irrigation supply flows decrease from 254.8 Mm<sup>3</sup>/a without EWR to 250.6 Mm<sup>3</sup>/a with allocation to the EWR. in the present-day scenario resulting in a deficit of 4.2 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-161</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-238</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -161 | Jobs | Number | -238 |
|                              | Macro-economic impacts                      |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                        |  |  |  |         |           |      |                 |                              |     |                |      |      |        |      |
| Economy                      | Indicator                                   | Unit           | Economic Effect                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                        |  |  |  |         |           |      |                 |                              |     |                |      |      |        |      |
| Upper Orange River catchment | GDP                                         | Million Rand/a | -161                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                        |  |  |  |         |           |      |                 |                              |     |                |      |      |        |      |
|                              | Jobs                                        | Number         | -238                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                        |  |  |  |         |           |      |                 |                              |     |                |      |      |        |      |
|                              |                                             |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                        |  |  |  |         |           |      |                 |                              |     |                |      |      |        |      |

| Scenario                              | Flow impact and socio-economic consequences |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|---------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|-------|------|--------|-----|
| Medium term (2040) Scenario 2         |                                             | <p>In the medium-term scenario, the impact from the implementation of the EWR is also only for the irrigation users. The irrigation supply flows decrease from 254.8 Mm<sup>3</sup>/a without EWR to 252.1 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 2.72 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River Catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-35.8</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-53</td> </tr> </tbody> </table>                        | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River Catchment | GDP | Million Rand/a | -35.8 | Jobs | Number | -53 |
| Macro-economic impacts                |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                               | Indicator                                   | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River Catchment          | GDP                                         | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | -35.8                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                                       | Jobs                                        | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | -53                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Medium term (2040) Scenario 2 estuary |                                             | <p>In this alternative medium-term scenario, the impact from the implementation of the EWR is also only for the irrigation users. The irrigation supply flows decrease from 254.79 Mm<sup>3</sup>/a without EWR to 253.59 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 1.2 million m<sup>3</sup>/annum as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River Catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-48</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-68</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River Catchment | GDP | Million Rand/a | -48   | Jobs | Number | -68 |
| Macro-economic impacts                |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                               | Indicator                                   | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River Catchment          | GDP                                         | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | -48                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                                       | Jobs                                        | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | -68                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |

### 9.12.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 8 (Vanderkloof Dam) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 68 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

Environmental effect statement for IUA 8:

- Waterways (Rivers and Riparian Ecosystems)

Scenario flows, with or without EWR implementation, generally align with the flow preferences of indicator biota, even under future dam proposals (e.g., Verbeeldingskraal, Pohlihal, and Makhaleng).

Habitat for species is likely to remain constrained if proposed upstream dams are constructed. These dams will trap coarse sediment, such as gravel, which is crucial for biotic habitats, while fine sediments will continue to increase turbidity, sediment deposition, and the embedding of

rocky habitats. These changes adversely impact biota by clogging gills (physiological stress impacting on reproduction), narrowing riparian zones, promoting alien invasive plants, and degrading ecological responses.

- Wetlands

Priority wetlands in IUA 8 include the Philipstown unchannelled valley bottom wetland complex, Philipstown depression complex and the Luckhoff depression wetland complex. The main impact is for the Luckhoff depression complex where impacts are from extensive centre pivot irrigation agriculture to the northeast and risks to habitat and water quality.

**Table 68: CERA outcome - risks to associated ecosystem services in IUA 8**

| Environmental Hazard | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                                                                                                       | Likelihood | Consequence   | Risk   |
|----------------------|---------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------|---------------|--------|
| Reduced flow         | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                      | Unlikely   | Insignificant | Low    |
| Reduced flow         | Waterways                 | Fresh Water (Natural Sources) | The implications of implementing EWRs results in a decrease for irrigation supply flows (4.2 million m <sup>3</sup> /annum) | Likely     | Moderate      | High   |
| Sediment             | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                      | Possible   | Major         | High   |
| High nutrients       | Wetlands                  | Habitat for species           | Fauna and flora                                                                                                             | Possible   | Minor         | Medium |
| Climate Change       | Wetlands                  | Habitat for species           | Fauna and flora                                                                                                             | Possible   | Major         | High   |

### 9.13 IUA 9: Upper Modder River - Scenarios and Consequences

#### 9.13.1 Economic Trade-off Analysis

IUA 9 Upper Modder there are no significant changes in the volumes of water supplied within the IUA with the implementation of the EWR flows for both urban (domestic/mine) and irrigation users and would not result in any significant economic trade-offs in the present day, medium term or long-term scenarios.

#### 9.13.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 9 (Upper Modder River) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 69 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

#### **Environmental effect statement for IUA 9:**

- Waterways (Rivers and Riparian Ecosystems)

Scenario flows, with or without the implementation of EWRs, generally align with the flow preferences of the biota. Elevated flows are primarily due to releases from upstream WWTWs.

However, poor water quality resulting from agricultural runoff and WWTW discharges significantly impacts biota, reducing their ability to thrive and altering overall ecological conditions.

- Groundwater

Currently no over abstraction however with a reduced rainfall recharge (less 25%) the stress index of quaternary catchment C52G will increase to 78% and potentially increase the risk for sustainable groundwater provisioning in this quaternary catchment.

- Wetlands

This IUA has one priority wetland, the Aardoringspruit wetland. The main impact to the wetland is from agricultural activities.

**Table 69: CERA outcome - risks to associated ecosystem services in IUA 9**

| Environmental Hazard | Ecological Infrastructure | Ecosystem Service at Risk             | Beneficiaries at Risk                                                                    | Likelihood | Consequence   | Risk   |
|----------------------|---------------------------|---------------------------------------|------------------------------------------------------------------------------------------|------------|---------------|--------|
| Reduced flow         | Waterways                 | Habitats for species                  | Fish and invertebrates                                                                   | Unlikely   | Insignificant | Low    |
| Reduced flow         | Waterways                 | Fresh Water (Natural Sources)         | No water supply deficit to water users                                                   | Unlikely   | Insignificant | Low    |
| Poor water quality   | Waterways                 | Habitats for species                  | Fish and invertebrates                                                                   | Likely     | Major         | High   |
| Over abstraction     | Aquifer                   | Fresh Water (Natural Sources)         | Groundwater users for domestic use (Parts of Bleomfontein MM and Town of Winnie Mandela) | Unlikely   | Minor         | Low    |
| Land transformation  | Wetlands                  | Habitat for species                   | Fauna and flora                                                                          | Possible   | Minor         | Medium |
| High nutrients       | Wetlands                  | Water purification & waste management | Fauna and flora                                                                          | Unlikely   | Moderate      | Medium |

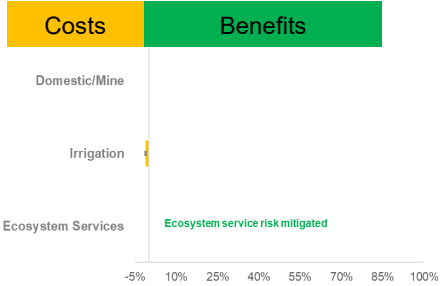
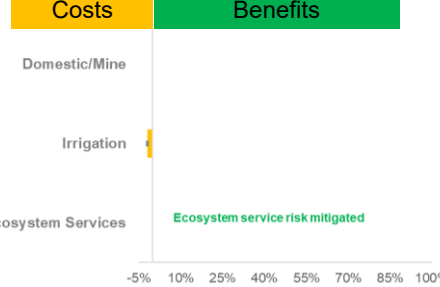
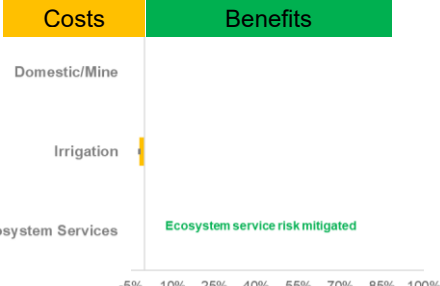
## 9.14 IUA 10: Modder/ Riet River - Scenarios and Consequences


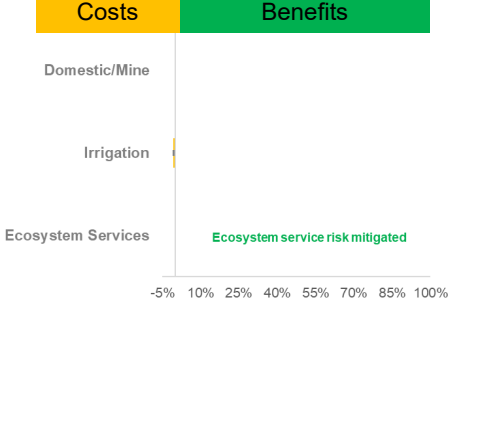
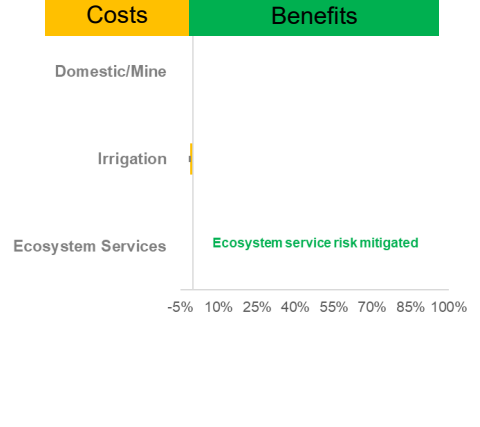
### 9.14.1 Economic Trade-off Analysis

The results of the economic analysis of the effect of the change in water flows for each of the different scenarios for IUA 10 Modder/Riet Rivers flows is evaluated and the consequent effect on the economy is determined as a result of the change in flows (Table 70).

In this IUA there are no significant flow changes for domestic/mining users. The implementation of the EWR in this IUA will only have an impact on the irrigation users. The impacts to the agricultural economy because of these potential supply deficits to irrigation users is seen in the present day, medium term and long-term scenarios. When the EWR is implemented, the impact on the agricultural sector will be less water available for irrigation and thus potentially fewer hectares that can be planted to irrigation agriculture across the IUA with associated economic trade-offs. Across these scenarios, the potential reduced hectares are between 108 to just under 330 ha.

**Table 70: Economic consequences resulting from the EWR impact in each of the analysed scenarios in IUA 10 Modder/Riet Rivers**

| Scenario                                     | Flow impact and socio-economic consequences                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|-------|------|--------|------|
| <p>Present day Scenario 1</p>                |  <p>The chart shows 'Costs' in yellow and 'Benefits' in green. For Domestic/Mine, the bar is at approximately -2%. For Irrigation, the bar is at approximately -1%. For Ecosystem Services, the bar is at approximately 100%, with a note 'Ecosystem service risk mitigated'.</p>   | <p>In IUA 10 Modder/Riet Rivers there are no impacts from urban (domestic/mine) user flows. The irrigation supply flows decrease from 168.3 Mm<sup>3</sup>/a without EWR to 166.4 Mm<sup>3</sup>/a with allocation to the EWR. in the present-day scenario resulting in a deficit of 1.91 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-83.7</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-123</td> </tr> </tbody> </table>      | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -83.7 | Jobs | Number | -123 |
| Macro-economic impacts                       |                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Economy                                      | Indicator                                                                                                                                                                                                                                                                                                                                                            | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Upper Orange River catchment                 | GDP                                                                                                                                                                                                                                                                                                                                                                  | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -83.7                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|                                              | Jobs                                                                                                                                                                                                                                                                                                                                                                 | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | -123                   |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| <p>Medium term (2040) Scenario 2</p>         |  <p>The chart shows 'Costs' in yellow and 'Benefits' in green. For Domestic/Mine, the bar is at approximately -2%. For Irrigation, the bar is at approximately -1%. For Ecosystem Services, the bar is at approximately 100%, with a note 'Ecosystem service risk mitigated'.</p>  | <p>In the medium-term scenario, the impact from the implementation of the EWR is also only for the irrigation users. The irrigation supply flows decrease from 168.1 Mm<sup>3</sup>/a without EWR to 166.2 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 1.84 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-79.6</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-118</td> </tr> </tbody> </table>            | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River catchment | GDP | Million Rand/a | -79.6 | Jobs | Number | -118 |
| Macro-economic impacts                       |                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Economy                                      | Indicator                                                                                                                                                                                                                                                                                                                                                            | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Upper Orange River catchment                 | GDP                                                                                                                                                                                                                                                                                                                                                                  | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -79.6                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|                                              | Jobs                                                                                                                                                                                                                                                                                                                                                                 | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | -118                   |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| <p>Medium term (2040) Scenario 2 estuary</p> |  <p>The chart shows 'Costs' in yellow and 'Benefits' in green. For Domestic/Mine, the bar is at approximately -2%. For Irrigation, the bar is at approximately -1%. For Ecosystem Services, the bar is at approximately 100%, with a note 'Ecosystem service risk mitigated'.</p> | <p>In this alternative medium-term scenario, the impact from the implementation of the EWR is also only for the irrigation users. The irrigation supply flows decrease from 168.1 Mm<sup>3</sup>/a without EWR to 166.0 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 2.05 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River Catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-89</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-131</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River Catchment | GDP | Million Rand/a | -89   | Jobs | Number | -131 |
| Macro-economic impacts                       |                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Economy                                      | Indicator                                                                                                                                                                                                                                                                                                                                                            | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Upper Orange River Catchment                 | GDP                                                                                                                                                                                                                                                                                                                                                                  | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | -89                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|                                              | Jobs                                                                                                                                                                                                                                                                                                                                                                 | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | -131                   |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |

| Scenario                                   | Flow impact and socio-economic consequences                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|--------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|-------|------|--------|------|
| <p>Medium term (2040)<br/>Scenario 2.1</p> |    | <p>In this alternative medium-term scenario, there are no impacts to the domestic/mine users and the impact is for the irrigation users. The irrigation supply flows decrease from 168.1 Mm<sup>3</sup>/a without EWR to 167 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 1.05 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River Catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-45.7</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>67</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River Catchment | GDP | Million Rand/a | -45.7 | Jobs | Number | 67   |
| Macro-economic impacts                     |                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Economy                                    | Indicator                                                                           | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Upper Orange River Catchment               | GDP                                                                                 | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | -45.7                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|                                            | Jobs                                                                                | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 67                     |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| <p>Long Term (2060)<br/>Scenario 3</p>     |   | <p>In the long term the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 168.1 Mm<sup>3</sup>/a without EWR to 167.04 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 1.05 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River Catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-45.8</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-67</td> </tr> </tbody> </table>                              | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River Catchment | GDP | Million Rand/a | -45.8 | Jobs | Number | -67  |
| Macro-economic impacts                     |                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Economy                                    | Indicator                                                                           | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Upper Orange River Catchment               | GDP                                                                                 | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | -45.8                  |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|                                            | Jobs                                                                                | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | -67                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| <p>Long Term (2060)<br/>Scenario 3.1</p>   |  | <p>In this first alternative long-term scenario, the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 167.8 Mm<sup>3</sup>/a without EWR to 165.9 Mm<sup>3</sup>/a with allocation to the EWR. This is a deficit of 1.9 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1"> <thead> <tr> <th colspan="4">Macro-economic impacts</th> </tr> <tr> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River Catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-83</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-123</td> </tr> </tbody> </table>    | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River Catchment | GDP | Million Rand/a | -83   | Jobs | Number | -123 |
| Macro-economic impacts                     |                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Economy                                    | Indicator                                                                           | Unit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Economic Effect        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
| Upper Orange River Catchment               | GDP                                                                                 | Million Rand/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | -83                    |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |
|                                            | Jobs                                                                                | Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | -123                   |  |  |  |         |           |      |                 |                              |     |                |       |      |        |      |

| Scenario                      | Flow impact and socio-economic consequences |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|-------------------------------|---------------------------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--|--|--|---------|-----------|------|-----------------|------------------------------|-----|----------------|-------|------|--------|-----|
| Long Term (2060) Scenario 3.3 |                                             |                | <p>In the third long-term scenario the impacts from the implementation of the EWR are only for the irrigation users. The irrigation supply flows decrease from 167.8 Mm<sup>3</sup>/a without EWR to 167.2 Mm<sup>3</sup>/a with allocation to the EWR. This is a smaller deficit of 0.9 Mm<sup>3</sup>/a as illustrated in the adjacent figure.</p> <p>Analysis shows the following economic trade-offs:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr style="background-color: #4a7ebb; color: white;"> <th colspan="4">Macro-economic impacts</th> </tr> <tr style="background-color: #4a7ebb; color: white;"> <th>Economy</th> <th>Indicator</th> <th>Unit</th> <th>Economic Effect</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Upper Orange River Catchment</td> <td>GDP</td> <td>Million Rand/a</td> <td>-39.7</td> </tr> <tr> <td>Jobs</td> <td>Number</td> <td>-58</td> </tr> </tbody> </table> | Macro-economic impacts |  |  |  | Economy | Indicator | Unit | Economic Effect | Upper Orange River Catchment | GDP | Million Rand/a | -39.7 | Jobs | Number | -58 |
| Macro-economic impacts        |                                             |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Economy                       | Indicator                                   | Unit           | Economic Effect                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
| Upper Orange River Catchment  | GDP                                         | Million Rand/a | -39.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |
|                               | Jobs                                        | Number         | -58                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                        |  |  |  |         |           |      |                 |                              |     |                |       |      |        |     |

### 9.14.2 Comparative Ecological Risk Assessment

The results of the CERA for IUA 10 (Modder/ Riet River) are discussed below. The purpose of this CERA was to assess which ecosystem services are potentially at risk within the overall IUA considering water flows without the allocation of the EWR, water quality and non-flow aspects such as climate change or land transformation. Table 71 highlights the ecological infrastructure with associated ecosystem services that are comparatively rated as being at risk in the IUA.

#### **Environmental effect statement for IUA 10:**

- Waterways (Rivers and Riparian Ecosystems)

Currently the flows with or without the EWR implemented, do not meet the flow requirements for the specified indicator species/taxon during the wet season.

- Groundwater

Three quaternary catchments of the total 16 in IUA 10 have a high stress index and where there is a potential risk to groundwater provisioning. Two quats (D52H and D52J) likely to be over abstracted if rainfall recharge is reduced by 25%. D52H current stress index of 90% and increases to 121% with 25% less rainfall recharge and D52J current stress index of 82% and increasing to 109% with 25% less rainfall recharge.

- Wetlands

There are three priority wetland complexes in IUA 10 and include the Soutpan depression wetland complex, Jagersfontein channelled valley bottom wetland and the Kaalspruit wetland complex. The main impacts at Soutpan and Kaalspruit are from grazing and extensive cultivations which poses risks for water quality, quantity and habitat for unique biota. The past spills at Jagersfontein mine place the water quality for the Jagersfontein wetland and biodiversity at risk.

**Table 71: CERA outcome - risks to associated ecosystem services in IUA 10**

| Environmental Hazard                 | Ecological Infrastructure | Ecosystem Service at Risk     | Beneficiaries at Risk                                                                                                                                           | Likelihood     | Consequence | Risk    |
|--------------------------------------|---------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-------------|---------|
| Reduced flow                         | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                                                          | Likely         | Major       | Extreme |
| Reduced flow                         | Waterways                 | Fresh Water (Natural Sources) | The implications of implementing EWRs results in a decrease for irrigation supply flows (1 million m <sup>3</sup> /annum)                                       | Likely         | Minor       | High    |
| Poor water quality                   | Waterways                 | Habitats for species          | Fish and invertebrates                                                                                                                                          | Likely         | Moderate    | High    |
| Over abstraction (Quats: D52H, D52J) | Aquifer                   | Fresh Water (Natural Sources) | Groundwater users for domestic (towns such as Dealesville and some suburb and small holdings areas of Bloemfontein MM), irrigation users and salt mining users. | Possible       | Moderate    | High*   |
| Land transformation                  | Wetlands                  | Fresh Water (Natural Sources) | Fauna and flora                                                                                                                                                 | Possible       | Minor       | Medium  |
| Land transformation                  | Wetlands                  | Habitat for species           | Fauna and flora                                                                                                                                                 | Almost certain | Moderate    | High    |
| High nutrients                       | Wetlands                  | Fresh Water (Natural Sources) | Downstream water users and wetland habitat                                                                                                                      | Almost certain | Severe      | Extreme |
| Climate Change                       | Wetlands                  | Habitat for species           | Fauna and flora                                                                                                                                                 | Possible       | Moderate    | High    |

\* only a risk in the quaternary catchments where over abstraction is taking place and not a high risk across the entire IUA

### 9.15 Economic trade-off analysis relating to hydropower

The effects of the change in water flows with the implementation of the EWR in the present day, medium term and the long term was evaluated for its combined effect on the hydroelectricity power stations at the Gariep and the Vanderkloof dams. The change in flows was converted into the potential change in the annual average gigawatt hours per annum from these two hydropower stations.

An economic analysis of these changes per scenario was done to estimate the expected impact on the revenue to the electricity sector. Hydropower energy is used by Eskom in its overall energy mix for distribution across South Africa (Table 72). These power stations feed electricity into the national grid and are particularly important for supplying power for peak and emergency demand periods, and the units can come online rapidly within three minutes and contribute to grid stability in these periods. Additional benefits include clean energy production and the lower cost of electricity production from these plants. If these plants are not producing

electricity Eskom must source all needs from the thermal power stations at twice the cost. Together the stations have the generation capacity to produce 590 MW at full load capacity.

The reduction in water flow will result in reduced capability to generate electricity at the two hydroelectricity plants at Gariiep and Vanderkloof dams and would result in a direct loss in revenue for the electricity distribution sector. It will impact the availability of emergency generation capacity in the country, and this may potentially lead to an increased risk of loadshedding with its own associated high economic impact to the economy.

**Table 72: Economic consequences resulting from the EWR impact in each of the analysed scenarios on hydropower electricity generation**

| Scenario                        | Economic impact indicator                |                                                  |
|---------------------------------|------------------------------------------|--------------------------------------------------|
|                                 | GWh loss per scenario estimate per annum | Revenue loss electricity sector (Million Rand/a) |
| Present day Scenario 1          | 20.86                                    | 38.6                                             |
| Medium-term (2040) Scenario 2   | 45.75                                    | 84.6                                             |
| Medium-term (2040) Scenario 2.1 | 4.75                                     | 8.8                                              |
| Long-Term (2060) Scenario 3     | 34.25                                    | 63.4                                             |
| Long-Term (2060) Scenario 3.1   | 52.94                                    | 97.9                                             |
| Long-Term (2060) Scenario 3.3   | 26.36                                    | 48.8                                             |

## 10 SUMMARY OF SCENARIO EVALUATION RESULTS

Table 73 summarises the proposed ecological category against the ESBC, which is the REC, and the recommendations based on the scenario evaluations described in the report, that will be taken forward to inform the water resources class.

**Table 73: Summary of proposed ecological category based on the scenarios evaluated**

| IUA |                     | EWR Site   | River          | Ecological Category |     | Overall Comments/ Recommendations                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----|---------------------|------------|----------------|---------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |                     |            |                | REC (ESBC)          | TEC |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 1   | Golden Gate         | UO_EWR01_R | Little Caledon | B/C                 | B/C | <ul style="list-style-type: none"> <li>No economic impact.</li> <li>Minor trade off on biota in drier months</li> <li>Maintain B/C as TEC.</li> </ul>                                                                                                                                                                                                                                                                                                                                           |
| 2   | Caledon/ Leeu River | UO_EWR01_I | Middle Caledon | D                   | D   | <ul style="list-style-type: none"> <li>No economic impact.</li> <li>Some trade-offs for biota in the drier months.</li> <li>Maintain PES of D - TEC as D</li> <li>Excessive sedimentation impacts from Lesotho; nutrients from Ficksburg.</li> <li><i>Note:</i> Lesotho future development - Lowlands (release from Muela Dam to Hlotsi to augment the supply for domestic use in Lesotho (12-14 million m<sup>3</sup> during extreme dry periods). May develop a dam on the Hlotsi.</li> </ul> |
| 3   | Caledon River       | UO_EWR04_I | Lower Caledon  | C/D                 | C/D | <ul style="list-style-type: none"> <li>Maintain REC as TEC (C/D category)</li> <li>Implement EWR - some implications for local users (irrigation and domestic).</li> <li>IUA will be impacted by development in Lesotho, however this is unknown at this stage.</li> <li>Excessive sedimentation impacts from Lesotho</li> </ul>                                                                                                                                                                |

| IUA |                    | EWR Site   | River       | Ecological Category |     | Overall Comments/ Recommendations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----|--------------------|------------|-------------|---------------------|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |                    |            |             | REC (ESBC)          | TEC |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 4   | Kraai River        | UO_EWR08_I | Lower Kraai | B/C                 | B/C | <ul style="list-style-type: none"> <li>• <b>Implement Scenario 1a</b></li> <li>• No economic impact</li> <li>• Some trade-offs for biota in dry season</li> <li>• System is in balance</li> <li>• Improve baseflow.</li> <li>• Water quality to be managed to prevent further deterioration, specifically from upstream irrigation.</li> <li>• Currently the only free flowing river in the system. Boskraai Dam (site close to Orange River confluence), (Scenario 3.2) will mean that it will no longer be a free-flowing river; loss of natural floods and freshets Trapping of sediments (natural); loss of coarse sediments (gravel). Loss of habitat; loss of armouring; fish migration and longitudinal connectivity (lower portion of reach) will be impacted</li> </ul> |
| 5   | Upper Orange River | UO_EWR02_I | Sterkspruit | C/D                 | D   | <ul style="list-style-type: none"> <li>• PES category - address with non-flow measures.</li> <li>• No trade off</li> <li>• No supply by system because of capacity constraints due to the pipeline from Johana's Hoek Dam to the town, so no releases to the river.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| IUA       | EWR Site                  | River      | Ecological Category                               |            | Overall Comments/ Recommendations |                                                                                                                                                                                                                                                                                                         |
|-----------|---------------------------|------------|---------------------------------------------------|------------|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |                           |            | REC (ESBC)                                        | TEC        |                                   |                                                                                                                                                                                                                                                                                                         |
|           |                           | UO_EWR03_I | Upper Orange                                      | <b>D</b>   | <b>D present status (no EWR)</b>  | <ul style="list-style-type: none"> <li>• Trade -off - no EWR</li> <li>• Limited habitat availability - but representative of the reach</li> <li>• Improvement to C/D is linked to water quality drivers (sedimentation and other water quality issues from the extensive villages)</li> </ul>           |
| <b>6</b>  | <b>Gariiep Dam</b>        | UO_FMP     | Orange River between Gariiep and Vanderkloof dams |            |                                   | <ul style="list-style-type: none"> <li>• No formal consequences</li> <li>• This reach relates to the FMP</li> </ul>                                                                                                                                                                                     |
| <b>7</b>  | <b>Seekoei River</b>      | UO_EWR05_I | Seekoei                                           | <b>C</b>   | <b>C</b>                          | <ul style="list-style-type: none"> <li>• No trade off</li> <li>• Minor economic impact</li> </ul>                                                                                                                                                                                                       |
| <b>8</b>  | <b>Vanderkloof Dam</b>    | UO_EWR10_I | Lower Orange Marksdrift                           | <b>C</b>   | <b>C</b>                          | <ul style="list-style-type: none"> <li>• Ecological requirements achieved (note - limited habitat availability)</li> <li>• Exclusion of the larger floods as part of Reserve will have a significant impact on geomorphology and riparian veg (trade off), and the REC will not be achieved.</li> </ul> |
| <b>9</b>  | <b>Upper Modder River</b> | UO_EWR07_I | Upper Modder                                      | <b>C/D</b> | <b>C/D</b>                        | <ul style="list-style-type: none"> <li>• No trade off; (minor domestic trade off)</li> </ul>                                                                                                                                                                                                            |
| <b>10</b> |                           | UO_EWR06_I | Upper Riet                                        | <b>C</b>   | <b>C</b>                          | <ul style="list-style-type: none"> <li>• Maintain a C</li> </ul>                                                                                                                                                                                                                                        |

| IUA                | EWR Site   | River      | Ecological Category |     | Overall Comments/ Recommendations                                                                                                                            |
|--------------------|------------|------------|---------------------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                    |            |            | REC (ESBC)          | TEC |                                                                                                                                                              |
| Modder-Riet Rivers | UO_EWR09_I | Lower Riet | B/C                 |     | <ul style="list-style-type: none"> <li>Ecology and socio-economic trade-off (irrigation and domestic).</li> <li>Water quality improvements needed</li> </ul> |

EWR: Ecological Water Requirements; REC: Recommended Ecological Category; ESBC: Ecological Sustainable Base Configuration ; TEC: Target Ecological Category

## **11 REFERENCES**

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## **APPENDIX A: Notes from the Planning meeting**



## water & sanitation

Department:  
Water and Sanitation  
REPUBLIC OF SOUTH AFRICA

### Chief Directorate: Water Ecosystems Management

#### The Determination of Water Resource Classes and Associated Resource Quality Objectives in the Upper and Lower Orange Catchments

#### SPECIALIST MEETING: SCENARIO ANALYSIS

#### AGENDA

|                           |                                                                                                                                                                                                                                                                                                                                            |
|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Dates:</b>             | <b>Tuesday, 11<sup>th</sup> February 2025</b>                                                                                                                                                                                                                                                                                              |
| <b>Venues:</b>            | <b>4025 Ndinaye Building, DWS HO</b>                                                                                                                                                                                                                                                                                                       |
| <b>Time:</b>              | <b>10h30 to 13h30</b>                                                                                                                                                                                                                                                                                                                      |
| <b>Chairperson:</b>       | <b>Director: Water Resource Classification - Ms Lebogang Matlala</b>                                                                                                                                                                                                                                                                       |
| <b>Purpose of Meeting</b> | <ul style="list-style-type: none"><li>To present the Orange River System proposed planning scenarios (present day and future) for the analysis as part of the Water Resource Classification Studies.</li><li>To present the proposed groundwater scenarios to be analysed for the groundwater IUAs in the Lower Orange Catchment</li></ul> |

|              |                                                 |             |
|--------------|-------------------------------------------------|-------------|
| <b>10h30</b> | 1 WELCOME AND INTRODUCTIONS                     | Chairperson |
| <b>10h35</b> | 2 ATTENDANCE/APOLOGIES                          | Chairperson |
| <b>10h40</b> | 3 ACCEPTANCE OF AGENDA                          | Chairperson |
| <b>10h45</b> | 4 PURPOSE OF THE MEETING                        | Chairperson |
| <b>10h50</b> | 5 OVERVIEW OF THE STUDY AND OBJECTIVES          | Study Team  |
| <b>10h55</b> | 6 PROPOSED PLANNING SCENARIOS TO BE ANALYSED    | Study Team  |
| <b>11h50</b> | <b><i>Comfort Break</i></b>                     |             |
| <b>12h00</b> | 7 DISCUSSION and AGREEMENT                      | All         |
| <b>12h30</b> | 8 PROPOSED GROUNDWATER SCENARIOS TO BE ANALYSED | Study Team  |
| <b>13h00</b> | 9 DISCUSSION and AGREEMENT                      | All         |
| <b>13h25</b> | 10 CLOSURE AND WAY FORWARD                      | Chairperson |



water & sanitation

Department:  
Water and Sanitation  
REPUBLIC OF SOUTH AFRICA

**Chief Directorate: Water Ecosystems Management**

**Scenarios Meeting - Tuesday 11 February 2025**

**DWS Offices, Boardroom 4025 in Ndiyane Building**

**Attendance**

| <b>NAME</b>               | <b>ORGANISATION</b>                            |
|---------------------------|------------------------------------------------|
| Ms Lebogang Matlala       | DWS: Directorate Water Resource Classification |
| Ms Nolusindiso Jafta      | DWS: Directorate Water Resource Classification |
| Ms Mohlapa Sekoele        | DWS: Directorate Water Resource Classification |
| Ms Koleka Makanda         | DWS: Directorate Water Resource Classification |
| Ms Priya Moodley          | Study Team                                     |
| Mr Trevor Coleman         | Study Team                                     |
| Mr Jonathan Schroder      | Study Team                                     |
| Mr Eddie van Wyk          | Study Team                                     |
| Ms Lee Boyd               | Study Team                                     |
| Mr Kwazikwake Majola      | DWS, D: RD                                     |
| Ms Ndivhuvo Netshiendeulu | DWS, D: RD                                     |
| Ms Nolusindiso Jafta      | DWS, D: WRC                                    |
| Mr Jurgo van Wyk          | DWS, NWRP: WRMP                                |
| Ms Precious Rambasa       | DWS, D: RD                                     |
| Ms Barbara Weston         | DWS, D: RD                                     |
| Ms Celiwe Ntuli           | DWS, D: RD                                     |
| Ms Jolene Towell          | DWS, Upington Office                           |
| Mr Malose Ngoepe          | DWS                                            |
| Ms Timyiko Mpete          | DWS, D: RD                                     |
| Mr Mehari Frezghi         | DWS, D: NWRM                                   |
| Mr Henno Gericke          | DWS: Kimberley Office                          |
| Ms Retha Stassen          | Project Team                                   |
| Mr Luckson Muchingambi    | DWS, D: NWRP                                   |
| Mr Christiaan Schutte     | Project Team                                   |
| Mr Fedzisani Ramusiyi     | DWS                                            |
| Ms Olebogeng Thebe        | DWS: Kimberley Office                          |
| Mr Mongezi Gxama          | DW, D: NWRM                                    |
| Mr Salagae Modukanele     | DWS                                            |
| Dr Dayton Tagwi           | DWS, D: NWMP                                   |

## **Scenarios – working draft**

### **Sources of information**

The scenarios have been drawn from the following sources of information:

- The Upper Orange Reserve Scenarios Report (2024)
- Determination of the EWRs for the Lower Orange Report (2017)
- 2024 Orange River AOA (Report and model)
- Vioolsdrift/Noordoewer Feasibility Study (2020)
- ORASECOM (latest planning studies Reports – was considered in the Upper Orange /reserve)
- Previous completed Reconciliation Strategy for the Orange.
- Estuary documentation? (check with specialist if there is anything additional). List in a bit more detail. Orange Estuary management plan by ORASECOM – relevant?
- Lesotho based docs – Lesotho Lowlands master plan; MCC Irrigation Feasibility; and feasibility / planning for a dam on the Makhalleng and possible Botswana Transfer (check on what was received from Patsie on the associated EWR below the Makhalleng Dam).

### **Scenario variables:**

#### **Development levels/Time slices**

The following development level/time slices are proposed (if aligned with the Upper Orange Reserve).

**Scenario 0:** Natural (completed, and more for the reference and EWR generation)

**Scenario 1:** Present day (year associated with water requirements to be confirmed, but will be within the last few years associated with when PES work was completed)

**Scenario 2:** Medium term (2040 – as per Upper Orange Reserve) with interventions and growth that are relatively well advanced and anticipated, e.g. Polihali, Vioolsdrift etc.

**Scenario 3:** Long term (2060 – as per Upper Orange Reserve) with interventions planned for long-term water supply and system reconciliation, e.g. Verbeeldingskraal, etc.

Alternatively, a 2035 has been completed / developed for the ORASECOM environmental flows work recently conducted. AS it is unlikely that all the large dams are in place by 2035, the option of a 2040 and 2060 are recommended to be continued with. This will also create more continuity with the recent Upper Orange Reserve Study.

#### **Ecological water requirements**

For each scenario (other than Scenario 0 – the Natural), the following will be included:

- a) Without EWRs active and operationalised to show the impacts on ecological water flows and associated consequences of prioritising and maximising consumptive water use and socio-economic supply and development.
- b) With EWRs switched on and active in a prioritised way to show the consequence on the socio-economic sector of prioritising the EWRs implementation. There may be some optimisation of these leading up to and during the workshop. The need to just

replace (override) the scenario results with the latest EWR requirements, or to keep these and create a new unique numbering will be discussed with the DWS and team.

Additional to the a and b for each scenario, an alternative intervention (or combination of such) may also be required for a given time slice. This is of particular importance for the future scenarios, where the interventions may not yet be fully confirmed and committed to. In such case, there will be a decimal number added, e.g. 3.1 and 3.2 for such alternative scenarios within a given time-slice.

### **Intervention options**

The volumes of the proposed interventions on the Orange can be revised as needed through discussions with the DWS / stakeholders. Preliminary proposals are captured below, based on the sources of information and sizes considered in previous planning studies. In some instances, multiple sizes are proposed, especially for the Vioolsdrift Dam, due to it's proximity to the estuary and likely consequences.

| Intervention options * | Capacity (option 1) | Capacity (option 2) | Capacity (option 3) | Comment                                                                                                                                                |
|------------------------|---------------------|---------------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| LHWP2 - Polihali       | 2322                |                     |                     | Design capacity for construction                                                                                                                       |
| Makhaleng              | 1216                |                     |                     | Pre-feasibility Study Phase II                                                                                                                         |
| Vioolsdrift            | 300                 | 600/700             | 2800                | 2216 used for upper orange reserve model.<br>Feasibility ranged from 300 (re-reg focus) to 2800 (yield focus)                                          |
| Verbeeldingskraal      | 1 363               |                     |                     | As per Upper Orange Reserve WRPM.                                                                                                                      |
| Boskraai/Bosberg       | 11 894              | 11 894              |                     | In current WRPM config.<br>Ecological impact concerns.<br>Is this the larger Bosberg dam?<br>Need to check what the dam just on the Kraai is sized at? |
| Raising of Gariep      | TBC                 |                     |                     | Not preferred - high evaporative losses                                                                                                                |

*Notes: \*some interventions such as the Raising of Gariep were identified as options previously considered by the Reconciliation Strategy, but have not bene included in a scenario as there are preferred alternatives that provide a similar indication of the impacts of additional storage in the Upper Orange.*

### **Scenarios Summary**

A summary of the proposed scenarios and associated development levels, interventions and operational considerations is included in the table below.

| Scenario number | Scenario Name                   | Time slice / dev. level | Interventions included            | operations                  |
|-----------------|---------------------------------|-------------------------|-----------------------------------|-----------------------------|
| 0               | Natural                         | N/A                     | none                              |                             |
| 1a              | Present day <u>without</u> EWRs | 2020                    | As per present day (excl. LHWP2). | Supply to users prioritised |

|      |                                                      |      |                                                                                                      |                             |
|------|------------------------------------------------------|------|------------------------------------------------------------------------------------------------------|-----------------------------|
| 1b   | Present day <u>with</u> EWRs                         | 2020 | As per present day (excl. LHWP2)                                                                     | EWR prioritised             |
| 1c   | Present day <u>with</u> adjusted EWRs                |      | Adjusted F14.dat to align with ORS yield impact for lower Orange. River management plan              | Temp option until new dam   |
| 2a   | Medium term without EWRs                             | 2040 | LHWP2-Polihali, Vioolsdrift (size option 2), Gariep to Bloem pipeline                                | Supply to users prioritised |
| 2b   | Medium term with EWRs                                | 2040 | LHWP2-Polihali, Vioolsdrift (size option 2), Gariep to Bloem pipeline                                | EWR prioritised             |
| 2.1a | Medium term alternative <u>without</u> EWRs          | 2040 | LHWP2-Polihali, Vioolsdrift (size option 3), Makhaleng & Botswana Transfer, Gariep to Bloem pipeline | Supply to users prioritised |
| 2.2b | Medium term alternative <u>with</u> EWR              | 2040 | LHWP2-Polihali, Vioolsdrift (size option 3), Makhaleng & Botswana Transfer, Gariep to Bloem pipeline | EWR prioritised             |
| 3a   | Long term without EWRs                               | 2060 | LHWP2-Polihali, Vioolsdrift (size option 1), with Verbeeldingskraal                                  | Supply to users prioritised |
| 3b   | Medium term with EWRs                                | 2060 | LHWP2-Polihali, Vioolsdrift (size option 1), with Verbeeldingskraal                                  | EWR prioritised             |
| 3.1a | Long term alternative 1 <u>without</u> EWRs          | 2060 | LHWP2-Polihali, Vioolsdrift (Size option 2), with Verbeeldingskraal and Makaleng                     | Supply to users prioritised |
| 3.1b | Long term alternative 1 <u>with</u> EWRs             | 2060 | LHWP2-Polihali, Vioolsdrift (Size option 2), with Verbeeldingskraal and Makaleng                     | EWR prioritised             |
| 3.2a | Long term (bigger) alternative 2 <u>without</u> EWRs | 2060 | LHWP2-Polihali, Vioolsdrift (size option 3), with Boskraai and Makaleng                              | Supply to users prioritised |
| 3.2b | Long term alternative 2 <u>with</u> EWRs             | 2060 | LHWP2-Polihali, Vioolsdrift (size option 3), with Boskraai and Makaleng                              | EWR prioritised             |
| 4    | Water Quality                                        | TBC  | If modelling with quality (TDS) is not possible / sufficient                                         |                             |

If additional scenarios are required for estuary sensitivity / response are needed, these will be confirmed with the specialists.

## **Motivation for scenarios and combinations of interventions selected**

- Scenario 1a and 1b are the standard with and without EWR scenarios for the present day.
- Scenario 1c is a temporary compromise scenario. It is proposed as an improvement from the present day with no EWRs, but with impacts on socio-economic consumptive water supply limited until such time as the Vaal and Orange Rivers can be augmented with a new water resource. This compromise scenario includes preliminary or reduced target flows for the following areas:
  - i. Gariep to Vanderkloof with the proposed river management plan
  - ii. Sendelingsdrift having a preliminary EWR that is similar in magnitude and yield impact to the original Orange River Study (ORS) compensation flows, but refined to match the seasonality and flow patterns of a full (rule file based) EWR.
  - iii. Present day flows for the lowest Vaal EWR site (Smitsdrift).
- Scenario 2 is a lower storage option for the medium development level. This includes the smaller Vioolsdrift (size option 2) after the LHWP2- Polihali Dam. The motivation is for a scenario with some additional yield and re-regulation, but with less storage and flooding impacts. The ability to provide sufficient yield in the system to meet water requirements and the baseflows portion of the EWRS will need to be tested and is the likely biggest risk/issue with this scenario.
- Scenario 2.1 is for a higher level of development for the 2040 time slice with the Larger Vioolsdrift (option 3) to create more yield off-set needed due to LHWP2-Polihali and the Dam on the Makhaleng with associated transfers to Botswana. This scenario provides a perspective of greater storage being included.
- Scenario 3 is for the lower storage option for the long term 2060 future scenario. This is for just the reregulation function by Vioolsdrift (size option 3), and the Verbeedingskraal Dam. Again this is to test a scenario with the least storage added. Sufficient yield for water supply and EWR baseflows will need to be tested.
- Scenario 3.1 is for a combination of interventions, not trying to maximise storage, but also including more development than scenario 3.
- Scenario 3.2 is for the largest storage option where the larger dam options are selected including Vioolsdrift (option 3), the bigger Boskraai Dam, and the Makhaleng Dam and Transfer. This scenario is likely to generate sufficient water resources to satisfy the water users and EWR base Flows, but is likely to have a significant impact on floods that propagate down the system and reach the estuary.

While there are possibly more combinations of the intervention options possible, the intention of the scenarios is not to try and optimise the scenarios and sizes of the dams. The intention is rather to consider a practical range of options that caters for the future projected needs, and provides indicative impacts on the ecology.

### **Comments are areas where clarification will be required.**

- Storage required to address low flows and loss of yield. Too much storage however takes away from floods and peaks in the system. Likely need some for m of balance and it likely to include larger sizes of all dam options in a scenario.

- Makhaleng: we need to check the final size of the dam and transfer, as well as the final EWR required below the dam (ORASECOM report – feasibility phase – Makhaleng River Environmental Requirements Report received).
- Lesotho Developments: Hlotse and weirs on the Caledon. Need to confirm likely scenarios and possibly add irrigation schemes (MCC compact).
- Transfers from Gariep to Fish (EC) – confirm volume and align with recons and classification for the Fish. Fish Classification assumed 697 million m<sup>3</sup>/a into the Fish. Abstraction from Gariep is similar at 88 for irrigation and 612 for domestic (700 total).
- Gariep to Bloem pipeline was included in 2040 future reserve scenarios. Confirm correctness and volume.
- Verbeeldingskraal was preferred technical / ecological option. Is an alternative required, e.g. Boskraai? Required to reset/reconcile the orange yield after reductions by upstream dams, e.g. Polihali, Makhaleng.
- The Vaal EWRs do not appear to be influencing Lesotho transfer needs (i.e. operating rule driven), as the Lesotho transfer amounts have been fixed (with annual growth). Only active EWR in the Vaal is Below Grootdraai. Other EWRs were aligned with the present day development level / flows for the Vaal. A key check may be Schmitsdrift (lowest gazetted site just above Douglas). Check if Vaal is meeting these, as well as impact on the Lower Orange if they are or are not?
- Lara notes that the estuary for the Orange experiences dry periods of close to or zero flows. Not being shown in the model. Need to potentially amend
  - Could improve through increasing Namibian irrigation, or
  - Losses might not be fully aligned (like irrigation for really hot periods).

## **APPENDIX B: WRPM Analyses Results**

**Table B-1: Upper Orange IUA 1 - Average annual volume supplied (Mm<sup>3</sup>/a)**

| User type            | Channel number | Channel name     | 1A           | 2A           | 3A           | 1B           | 1C           | 2B           | 2.1A         | 2.1B         | 3B           | 3.1A         | 3.1B         | 3.2A         | 3.2B         | 3.2A         | 3.2B         | 3.3          | 4 |
|----------------------|----------------|------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|---|
| Irrigation           | 4713           | Caledon IRRIG    | 5.637        | 5.626        | 5.636        | 5.637        |              | 5.626        | 5.626        | 5.626        | 5.636        | 5.636        | 5.636        |              |              |              |              | 6.230        |   |
| Irrigation           | 4724           | Caledon IRRIG    | 0.000        | 0.000        | 0.000        | 0.000        |              | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        |              |              |              |              | 0.000        |   |
| Domestic/Mine        | 8052           | Caledon Clarence | 0.600        | 0.600        | 0.600        | 0.600        |              | 0.600        | 0.600        | 0.600        | 0.600        | 0.600        | 0.600        |              |              |              |              | 0.600        |   |
| <b>Irrigation</b>    |                |                  | <b>5.637</b> | <b>5.626</b> | <b>5.636</b> | <b>5.637</b> | <b>0.000</b> | <b>5.626</b> | <b>5.626</b> | <b>5.626</b> | <b>5.636</b> | <b>5.636</b> | <b>5.636</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>6.230</b> |   |
| <b>Domestic/Mine</b> |                |                  | <b>0.600</b> | <b>0.600</b> | <b>0.600</b> | <b>0.600</b> | <b>0.000</b> | <b>0.600</b> | <b>0.600</b> | <b>0.600</b> | <b>0.600</b> | <b>0.600</b> | <b>0.600</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.600</b> |   |
| <b>IUA</b>           |                |                  | <b>6.236</b> | <b>6.226</b> | <b>6.235</b> | <b>6.236</b> | <b>0.000</b> | <b>6.226</b> | <b>6.226</b> | <b>6.226</b> | <b>6.235</b> | <b>6.235</b> | <b>6.235</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>6.830</b> |   |

**Table B-2: Upper Orange IUA 2 - Average annual supplied volume (Mm<sup>3</sup>/a)**

| User type     | Channel number | Channel name         | 1A    | 2A    | 3A    | 1B    | 1C | 2B    | 2.1A  | 2.1B  | 3B    | 3.1A  | 3.1B  | 3.2A | 3.2B | 3.2A | 3.2B | 3.3   | 4 |
|---------------|----------------|----------------------|-------|-------|-------|-------|----|-------|-------|-------|-------|-------|-------|------|------|------|------|-------|---|
| Domestic/Mine | 4784           | CALEDON BERA         | 3.742 | 6.279 | 7.244 | 3.076 |    | 5.143 | 6.279 | 5.144 | 5.928 | 7.234 | 5.927 |      |      |      |      | 5.928 |   |
| Irrigation    | 4715           | CALEDON IRRIG        | 1.338 | 1.337 | 1.339 | 1.338 |    | 1.337 | 1.337 | 1.334 | 1.336 | 1.338 | 1.336 |      |      |      |      | 1.339 |   |
| Irrigation    | 4718           | CALEDON IRRIG        | 5.668 | 5.509 | 5.385 | 4.798 |    | 4.645 | 5.509 | 4.647 | 4.473 | 5.382 | 4.475 |      |      |      |      | 4.473 |   |
| Irrigation    | 4720           | CALEDON IRRIG        | 7.355 | 7.315 | 7.193 | 7.283 |    | 7.138 | 7.315 | 7.138 | 6.872 | 7.189 | 6.872 |      |      |      |      | 6.872 |   |
| Irrigation    | 4728           | CALEDON IRRIG        | 0.490 | 0.519 | 0.499 | 0.490 |    | 0.519 | 0.519 | 0.519 | 0.499 | 0.499 | 0.499 |      |      |      |      | 0.499 |   |
| Irrigation    | 4730           | CALEDON IRRIG        | 1.614 | 1.610 | 1.612 | 1.611 |    | 1.602 | 1.610 | 1.602 | 1.594 | 1.612 | 1.594 |      |      |      |      | 1.594 |   |
| Irrigation    | 4733           | CALEDON IRRIG        | 2.027 | 2.025 | 2.026 | 2.027 |    | 2.025 | 2.025 | 2.025 | 2.026 | 2.026 | 2.026 |      |      |      |      | 2.026 |   |
| Irrigation    | 4734           | CALEDON IRRIG        | 2.294 | 2.295 | 2.297 | 2.294 |    | 2.295 | 2.295 | 2.295 | 2.297 | 2.297 | 2.297 |      |      |      |      | 2.297 |   |
| Irrigation    | 4739           | CALEDON IRRIG        | 2.508 | 2.508 | 2.508 | 2.507 |    | 2.498 | 2.508 | 2.505 | 2.500 | 2.502 | 2.498 |      |      |      |      | 2.501 |   |
| Irrigation    | 4742           | CALEDON IRRIG        | 1.564 | 1.536 | 1.527 | 1.468 |    | 1.435 | 1.536 | 1.435 | 1.396 | 1.527 | 1.396 |      |      |      |      | 1.396 |   |
| Irrigation    | 4749           | CALEDON IRRIG        | 0.873 | 0.860 | 0.850 | 0.812 |    | 0.796 | 0.860 | 0.796 | 0.775 | 0.850 | 0.776 |      |      |      |      | 0.775 |   |
| Domestic/Mine | 4767           | CALEDON MAPOTENG     | 3.691 | 2.429 | 3.218 | 3.691 |    | 2.429 | 2.429 | 2.429 | 3.218 | 3.218 | 3.218 |      |      |      |      | 3.218 |   |
| Domestic/Mine | 4789           | CALEDON MASERU RURAL | 3.706 | 6.650 | 9.420 | 3.065 |    | 5.500 | 6.650 | 5.506 | 7.732 | 9.403 | 7.726 |      |      |      |      | 7.733 |   |
| Domestic/Mine | 4774           | CALEDON MORIJA       | 0.333 | 0.328 | 0.322 | 0.275 |    | 0.270 | 0.328 | 0.270 | 0.265 | 0.322 | 0.265 |      |      |      |      | 0.265 |   |

| User type            | Channel number | Channel name                           | 1A            | 2A            | 3A            | 1B            | 1C           | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A         | 3.2B         | 3.2A         | 3.2B         | 3.3           | 4 |
|----------------------|----------------|----------------------------------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|--------------|--------------|--------------|--------------|---------------|---|
| Irrigation           | 8065           | CALEDON IRRIG                          | 1.080         | 1.046         | 1.023         | 0.902         |              | 0.869         | 1.046         | 0.868         | 0.849         | 1.022         | 0.850         |              |              |              |              | 0.849         |   |
| Domestic/Mine        | 4314           | Caledon Weesspruit                     | 0.021         | 0.663         | 0.663         | 0.663         |              | 0.663         | 0.663         | 0.663         | 0.663         | 0.663         | 0.663         |              |              |              |              | 0.663         |   |
| Domestic/Mine        | 4307           | Caledon HOBHOUSE/TH ABA PATSOE         | 0.013         | 0.505         | 0.694         | 0.410         |              | 0.505         | 0.505         | 0.505         | 0.694         | 0.694         | 0.694         |              |              |              |              | 0.694         |   |
| Domestic/Mine        | 4310           | CALEDON LADYBRAND/ FICKSBURG/ CLOCOLAN | 0.311         | 14.770        | 20.703        | 9.752         |              | 14.581        | 14.770        | 14.581        | 20.230        | 20.640        | 20.230        |              |              |              |              | 20.230        |   |
| Domestic/Mine        | 4316           | CALEDON FOURIESBURG                    | 0.032         | 1.010         | 1.010         | 1.010         |              | 1.010         | 1.010         | 1.010         | 1.010         | 1.010         | 1.010         |              |              |              |              | 1.010         |   |
| Domestic/Mine        | 4329           | CALEDON LESOTHO URBAN                  | 0.149         | 4.671         | 4.639         | 3.977         |              | 3.977         | 4.671         | 3.977         | 3.945         | 4.639         | 3.945         |              |              |              |              | 3.945         |   |
| Domestic/Mine        | 3483           | CALEDON 3483 - HLOTSE LERIBE UR DEM    | 0.075         | 2.998         | 3.629         | 2.367         |              | 2.935         | 2.998         | 2.967         | 3.598         | 3.629         | 3.598         |              |              |              |              | 3.598         |   |
| Domestic/Mine        | 3492           | CALEDON 3492 - MAPOTSOE/BU THA URB     | 0.157         | 4.955         | 4.955         | 4.892         |              | 4.860         | 4.955         | 4.923         | 4.923         | 4.923         | 4.892         |              |              |              |              | 4.923         |   |
| Domestic/Mine        | 3510           | CALEDON MASERU DEMAND                  | 0.082         | 4.261         | 6.091         | 2.588         |              | 4.261         | 4.261         | 4.261         | 6.091         | 6.091         | 6.091         |              |              |              |              | 6.091         |   |
| <b>Irrigation</b>    |                |                                        | <b>26.809</b> | <b>26.559</b> | <b>26.261</b> | <b>25.529</b> | <b>0.000</b> | <b>25.158</b> | <b>26.559</b> | <b>25.164</b> | <b>24.617</b> | <b>26.245</b> | <b>24.619</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>24.621</b> |   |
| <b>Domestic/Mine</b> |                |                                        | <b>12.31</b>  | <b>49.52</b>  | <b>62.59</b>  | <b>35.77</b>  | <b>0.00</b>  | <b>46.13</b>  | <b>49.52</b>  | <b>46.23</b>  | <b>58.30</b>  | <b>62.47</b>  | <b>58.26</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>58.30</b>  |   |
| <b>IUA</b>           |                |                                        | <b>39.121</b> | <b>76.078</b> | <b>88.851</b> | <b>61.294</b> | <b>0.000</b> | <b>71.290</b> | <b>76.078</b> | <b>71.398</b> | <b>82.914</b> | <b>88.713</b> | <b>82.877</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>82.919</b> |   |

**Table B-3: Projected water supplied for Upper Orange IUA 3 - Average annual volume (Mm<sup>3</sup>/a)**

| User type  | Channel number | Channel name         | 1A    | 2A    | 3A    | 1B    | 1C | 2B    | 2.1A  | 2.1B  | 3B    | 3.1A  | 3.1B  | 3.2A | 3.2B | 3.2A | 3.2B | 3.3   | 4 |
|------------|----------------|----------------------|-------|-------|-------|-------|----|-------|-------|-------|-------|-------|-------|------|------|------|------|-------|---|
| Irrigation | 4753           | <b>CALEDON IRRIG</b> | 1.978 | 1.978 | 1.977 | 1.976 |    | 1.975 | 1.978 | 1.975 | 1.975 | 1.977 | 1.975 |      |      |      |      | 1.975 |   |
| Irrigation | 4745           | <b>CALEDON IRRIG</b> | 4.305 | 4.286 | 4.280 | 4.305 |    | 4.286 | 4.286 | 4.286 | 4.280 | 4.280 | 4.280 |      |      |      |      | 4.280 |   |
| Irrigation | 4764           | <b>CALEDON IRRIG</b> | 0.295 | 0.295 | 0.295 | 0.295 |    | 0.295 | 0.295 | 0.295 | 0.295 | 0.295 | 0.295 |      |      |      |      | 0.295 |   |
| Irrigation | 4771           | <b>CALEDON IRRIG</b> | 2.300 | 2.288 | 2.283 | 1.067 |    | 0.970 | 2.283 | 0.984 | 0.953 | 2.279 | 0.940 |      |      |      |      | 0.957 |   |
| Irrigation | 4769           | <b>CALEDON IRRIG</b> | 0.464 | 0.464 | 0.464 | 0.464 |    | 0.464 | 0.464 | 0.464 | 0.464 | 0.464 | 0.464 |      |      |      |      | 0.464 |   |

| User type         | Channel number | Channel name                                                       | 1A            | 2A            | 3A            | 1B            | 1C           | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A         | 3.2B         | 3.2A         | 3.2B         | 3.3           | 4 |
|-------------------|----------------|--------------------------------------------------------------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|--------------|--------------|--------------|--------------|---------------|---|
| Irrigation        | 4775           | CALEDON IRRIG                                                      | 9.280         | 9.242         | 9.224         | 4.020         |              | 3.592         | 9.247         | 3.628         | 3.554         | 9.222         | 3.500         |              |              |              |              | 3.567         |   |
| Irrigation        | 4777           | CALEDON IRRIG                                                      | 3.641         | 3.630         | 3.643         | 1.665         |              | 1.506         | 3.630         | 1.517         | 1.445         | 3.629         | 1.427         |              |              |              |              | 1.450         |   |
| Irrigation        | 4783           | CALEDON IRRIG                                                      | 1.465         | 1.464         | 1.466         | 1.448         |              | 1.437         | 1.464         | 1.456         | 1.456         | 1.463         | 1.446         |              |              |              |              | 1.456         |   |
| Irrigation        | 4758           | CALEDON IRRIG                                                      | 1.252         | 1.252         | 1.255         | 1.252         |              | 1.250         | 1.252         | 1.252         | 1.255         | 1.255         | 1.253         |              |              |              |              | 1.255         |   |
| Domestic/Mine     | 4772           | CALEDON MAFETENG                                                   | 1.428         | 1.915         | 2.054         | 1.428         |              | 1.915         | 1.915         | 1.915         | 2.054         | 2.054         | 2.054         |              |              |              |              | 2.054         |   |
| Domestic/Mine     | 4786           | CALEDON MAFETENG DR                                                | 2.331         | 3.502         | 4.313         | 1.930         |              | 2.901         | 3.503         | 2.904         | 3.531         | 4.300         | 3.528         |              |              |              |              | 3.531         |   |
| Domestic/Mine     | 101            | RIET-MODDER SUBSYSTEM:<br>SMALL USERS & TOWNS ABSTRACTING ALONG WE | 2.509         | 2.501         | 2.500         | 2.501         |              | 2.499         | 2.501         | 2.501         | 2.500         | 2.500         | 2.497         |              |              |              |              | 2.500         |   |
| Domestic/Mine     | 4313           | CALEDON VAN STADENSRUS                                             | 0.095         | 0.095         | 0.095         | 0.095         |              | 0.095         | 0.095         | 0.095         | 0.095         | 0.095         | 0.095         |              |              |              |              | 0.095         |   |
| Domestic/Mine     | 4315           | CALEDON ROUXVILLE                                                  | 0.821         | 0.821         | 0.821         | 0.821         |              | 0.821         | 0.821         | 0.821         | 0.821         | 0.821         | 0.821         |              |              |              |              | 0.821         |   |
| Domestic/Mine     | 4312           | CALEDON SMITHFIELD                                                 | 0.694         | 0.694         | 0.694         | 0.694         |              | 0.694         | 0.694         | 0.694         | 0.694         | 0.694         | 0.694         |              |              |              |              | 0.694         |   |
| <b>Irrigation</b> |                |                                                                    | <b>24.980</b> | <b>24.899</b> | <b>24.888</b> | <b>16.493</b> | <b>0.000</b> | <b>15.774</b> | <b>24.899</b> | <b>15.857</b> | <b>15.677</b> | <b>24.864</b> | <b>15.580</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>15.699</b> |   |
| <b>Irrigation</b> |                |                                                                    | <b>7.877</b>  | <b>9.528</b>  | <b>10.476</b> | <b>7.468</b>  | <b>0.000</b> | <b>8.925</b>  | <b>9.529</b>  | <b>8.930</b>  | <b>9.694</b>  | <b>10.463</b> | <b>9.689</b>  | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>9.694</b>  |   |
| <b>IUA</b>        |                |                                                                    | <b>32.857</b> | <b>34.427</b> | <b>35.364</b> | <b>23.961</b> | <b>0.000</b> | <b>24.698</b> | <b>34.427</b> | <b>24.787</b> | <b>25.372</b> | <b>35.327</b> | <b>25.268</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>25.394</b> |   |

**Table B-4: Projected water supplied for Upper Orange IUA 4 - Average annual volume (Mm<sup>3</sup>/a)**

| User type  | Channel number | Channel name        | 1A     | 2A     | 3A     | 1B     | 1C | 2B     | 2.1A   | 2.1B   | 3B     | 3.1A   | 3.1B   | 3.2A | 3.2B | 3.2A | 3.2B | 3.3    | 4 |
|------------|----------------|---------------------|--------|--------|--------|--------|----|--------|--------|--------|--------|--------|--------|------|------|------|------|--------|---|
| Irrigation | 4797           | UPPER ORANGE: IRRIG | 7.919  | 7.909  | 7.931  | 5.951  |    | 5.839  | 7.912  | 5.943  | 5.945  | 7.914  | 5.881  |      |      |      |      | 5.929  |   |
| Irrigation | 4858           | UPPER ORANGE: IRRIG | 13.313 | 13.286 | 13.341 | 10.695 |    | 10.483 | 13.283 | 10.493 | 10.506 | 13.315 | 10.454 |      |      |      |      | 10.531 |   |
| Irrigation | 4865           | UPPER ORANGE: IRRIG | 3.698  | 3.685  | 3.706  | 3.186  |    | 3.113  | 3.685  | 3.152  | 3.157  | 3.694  | 3.140  |      |      |      |      | 3.160  |   |

| User type            | Channel number | Channel name                       | 1A           | 2A           | 3A           | 1B           | 1C          | 2B           | 2.1A         | 2.1B         | 3B           | 3.1A         | 3.1B         | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3          | 4 |
|----------------------|----------------|------------------------------------|--------------|--------------|--------------|--------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|-------------|--------------|---|
| Irrigation           | 4866           | UPPER ORANGE: IRRIG                | 5.555        | 5.535        | 5.559        | 5.072        |             | 4.963        | 5.535        | 5.027        | 5.035        | 5.544        | 5.003        |             |             |             |             | 5.047        |   |
| Irrigation           | 3132           | UPPER ORANGE: RESOURCE POOR KRAAI  | 9.867        | 9.866        | 9.876        | 9.730        |             | 9.658        | 9.866        | 9.771        | 9.780        | 9.847        | 9.733        |             |             |             |             | 9.798        |   |
| Domestic/Mine        | 4323           | UPPER ORANGE: RHODES / BARKLY EAST | 0.316        | 0.316        | 0.316        | 0.316        |             | 0.316        | 0.316        | 0.316        | 0.316        | 0.316        | 0.316        |             |             |             |             | 0.316        |   |
| Domestic/Mine        | 4328           | UPPER ORANGE: JAMESTOWN            | 0.158        | 0.158        | 0.158        | 0.158        |             | 0.158        | 0.158        | 0.158        | 0.158        | 0.158        | 0.158        |             |             |             |             | 0.158        |   |
| Domestic/Mine        | 4322           | UPPER ORANGE: DORDRECH             | 0.410        | 0.410        | 0.410        | 0.410        |             | 0.410        | 0.410        | 0.410        | 0.410        | 0.410        | 0.410        |             |             |             |             | 0.410        |   |
| <b>Irrigation</b>    |                |                                    | <b>40.35</b> | <b>40.28</b> | <b>40.41</b> | <b>34.63</b> | <b>0.00</b> | <b>34.06</b> | <b>40.28</b> | <b>34.39</b> | <b>34.42</b> | <b>40.31</b> | <b>34.21</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>34.46</b> |   |
| <b>Domestic/Mine</b> |                |                                    | <b>0.88</b>  | <b>0.88</b>  | <b>0.88</b>  | <b>0.88</b>  | <b>0.00</b> | <b>0.88</b>  | <b>0.88</b>  | <b>0.88</b>  | <b>0.88</b>  | <b>0.88</b>  | <b>0.88</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.88</b>  |   |
| <b>IUA</b>           |                |                                    | <b>41.24</b> | <b>41.17</b> | <b>41.30</b> | <b>35.52</b> | <b>0.00</b> | <b>34.94</b> | <b>41.17</b> | <b>35.27</b> | <b>35.31</b> | <b>41.20</b> | <b>35.09</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>35.35</b> |   |

**Table B-5: Projected water supplied for Upper Orange IUA 5 - Average annual volume (Mm<sup>3</sup>/a)**

| User type     | Channel number | Channel name        | 1A    | 2A     | 3A     | 1B    | 1C | 2B     | 2.1A   | 2.1B   | 3B     | 3.1A   | 3.1B   | 3.2A | 3.2B | 3.2A | 3.2B | 3.3    | 4 |
|---------------|----------------|---------------------|-------|--------|--------|-------|----|--------|--------|--------|--------|--------|--------|------|------|------|------|--------|---|
| Domestic/Mine | 4791           | SENQU: MOHALES HOEK | 6.171 | 10.039 | 10.884 | 6.171 |    | 10.030 | 10.039 | 10.030 | 10.875 | 10.042 | 10.753 |      |      |      |      | 10.875 |   |
| Domestic/Mine | 4782           | SENQU: MOKHATLONG   | 1.155 | 1.605  | 1.892  | 1.155 |    | 1.605  | 1.605  | 1.605  | 1.892  | 1.892  | 1.892  |      |      |      |      | 1.892  |   |
| Domestic/Mine | 4790           | SENQU: QUACHAS NEK  | 1.390 | 1.970  | 2.329  | 1.390 |    | 1.966  | 1.970  | 1.966  | 2.325  | 2.329  | 2.325  |      |      |      |      | 2.325  |   |
| Domestic/Mine | 4780           | SENQU: QUITHING     | 0.585 | 1.078  | 1.223  | 0.557 |    | 0.975  | 1.078  | 0.984  | 1.211  | 1.221  | 1.197  |      |      |      |      | 1.216  |   |
| Domestic/Mine | 4778           | SENQU: THABA TSEKA  | 1.362 | 2.010  | 2.405  | 1.362 |    | 2.008  | 2.010  | 2.010  | 2.405  | 2.405  | 2.402  |      |      |      |      | 2.405  |   |
| Irrigation    | 4787           | UPPER ORANGE: IRRIG | 6.033 | 6.033  | 6.034  | 6.033 |    | 6.032  | 6.033  | 6.033  | 6.034  | 6.034  | 6.033  |      |      |      |      | 6.034  |   |

| User type         | Channel number | Channel name                               | 1A            | 2A            | 3A            | 1B            | 1C          | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3           | 4 |
|-------------------|----------------|--------------------------------------------|---------------|---------------|---------------|---------------|-------------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|-------------|-------------|-------------|---------------|---|
| Irrigation        | 4893           | UPPER ORANGE: IRRIG                        | 6.101         | 6.095         | 6.101         | 6.101         |             | 6.095         | 6.095         | 6.095         | 6.101         | 6.101         | 6.101         |             |             |             |             | 6.101         |   |
| Irrigation        | 4900           | UPPER ORANGE: IRRIG                        | 3.027         | 3.026         | 3.027         | 3.027         |             | 3.026         | 3.026         | 3.026         | 3.027         | 3.027         | 3.026         |             |             |             |             | 3.027         |   |
| Irrigation        | 4897           | UPPER ORANGE: IRRIG                        | 2.012         | 2.012         | 2.012         | 1.999         |             | 1.990         | 2.012         | 2.007         | 2.008         | 2.011         | 1.997         |             |             |             |             | 2.007         |   |
| Irrigation        | 4877           | UPPER ORANGE: IRRIG                        | 6.884         | 6.870         | 6.901         | 6.747         |             | 6.716         | 6.870         | 6.795         | 6.842         | 6.878         | 6.766         |             |             |             |             | 6.871         |   |
| Irrigation        | 4884           | UPPER ORANGE: IRRIG                        | 2.848         | 2.848         | 2.848         | 2.848         |             | 2.848         | 2.848         | 2.848         | 2.848         | 2.848         | 2.848         |             |             |             |             | 2.848         |   |
| Irrigation        | 3136           | UPPER ORANGE: IRRIG                        | 6.088         | 6.082         | 6.096         | 5.792         |             | 5.471         | 6.082         | 5.540         | 6.040         | 6.079         | 5.965         |             |             |             |             | 6.070         |   |
| Irrigation        | 3133           | UPPER ORANGE: IRRIG                        | 1.338         | 1.336         | 1.340         | 1.312         |             | 1.302         | 1.336         | 1.321         | 1.329         | 1.335         | 1.313         |             |             |             |             | 1.334         |   |
| Irrigation        | 1878           | UPPER ORANGE: RR239: Orange Riet Canal Irr | 171.060       | 171.060       | 171.060       | 167.820       |             | 170.015       | 171.060       | 171.060       | 171.060       | 171.060       | 170.438       |             |             |             |             | 171.060       |   |
| Domestic/Mine     | 4324           | UPPER ORANGE: VENTERSTAD & OVISTON         | 0.000         | 0.000         | 0.000         | 0.000         |             | 0.000         | 0.000         | 0.000         | 0.000         | 0.000         | 0.000         |             |             |             |             | 0.000         |   |
| Domestic/Mine     | 4321           | UPPER ORANGE: MOLTENO                      | 0.473         | 0.473         | 0.473         | 0.473         |             | 0.473         | 0.473         | 0.473         | 0.473         | 0.473         | 0.473         |             |             |             |             | 0.473         |   |
| Domestic/Mine     | 4320           | UPPER ORANGE: BURGERSDORP                  | 0.284         | 0.284         | 0.284         | 0.284         |             | 0.284         | 0.284         | 0.284         | 0.284         | 0.284         | 0.284         |             |             |             |             | 0.284         |   |
| Domestic/Mine     | 4317           | UPPER ORANGE: STERKSPRUIT                  | 4.766         | 4.766         | 4.766         | 4.734         |             | 4.734         | 4.766         | 4.734         | 4.734         | 4.766         | 4.734         |             |             |             |             | 4.734         |   |
| Domestic/Mine     | 4327           | UPPER ORANGE: ZASTRON/LADY GREY            | 1.862         | 1.862         | 1.862         | 1.862         |             | 1.862         | 1.862         | 1.862         | 1.862         | 1.862         | 1.862         |             |             |             |             | 1.862         |   |
| Domestic/Mine     | 4325           | UPPER ORANGE: ALIWAL NORTH                 | 1.136         | 1.136         | 1.136         | 1.105         |             | 1.105         | 1.136         | 1.136         | 1.136         | 1.136         | 1.105         |             |             |             |             | 1.136         |   |
| <b>Irrigation</b> |                |                                            | <b>205.39</b> | <b>205.36</b> | <b>205.42</b> | <b>201.68</b> | <b>0.00</b> | <b>203.50</b> | <b>205.36</b> | <b>204.72</b> | <b>205.29</b> | <b>205.37</b> | <b>204.49</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>205.35</b> |   |

| User type                 | Channel number | Channel name | 1A     | 2A     | 3A     | 1B     | 1C   | 2B     | 2.1A   | 2.1B   | 3B     | 3.1A   | 3.1B   | 3.2A | 3.2B | 3.2A | 3.2B | 3.3    | 4 |
|---------------------------|----------------|--------------|--------|--------|--------|--------|------|--------|--------|--------|--------|--------|--------|------|------|------|------|--------|---|
| <b>Domestic/<br/>Mine</b> |                |              | 19.18  | 25.22  | 27.25  | 19.09  | 0.00 | 25.04  | 25.22  | 25.09  | 27.20  | 26.41  | 27.03  | 0.00 | 0.00 | 0.00 | 0.00 | 27.20  |   |
| <b>IUA</b>                |                |              | 224.58 | 230.59 | 232.67 | 220.77 | 0.00 | 228.54 | 230.59 | 229.81 | 232.49 | 231.78 | 231.51 | 0.00 | 0.00 | 0.00 | 0.00 | 232.55 |   |

**Table B-6: Projected water supplied for Upper Orange IUA 6 - Average annual volume (Mm<sup>3</sup>/a)**

| User type            | Channel number | Channel name                                       | 1A           | 2A           | 3A           | 1B           | 1C          | 2B           | 2.1A         | 2.1B         | 3B           | 3.1A         | 3.1B         | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3          | 4 |
|----------------------|----------------|----------------------------------------------------|--------------|--------------|--------------|--------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|-------------|--------------|---|
| Domestic/Mine        | 4326           | UPPER ORANGE: BETHULIE                             | 1.474        | 1.539        | 1.651        | 1.474        |             | 1.539        | 1.539        | 1.539        | 1.651        | 1.651        | 1.651        |             |             |             |             | 1.651        |   |
| Irrigation           | 484            | UPPER ORANGE: Irr from Gariep compensation         | 21.912       | 21.913       | 21.913       | 21.503       |             | 21.779       | 21.913       | 21.913       | 21.913       | 21.913       | 21.826       |             |             |             |             | 21.913       |   |
| Irrigation           | 4907           | UPPER ORANGE: IRRIG                                | 1.932        | 1.932        | 1.932        | 1.922        |             | 1.921        | 1.932        | 1.931        | 1.932        | 1.932        | 1.929        |             |             |             |             | 1.932        |   |
| Irrigation           | 4967           | UPPER ORANGE: IRRIG                                | 0.246        | 0.246        | 0.246        | 0.243        |             | 0.239        | 0.246        | 0.245        | 0.246        | 0.246        | 0.244        |             |             |             |             | 0.246        |   |
| Irrigation           | 4976           | UPPER ORANGE: IRRIG                                | 0.906        | 0.907        | 0.907        | 0.897        |             | 0.903        | 0.907        | 0.907        | 0.907        | 0.907        | 0.907        |             |             |             |             | 0.907        |   |
| Domestic/Mine        | 1883           | UPPER ORANGE: Urb Between Gariep & Vdklf           | 3.586        | 4.098        | 4.843        | 3.533        |             | 4.062        | 4.098        | 4.098        | 4.843        | 4.843        | 4.809        |             |             |             |             | 4.843        |   |
| Hydro power          | 2067           | UPPER ORANGE: ORANGE hydroPOWER                    | 0.000        | 0.000        | 0.000        | 0.000        |             | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        |             |             |             |             | 0.000        |   |
| Hydro power          | 2158           | UPPER ORANGE: EXTRA ESKOM DEMAND (FROM GARIEP DAM) | 0.000        | 0.000        | 0.000        | 0.000        |             | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        |             |             |             |             | 0.000        |   |
| <b>Irrigation</b>    |                |                                                    | <b>25.00</b> | <b>25.00</b> | <b>25.00</b> | <b>24.56</b> | <b>0.00</b> | <b>24.84</b> | <b>25.00</b> | <b>25.00</b> | <b>25.00</b> | <b>25.00</b> | <b>24.91</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>25.00</b> |   |
| <b>Domestic/Mine</b> |                |                                                    | <b>5.06</b>  | <b>5.64</b>  | <b>6.49</b>  | <b>5.01</b>  | <b>0.00</b> | <b>5.60</b>  | <b>5.64</b>  | <b>5.64</b>  | <b>6.49</b>  | <b>6.49</b>  | <b>6.46</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>6.49</b>  |   |

|                    |  |  |              |              |              |              |             |              |              |              |              |              |              |             |             |             |             |              |             |
|--------------------|--|--|--------------|--------------|--------------|--------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|-------------|--------------|-------------|
| <b>Hydro power</b> |  |  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b> | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b>  | <b>0.00</b> |
| <b>IUA</b>         |  |  | <b>30.06</b> | <b>30.63</b> | <b>31.49</b> | <b>29.57</b> | <b>0.00</b> | <b>30.44</b> | <b>30.63</b> | <b>30.63</b> | <b>31.49</b> | <b>31.49</b> | <b>31.37</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>31.49</b> |             |

**Table B-7: Projected water supplied for Upper Orange IUA 7 - Average annual volume (Mm<sup>3</sup>/a)**

| User type                 | Channel number | Channel name        | 1A          | 2A          | 3A          | 1B          | 1C          | 2B          | 2.1A        | 2.1B        | 3B          | 3.1A        | 3.1B        | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3         | 4 |
|---------------------------|----------------|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---|
| Irrigation                | 4993           | UPPER ORANGE: IRRIG | 0.187       | 0.187       | 0.187       | 0.187       |             | 0.187       | 0.187       | 0.187       | 0.187       | 0.187       | 0.187       |             |             |             |             | 0.187       |   |
| Irrigation                | 4987           | UPPER ORANGE: IRRIG | 0.107       | 0.107       | 0.108       | 0.062       |             | 0.059       | 0.107       | 0.062       | 0.061       | 0.107       | 0.059       |             |             |             |             | 0.062       |   |
| Irrigation                | 4995           | UPPER ORANGE: IRRIG | 0.237       | 0.237       | 0.238       | 0.134       |             | 0.128       | 0.237       | 0.135       | 0.133       | 0.237       | 0.128       |             |             |             |             | 0.133       |   |
| Irrigation                | 4983           | UPPER ORANGE: IRRIG | 0.369       | 0.369       | 0.367       | 0.190       |             | 0.180       | 0.369       | 0.187       | 0.186       | 0.368       | 0.179       |             |             |             |             | 0.185       |   |
| Irrigation                | 4989           | UPPER ORANGE: IRRIG | 0.055       | 0.055       | 0.055       | 0.055       |             | 0.055       | 0.055       | 0.055       | 0.055       | 0.055       | 0.055       |             |             |             |             | 0.055       |   |
| Irrigation                | 4000           | UPPER ORANGE: IRRIG | 0.391       | 0.391       | 0.391       | 0.386       |             | 0.389       | 0.391       | 0.391       | 0.391       | 0.391       | 0.391       |             |             |             |             | 0.391       |   |
| <b>Irrigation</b>         |                |                     | <b>1.34</b> | <b>1.34</b> | <b>1.35</b> | <b>1.01</b> | <b>0.00</b> | <b>1.00</b> | <b>1.34</b> | <b>1.02</b> | <b>1.01</b> | <b>1.35</b> | <b>1.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>1.01</b> |   |
| <b>Domestic/<br/>Mine</b> |                |                     | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> |   |
| <b>IUA</b>                |                |                     | <b>1.34</b> | <b>1.34</b> | <b>1.35</b> | <b>1.01</b> | <b>0.00</b> | <b>1.00</b> | <b>1.34</b> | <b>1.02</b> | <b>1.01</b> | <b>1.35</b> | <b>1.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>1.01</b> |   |

**Table B-8: Projected water supplied for Upper Orange IUA 8 - Average annual volume (Mm<sup>3</sup>/a)**

| User type     | Channel number | Channel name                       | 1A          | 2A          | 3A          | 1B          | 1C | 2B      | 2.1A        | 2.1B        | 3B          | 3.1A        | 3.1B        | 3.2A | 3.2B | 3.2A | 3.2B | 3.3         | 4 |
|---------------|----------------|------------------------------------|-------------|-------------|-------------|-------------|----|---------|-------------|-------------|-------------|-------------|-------------|------|------|------|------|-------------|---|
| Domestic/Mine | 1745           | UPPER ORANGE: Hopetown urban       | 2.421       | 3.254       | 4.364       | 2.383       |    | 3.225   | 3.254       | 3.254       | 4.364       | 4.364       | 4.334       |      |      |      |      | 4.364       |   |
| Irrigation    | 1743           | UPPER ORANGE: Irr Vdklf to Torquay | 171.03<br>1 | 171.03<br>1 | 171.03<br>1 | 168.24<br>5 |    | 169.115 | 171.03<br>1 | 171.03<br>1 | 171.03<br>1 | 171.03<br>1 | 169.53<br>4 |      |      |      |      | 171.03<br>1 |   |
| Irrigation    | 1853           | UPPER ORANGE: Ramah Canal          | 57.615      | 57.615      | 57.615      | 56.637      |    | 57.063  | 57.615      | 57.615      | 57.615      | 57.615      | 57.174      |      |      |      |      | 57.615      |   |

| User type            | Channel number | Channel name                                    | 1A            | 2A            | 3A            | 1B            | 1C          | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3           | 4 |
|----------------------|----------------|-------------------------------------------------|---------------|---------------|---------------|---------------|-------------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|-------------|-------------|-------------|---------------|---|
| Irrigation           | 2171           | UPPER ORANGE: RESOURCE POOR                     | 26.146        | 26.146        | 26.146        | 25.699        |             | 25.894        | 26.146        | 26.146        | 26.146        | 26.146        | 25.944        |             |             |             |             | 26.146        |   |
| Hydro power          | 2159           | UPPER ORANGE: EXTRA ESKOM DEMAND (FROM VDK DAM) | 0.000         | 0.000         | 0.000         | 0.000         |             | 0.000         | 0.000         | 0.000         | 0.000         | 0.000         | 0.000         |             |             |             |             | 0.000         |   |
| <b>Irrigation</b>    |                |                                                 | <b>254.79</b> | <b>254.79</b> | <b>254.79</b> | <b>250.58</b> | <b>0.00</b> | <b>252.07</b> | <b>254.79</b> | <b>254.79</b> | <b>254.79</b> | <b>254.79</b> | <b>252.65</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>254.79</b> |   |
| <b>Domestic/Mine</b> |                |                                                 | <b>2.42</b>   | <b>3.25</b>   | <b>4.36</b>   | <b>2.38</b>   | <b>0.00</b> | <b>3.23</b>   | <b>3.25</b>   | <b>3.25</b>   | <b>4.36</b>   | <b>4.36</b>   | <b>4.33</b>   | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>4.36</b>   |   |
| <b>Hydro power</b>   |                |                                                 | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b> | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b>   |   |
| <b>IUA</b>           |                |                                                 | <b>257.21</b> | <b>258.05</b> | <b>259.16</b> | <b>252.96</b> | <b>0.00</b> | <b>255.30</b> | <b>258.05</b> | <b>258.05</b> | <b>259.16</b> | <b>259.16</b> | <b>256.99</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>259.16</b> |   |

**Table B-9: Projected water supplied for Upper Orange IUA 9 - Average annual volume (Mm<sup>3</sup>/a)**

| User type         | Channel number | Channel name                                                     | 1A     | 2A     | 3A          | 1B     | 1C | 2B     | 2.1A   | 2.1B   | 3B          | 3.1A        | 3.1B        | 3.2A | 3.2B | 3.2A | 3.2B | 3.3         | 4 |
|-------------------|----------------|------------------------------------------------------------------|--------|--------|-------------|--------|----|--------|--------|--------|-------------|-------------|-------------|------|------|------|------|-------------|---|
| Domestic/<br>Mine | 950            | RIET-MODDER SUBSYSTEM: Bloemfontein consumptive use              | 73.981 | 84.258 | 101.53<br>5 | 73.933 |    | 84.160 | 84.268 | 84.206 | 101.49<br>2 | 101.50<br>5 | 101.43<br>7 |      |      |      |      | 101.50<br>2 |   |
| Domestic/<br>Mine | 943            | RIET-MODDER SUBSYSTEM: Botshabelo dem                            | 19.078 | 24.570 | 39.777      | 19.101 |    | 24.604 | 24.570 | 24.614 | 39.755      | 39.766      | 39.731      |      |      |      |      | 39.765      |   |
| Irrigation        | 962            | RIET-MODDER SUBSYSTEM: KRUGERSDRIFT MAINSTREAM IRRIG DEMAND (RR) | 6.577  | 6.586  | 6.598       | 6.577  |    | 6.586  | 6.586  | 6.586  | 6.598       | 6.598       | 6.598       |      |      |      |      | 6.598       |   |
| Irrigation        | 955            | RIET-MODDER SUBSYSTEM: KRUGERSDRIFT MAINSTREAM IRRIG DEMAND (RR) | 4.479  | 4.485  | 4.489       | 4.461  |    | 4.478  | 4.485  | 4.485  | 4.489       | 4.489       | 4.482       |      |      |      |      | 4.489       |   |
| Domestic/Min<br>e | 1700           | RIET-MODDER SUBSYSTEM: Manguang LM                               | 0.000  | 0.000  | 0.000       | 0.000  |    | 0.000  | 0.000  | 0.000  | 0.000       | 0.000       | 0.000       |      |      |      |      | 0.000       |   |

| User type                 | Channel number | Channel name                                                    | 1A            | 2A            | 3A            | 1B            | 1C          | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3           | 4 |
|---------------------------|----------------|-----------------------------------------------------------------|---------------|---------------|---------------|---------------|-------------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|-------------|-------------|-------------|---------------|---|
|                           |                | Demand supplied from Rustfon                                    |               |               |               |               |             |               |               |               |               |               |               |             |             |             |             |               |   |
| Irrigation                | 935            | RIET-MODDER SUBSYSTEM: MOCKE'S DD IRRIG DEMAND (RR416)          | 0.130         | 0.130         | 0.130         | 0.130         |             | 0.130         | 0.130         | 0.130         | 0.130         | 0.130         | 0.130         |             |             |             |             | 0.130         |   |
| Irrigation                | 944            | RIET-MODDER SUBSYSTEM: MOCKE'S MAINSTREAM IRRIG DEMAND (RR420)  | 0.447         | 0.677         | 0.689         | 0.449         |             | 0.676         | 0.677         | 0.676         | 0.689         | 0.689         | 0.689         |             |             |             |             | 0.689         |   |
| Irrigation                | 967            | RIET-MODDER SUBSYSTEM: RUSTFONTEIN DD IRRIG DEMAND (RR435)      | 1.067         | 1.061         | 1.062         | 1.067         |             | 1.061         | 1.061         | 1.061         | 1.062         | 1.062         | 1.062         |             |             |             |             | 1.062         |   |
| Irrigation                | 971            | RIET-MODDER SUBSYSTEM: RUSTFONTEIN MAINSTREAM IRRIG DEMAND (RR4 | 0.161         | 0.127         | 0.127         | 0.161         |             | 0.127         | 0.128         | 0.127         | 0.128         | 0.127         | 0.128         |             |             |             |             | 0.128         |   |
| Domestic/Min<br>e         | 748            | RIET-MODDER SUBSYSTEM: ThabaN'Chu dem                           | 3.723         | 14.312        | 18.356        | 3.716         |             | 14.220        | 14.295        | 14.238        | 18.356        | 18.358        | 18.360        |             |             |             |             | 18.355        |   |
| Domestic/Min<br>e         | 3127           | RIET-MODDER SUBSYSTEM: KRUGERSDRIFT URBAN                       | 0.352         | 0.487         | 0.680         | 0.352         |             | 0.487         | 0.487         | 0.487         | 0.680         | 0.680         | 0.680         |             |             |             |             | 0.680         |   |
| Domestic/Min<br>e         | 8073           | RIET-MODDER SUBSYSTEM: MOCKE'S MAINSTREAM IRRIG DEMAND (RR420)  | 0.819         | 0.840         | 0.868         | 0.820         |             | 0.841         | 0.842         | 0.841         | 0.869         | 0.868         | 0.869         |             |             |             |             | 0.869         |   |
| <b>Irrigation</b>         |                |                                                                 | <b>16.59</b>  | <b>27.38</b>  | <b>31.45</b>  | <b>16.56</b>  | <b>0.00</b> | <b>27.28</b>  | <b>27.36</b>  | <b>27.30</b>  | <b>31.45</b>  | <b>31.45</b>  | <b>31.45</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>31.45</b>  |   |
| <b>Domestic/Min<br/>e</b> |                |                                                                 | <b>97.95</b>  | <b>124.47</b> | <b>161.22</b> | <b>97.92</b>  | <b>0.00</b> | <b>124.31</b> | <b>124.46</b> | <b>124.39</b> | <b>161.15</b> | <b>161.18</b> | <b>161.08</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>161.17</b> |   |
| <b>IUA</b>                |                |                                                                 | <b>114.54</b> | <b>151.84</b> | <b>192.67</b> | <b>114.48</b> | <b>0.00</b> | <b>151.59</b> | <b>151.82</b> | <b>151.69</b> | <b>192.61</b> | <b>192.63</b> | <b>192.53</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>192.62</b> |   |

**Table B-10: Projected water supplied for Upper Orange IUA 10 - Average annual volume (Mm<sup>3</sup>/a)**

| User type      | Channel number | Channel name                                                     | 1A     | 2A     | 3A     | 1B     | 1C | 2B     | 2.1A   | 2.1B   | 3B     | 3.1A   | 3.1B   | 3.2A | 3.2B | 3.2A | 3.2B | 3.3    | 4 |
|----------------|----------------|------------------------------------------------------------------|--------|--------|--------|--------|----|--------|--------|--------|--------|--------|--------|------|------|------|------|--------|---|
| Irrigation     | 473            | RIET-MODDER SUBSYSTEM: KALKFONTEIN DAM IRRIG DEMAND (RR472)      | 4.755  | 4.755  | 4.755  | 4.750  |    | 4.750  | 4.755  | 4.750  | 4.750  | 4.755  | 4.750  |      |      |      |      | 4.750  |   |
| Irrigation     | 195            | RIET-MODDER SUBSYSTEM: KALKFONTEIN DD IRRIG DEMAND (RR468)       | 10.830 | 10.830 | 10.830 | 10.830 |    | 10.830 | 10.830 | 10.830 | 10.830 | 10.830 | 10.830 |      |      |      |      | 10.830 |   |
| Irrigation     | 490            | RIET-MODDER SUBSYSTEM: LOWER RIET MAINSTREAM IRRIG DEMAND (RR48) | 65.198 | 65.198 | 65.198 | 63.523 |    | 62.180 | 65.198 | 64.213 | 64.217 | 64.938 | 63.206 |      |      |      |      | 64.359 |   |
| Irrigation     | 981            | RIET-MODDER SUBSYSTEM: MODDER: DD 444 IRRIG DEMAND (RR445)       | 0.998  | 0.998  | 0.998  | 0.998  |    | 0.998  | 0.998  | 0.998  | 0.998  | 0.998  | 0.998  |      |      |      |      | 0.998  |   |
| Irrigation     | 986            | RIET-MODDER SUBSYSTEM: MODDER: DD 448 IRRIG DEMAND (RR453)       | 9.952  | 9.980  | 9.980  | 9.927  |    | 9.980  | 9.980  | 9.980  | 9.980  | 9.980  | 9.980  |      |      |      |      | 9.980  |   |
| Irrigation     | 989            | RIET-MODDER SUBSYSTEM: MODDER: DD 449 IRRIG DEMAND (RR454)       | 9.912  | 9.979  | 9.980  | 9.908  |    | 9.980  | 9.979  | 9.980  | 9.980  | 9.980  | 9.980  |      |      |      |      | 9.980  |   |
| Irrigation     | 992            | RIET-MODDER SUBSYSTEM: MODDER: DD 450 IRRIG DEMAND (RR455)       | 9.905  | 9.962  | 9.980  | 9.892  |    | 9.967  | 9.962  | 9.967  | 9.980  | 9.980  | 9.980  |      |      |      |      | 9.980  |   |
| Domestic /Mine | 1843           | RIET-MODDER SUBSYSTEM: Richie Town                               | 5.753  | 6.560  | 7.634  | 5.708  |    | 6.544  | 6.560  | 6.560  | 7.634  | 7.634  | 7.627  |      |      |      |      | 7.634  |   |
| Irrigation     | 1973           | RIET-MODDER SUBSYSTEM: RIET RIVER IRRIGATION DEMAND              | 8.028  | 7.738  | 7.738  | 7.938  |    | 7.651  | 7.738  | 7.738  | 7.738  | 7.738  | 7.650  |      |      |      |      | 7.738  |   |
| Irrigation     | 996            | RIET-MODDER SUBSYSTEM: RR342: KALKFONTEIN                        | 38.622 | 38.622 | 38.622 | 38.622 |    | 38.622 | 38.622 | 38.622 | 38.622 | 38.622 | 38.622 |      |      |      |      | 38.622 |   |

| User type                 | Channel number | Channel name                                                    | 1A            | 2A            | 3A            | 1B            | 1C          | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3           | 4 |
|---------------------------|----------------|-----------------------------------------------------------------|---------------|---------------|---------------|---------------|-------------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|-------------|-------------|-------------|---------------|---|
|                           |                | CANALS IRRIG ABSTRACT                                           |               |               |               |               |             |               |               |               |               |               |               |             |             |             |             |               |   |
| Irrigation                | 483            | RIET-MODDER SUBSYSTEM: SCHOLTZBURG MAINSTREAM IRRIG DEMAND (RR4 | 2.235         | 2.124         | 2.124         | 2.209         |             | 2.100         | 2.124         | 2.124         | 2.124         | 2.124         | 2.102         |             |             |             |             | 2.124         |   |
| Irrigation                | 152            | RIET-MODDER SUBSYSTEM: TIERPOORT DAM IRRIG DEMAND (RR469)       | 6.571         | 6.572         | 6.569         | 6.508         |             | 6.506         | 6.571         | 6.507         | 6.507         | 6.571         | 6.507         |             |             |             |             | 6.508         |   |
| Irrigation                | 144            | RIET-MODDER SUBSYSTEM: TIERPOORT DD IRRIG DEMAND (RR458)        | 0.545         | 0.545         | 0.545         | 0.545         |             | 0.545         | 0.545         | 0.545         | 0.545         | 0.545         | 0.545         |             |             |             |             | 0.545         |   |
| Irrigation                | 147            | RIET-MODDER SUBSYSTEM: TIERPOORT MAINSTREAM IRRIG DEMAND (RR461 | 0.768         | 0.767         | 0.770         | 0.764         |             | 0.766         | 0.768         | 0.765         | 0.765         | 0.768         | 0.764         |             |             |             |             | 0.763         |   |
| Domestic/Min<br>e         | 3128           | RIET-MODDER SUBSYSTEM: KALKFONTEIN URBAN                        | 5.093         | 6.257         | 7.842         | 5.093         |             | 6.257         | 6.257         | 6.257         | 7.842         | 7.842         | 7.842         |             |             |             |             | 7.842         |   |
| <b>Irrigation</b>         |                |                                                                 | <b>168.32</b> | <b>168.07</b> | <b>168.09</b> | <b>166.41</b> | <b>0.00</b> | <b>164.88</b> | <b>168.07</b> | <b>167.02</b> | <b>167.04</b> | <b>167.83</b> | <b>165.92</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>167.18</b> |   |
| <b>Domestic/Mi<br/>ne</b> |                |                                                                 | <b>10.85</b>  | <b>12.82</b>  | <b>15.48</b>  | <b>10.80</b>  | <b>0.00</b> | <b>12.80</b>  | <b>12.82</b>  | <b>12.82</b>  | <b>15.48</b>  | <b>15.48</b>  | <b>15.47</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>15.48</b>  |   |
| <b>IUA</b>                |                |                                                                 | <b>179.17</b> | <b>180.89</b> | <b>183.57</b> | <b>177.21</b> | <b>0.00</b> | <b>177.68</b> | <b>180.89</b> | <b>179.84</b> | <b>182.51</b> | <b>183.31</b> | <b>181.39</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>182.65</b> |   |

**Table B-11: Projected water supplied for Lower Orange IUA 1 - Average annual volume (Mm<sup>3</sup>/a)**

| User type                 | Channel number | Channel name               | 1A            | 2A            | 3A            | 1B            | 1C          | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3           | 4 |
|---------------------------|----------------|----------------------------|---------------|---------------|---------------|---------------|-------------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|-------------|-------------|-------------|---------------|---|
| Irrigation                | 1846           | IRRIG Boegoeberg upstream  | 169.44        | 170.14        | 167.09        | 157.84        |             | 158.20        | 172.37        | 167.09        | 160.19        | 161.94        | 150.59        |             |             |             |             | 161.54        |   |
| Irrigation                | 1866           | IRRIG Uppington            | 131.25        | 131.82        | 129.46        | 122.06        |             | 122.51        | 133.55        | 129.46        | 124.12        | 125.47        | 116.66        |             |             |             |             | 125.16        |   |
| Irrigation                | 1854           | IRRIG boegoeberg           | 127.85        | 128.41        | 126.11        | 118.95        |             | 119.39        | 130.10        | 126.12        | 120.90        | 122.23        | 113.64        |             |             |             |             | 121.92        |   |
| Irrigation                | 1855           | IRRIG Uppington            | 87.87         | 88.24         | 86.66         | 81.73         |             | 82.01         | 89.40         | 86.66         | 83.08         | 83.99         | 78.10         |             |             |             |             | 83.78         |   |
| Irrigation                | 1897           | IRRIG keimoes weir         | 66.38         | 66.66         | 65.46         | 61.72         |             | 61.94         | 67.53         | 65.46         | 62.76         | 63.45         | 58.99         |             |             |             |             | 63.29         |   |
| Domestic/<br>Mine         | 1884           | Kakamas Urban Demand       | 2.52          | 3.03          | 3.03          | 2.49          |             | 3.02          | 3.03          | 3.03          | 3.03          | 3.03          | 3.01          |             |             |             |             | 3.03          |   |
| Domestic/<br>Mine         | 1842           | Prieska Urban Demand       | 1.77          | 2.06          | 2.06          | 1.75          |             | 2.05          | 2.06          | 2.06          | 2.06          | 2.06          | 2.05          |             |             |             |             | 2.06          |   |
| Domestic/<br>Mine         | 1893           | Uppington and others Urban | 38.20         | 45.50         | 45.49         | 37.69         |             | 45.33         | 45.50         | 45.50         | 45.49         | 45.49         | 45.25         |             |             |             |             | 45.49         |   |
| <b>Irrigation</b>         |                |                            | <b>582.79</b> | <b>585.28</b> | <b>574.78</b> | <b>542.31</b> | <b>0.00</b> | <b>544.04</b> | <b>592.96</b> | <b>574.80</b> | <b>551.05</b> | <b>557.07</b> | <b>517.98</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>555.70</b> |   |
| <b>Domestic/<br/>Mine</b> |                |                            | <b>42.49</b>  | <b>50.60</b>  | <b>50.58</b>  | <b>41.92</b>  | <b>0.00</b> | <b>50.40</b>  | <b>50.60</b>  | <b>50.60</b>  | <b>50.58</b>  | <b>50.58</b>  | <b>50.32</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>50.58</b>  |   |
| <b>IUA</b>                |                |                            | <b>625.29</b> | <b>635.88</b> | <b>625.35</b> | <b>584.23</b> | <b>0.00</b> | <b>594.44</b> | <b>643.56</b> | <b>625.40</b> | <b>601.63</b> | <b>607.65</b> | <b>568.29</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>606.28</b> |   |

**TableB-12: Projected water supplied for Lower Orange IUA 2 - Average annual volume (Mm<sup>3</sup>/a)**

| User type  | Channel number | Channel name                                | 1A          | 2A          | 3A          | 1B          | 1C | 2B          | 2.1A        | 2.1B        | 3B          | 3.1A        | 3.1B        | 3.2A | 3.2B | 3.2A | 3.2B | 3.3         | 4 |
|------------|----------------|---------------------------------------------|-------------|-------------|-------------|-------------|----|-------------|-------------|-------------|-------------|-------------|-------------|------|------|------|------|-------------|---|
| Irrigation | 1927           | LOWER ORANGE SUBSYSTEM: IRRIG Neusberg weir | 134.89<br>3 | 135.48<br>6 | 133.05<br>4 | 125.42<br>9 |    | 125.87<br>6 | 137.26<br>4 | 133.06<br>0 | 127.56<br>2 | 128.95<br>5 | 119.89<br>3 |      |      |      |      | 128.63<br>9 |   |
| Irrigation | 1857           | LOWER ORANGE SUBSYSTEM: IRRIG Neusberg weir | 35.993      | 36.151      | 35.502      | 33.470      |    | 33.586      | 36.625      | 35.503      | 34.037      | 34.409      | 31.990      |      |      |      |      | 34.324      |   |

| User type                 | Channel number | Channel name                                         | 1A            | 2A            | 3A            | 1B            | 1C          | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3           | 4 |
|---------------------------|----------------|------------------------------------------------------|---------------|---------------|---------------|---------------|-------------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|-------------|-------------|-------------|---------------|---|
| Irrigation                | 1898           | LOWER ORANGE SUBSYSTEM: Namakwa Irrigation           | 66.361        | 66.646        | 65.452        | 61.718        |             | 61.969        | 67.515        | 65.450        | 62.750        | 63.435        | 58.975        |             |             |             |             | 63.279        |   |
| Irrigation                | 1894           | LOWER ORANGE SUBSYSTEM: Namakwa Irrigation           | 14.381        | 14.439        | 14.180        | 13.376        |             | 13.429        | 14.628        | 14.181        | 13.595        | 13.743        | 12.778        |             |             |             |             | 13.710        |   |
| Domestic/<br>Mine         | 1900           | LOWER ORANGE SUBSYSTEM: Namakwa Mine and Urban       | 15.054        | 15.054        | 15.054        | 14.855        |             | 15.040        | 15.054        | 15.054        | 15.054        | 15.054        | 14.961        |             |             |             |             | 15.054        |   |
| Irrigation                | 1859           | LOWER ORANGE SUBSYSTEM: Namibia Irrigation (Namakwa) | 9.662         | 9.705         | 9.529         | 8.986         |             | 9.017         | 9.833         | 9.532         | 9.136         | 9.236         | 8.586         |             |             |             |             | 9.213         |   |
| Domestic/<br>Mine         | 1818           | LOWER ORANGE SUBSYSTEM: Springbok Mine and Urban     | 10.376        | 12.135        | 12.130        | 10.239        |             | 12.123        | 12.135        | 12.135        | 12.130        | 12.130        | 12.085        |             |             |             |             | 12.130        |   |
| Domestic/<br>Mine         | 3129           | LOWER ORANGE SUBSYSTEM: ARIAMSVLEI ETC               | 0.416         | 0.459         | 0.459         | 0.410         |             | 0.458         | 0.459         | 0.459         | 0.459         | 0.459         | 0.456         |             |             |             |             | 0.459         |   |
| Irrigation                | 3139           | LOWER ORANGE SUBSYSTEM: RES SOURCE POOR              | 43.997        | 59.590        | 59.590        | 43.343        |             | 59.494        | 59.590        | 59.590        | 59.590        | 59.590        | 59.176        |             |             |             |             | 59.590        |   |
| <b>Irrigation</b>         |                |                                                      | <b>305.29</b> | <b>322.02</b> | <b>317.31</b> | <b>286.32</b> | <b>0.00</b> | <b>303.37</b> | <b>325.46</b> | <b>317.32</b> | <b>306.67</b> | <b>309.37</b> | <b>291.40</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>308.75</b> |   |
| <b>Domestic/<br/>Mine</b> |                |                                                      | <b>25.85</b>  | <b>27.65</b>  | <b>27.64</b>  | <b>25.50</b>  | <b>0.00</b> | <b>27.62</b>  | <b>27.65</b>  | <b>27.65</b>  | <b>27.64</b>  | <b>27.64</b>  | <b>27.50</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>27.64</b>  |   |
| <b>IUA</b>                |                |                                                      | <b>331.13</b> | <b>349.66</b> | <b>344.95</b> | <b>311.83</b> | <b>0.00</b> | <b>330.99</b> | <b>353.10</b> | <b>344.96</b> | <b>334.31</b> | <b>337.01</b> | <b>318.90</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>336.40</b> |   |

**Table B-13: Projected water supplied for Lower Orange IUA 3 - Average annual volume (Mm<sup>3</sup>/a)**

| User type  | Channel number | Channel name                        | 1A     | 2A     | 3A     | 1B     | 1C | 2B     | 2.1A   | 2.1B   | 3B     | 3.1A   | 3.1B   | 3.2A | 3.2B | 3.2A | 3.2B | 3.3    | 4 |
|------------|----------------|-------------------------------------|--------|--------|--------|--------|----|--------|--------|--------|--------|--------|--------|------|------|------|------|--------|---|
| Irrigation | 2146           | LOWER ORANGE SUBSYSTEM: Vioolsdrift | 58.958 | 92.475 | 91.735 | 56.574 |    | 88.627 | 92.952 | 91.458 | 89.823 | 90.390 | 87.067 |      |      |      |      | 90.178 |   |
| Irrigation | 2147           | LOWER ORANGE SUBSYSTEM: Vioolsdrift | 9.550  | 9.589  | 9.419  | 8.929  |    | 8.920  | 9.714  | 9.417  | 9.031  | 9.130  | 8.490  |      |      |      |      | 9.107  |   |
| Irrigation | 1861           | LOWER ORANGE SUBSYSTEM:             | 0.000  | 0.000  | 0.000  | 0.000  |    | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  | 0.000  |      |      |      |      | 0.000  |   |

| User type         | Channel number | Channel name                     | 1A           | 2A            | 3A            | 1B           | 1C          | 2B           | 2.1A          | 2.1B          | 3B           | 3.1A         | 3.1B         | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3          | 4 |
|-------------------|----------------|----------------------------------|--------------|---------------|---------------|--------------|-------------|--------------|---------------|---------------|--------------|--------------|--------------|-------------|-------------|-------------|-------------|--------------|---|
|                   |                | Namibia Irrigation (Vioolsdrift) |              |               |               |              |             |              |               |               |              |              |              |             |             |             |             |              |   |
| <b>Irrigation</b> |                |                                  | <b>68.51</b> | <b>102.06</b> | <b>101.15</b> | <b>65.50</b> | <b>0.00</b> | <b>97.55</b> | <b>102.67</b> | <b>100.88</b> | <b>98.85</b> | <b>99.52</b> | <b>95.56</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>99.28</b> |   |
| <b>0</b>          |                |                                  | <b>0.00</b>  | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>  | <b>0.00</b> | <b>0.00</b>  | <b>0.00</b>   | <b>0.00</b>   | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b>  |   |
| <b>IUA</b>        |                |                                  | <b>68.51</b> | <b>102.06</b> | <b>101.15</b> | <b>65.50</b> | <b>0.00</b> | <b>97.55</b> | <b>102.67</b> | <b>100.88</b> | <b>98.85</b> | <b>99.52</b> | <b>95.56</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>99.28</b> |   |

**Table B-14: Projected water supplied for Lower Orange IUA 4 - Average annual volume (Mm<sup>3</sup>/a)**

| User type                 | Channel number | Channel name                         | 1A           | 2A           | 3A           | 1B           | 1C          | 2B           | 2.1A         | 2.1B         | 3B           | 3.1A         | 3.1B         | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3          | 4 |
|---------------------------|----------------|--------------------------------------|--------------|--------------|--------------|--------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|-------------|--------------|---|
| Domestic/<br>Mine         | 1924           | Alex Bay Transhex small mines        | 4.897        | 5.296        | 5.778        | 4.895        |             | 5.292        | 5.296        | 5.296        | 5.778        | 5.778        | 5.766        |             |             |             |             | 5.778        |   |
| Irrigation                | 1918           | Alexander Bay Irrigation             | 7.958        | 7.994        | 7.853        | 7.437        |             | 7.446        | 8.099        | 7.848        | 7.536        | 7.617        | 7.099        |             |             |             |             | 7.596        |   |
| Domestic/<br>Mine         | 3130           | AUSSENKEHR NOORD URBAN               | 0.88         | 1.13         | 1.58         | 0.868        |             | 1.131        | 1.132        | 1.132        | 1.583        | 1.583        | 1.575        |             |             |             |             | 1.583        |   |
| Domestic/<br>Mine         | 1906           | Haib Mine                            | 0.00         | 0.00         | 0.00         | 0.000        |             | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        |             |             |             |             | 0.000        |   |
| Irrigation                | 659            | Lower Orange Irr Growth              | 0.00         | 0.00         | 0.00         | 0.000        |             | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        |             |             |             |             | 0.000        |   |
| Domestic/<br>Mine         | 1817           | Mines Rosh Pinah Auchas Skorpion     | 2.11         | 1.27         | 1.25         | 2.109        |             | 1.264        | 1.265        | 1.265        | 1.246        | 1.246        | 1.244        |             |             |             |             | 1.246        |   |
| Irrigation                | 1863           | Namibia Irrigation                   | 0.00         | 0.00         | 0.00         | 0.000        |             | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        |             |             |             |             | 0.000        |   |
| Domestic/<br>Mine         | 1865           | Urban Rosh Pinah Skorpion Oranjemund | 8.76         | 9.26         | 9.26         | 8.755        |             | 9.265        | 9.265        | 9.265        | 9.260        | 9.260        | 9.242        |             |             |             |             | 9.260        |   |
| <b>Irrigation</b>         |                |                                      | <b>7.96</b>  | <b>7.99</b>  | <b>7.85</b>  | <b>7.44</b>  | <b>0.00</b> | <b>7.45</b>  | <b>8.10</b>  | <b>7.85</b>  | <b>7.54</b>  | <b>7.62</b>  | <b>7.10</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>7.60</b>  |   |
| <b>Domestic/<br/>Mine</b> |                |                                      | <b>16.64</b> | <b>16.96</b> | <b>17.87</b> | <b>16.63</b> | <b>0.00</b> | <b>16.95</b> | <b>16.96</b> | <b>16.96</b> | <b>17.87</b> | <b>17.87</b> | <b>17.83</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>17.87</b> |   |
| <b>IUA</b>                |                |                                      | <b>24.60</b> | <b>24.95</b> | <b>25.72</b> | <b>24.06</b> | <b>0.00</b> | <b>24.40</b> | <b>25.06</b> | <b>24.81</b> | <b>25.40</b> | <b>25.48</b> | <b>24.93</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>25.46</b> |   |

**Table B14: Projected water supplied for Lower Orange IUA 6 - Average annual volume (Mm<sup>3</sup>/a)**

| User type  | Channel number | Channel name             | 1A            | 2A            | 3A            | 1B            | 1C           | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A         | 3.2B         | 3.2A         | 3.2B         | 3.3           | 4 |
|------------|----------------|--------------------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|--------------|--------------|--------------|--------------|---------------|---|
| Irrigation | 2600           | LOWER ORANGE TRIB: IRRIG | <b>10.039</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> |              | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> |              |              |              |              | <b>12.411</b> |   |
| <b>0</b>   |                |                          | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b> | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b>  | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b>  |   |

| User type         | Channel number | Channel name | 1A            | 2A            | 3A            | 1B            | 1C           | 2B            | 2.1A          | 2.1B          | 3B            | 3.1A          | 3.1B          | 3.2A         | 3.2B         | 3.2A         | 3.2B         | 3.3           | 4 |
|-------------------|----------------|--------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|--------------|--------------|--------------|--------------|---------------|---|
| <i>Irrigation</i> |                |              | <b>10.04</b>  | <b>12.41</b>  | <b>12.41</b>  | <b>12.41</b>  | <b>0.00</b>  | <b>12.41</b>  | <b>12.41</b>  | <b>12.41</b>  | <b>12.41</b>  | <b>12.41</b>  | <b>12.41</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>12.41</b>  |   |
| <i>IUA</i>        |                |              | <b>10.039</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>0.000</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>12.411</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>0.000</b> | <b>12.411</b> |   |

**Table B-15: Projected water supplied for Lower Orange IUA 7 - Average annual volume (Mm<sup>3</sup>/a)**

| User type         | Channel number | Channel name                                     | 1A           | 2A           | 3A           | 1B           | 1C          | 2B           | 2.1A         | 2.1B         | 3B           | 3.1A         | 3.1B         | 3.2A        | 3.2B        | 3.2A        | 3.2B        | 3.3          | 4 |
|-------------------|----------------|--------------------------------------------------|--------------|--------------|--------------|--------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|-------------|-------------|--------------|---|
| Irrigation        | 2596           | LOWER ORANGE<br>TRIB: IRRIG Riet<br>River        | 0.322        | 0.328        | 0.328        | 0.329        |             | 0.329        | 0.328        | 0.328        | 0.328        | 0.329        | 0.329        |             |             |             |             | 0.328        |   |
| Irrigation        | 2592           | LOWER ORANGE<br>TRIB: IRRIG Riet<br>River        | 5.684        | 5.685        | 5.685        | 5.685        |             | 5.684        | 5.685        | 5.685        | 5.685        | 5.685        | 5.685        |             |             |             |             | 5.685        |   |
| Irrigation        | 2587           | LOWER ORANGE<br>TRIB: IRRIG Vis river            | 0.492        | 0.492        | 0.492        | 0.492        |             | 0.492        | 0.492        | 0.492        | 0.492        | 0.492        | 0.492        |             |             |             |             | 0.492        |   |
| Irrigation        | 2577           | LOWER ORANGE<br>TRIB: IRRIG van<br>wyks vlei dam | 5.411        | 6.892        | 6.891        | 6.892        |             | 6.892        | 6.891        | 6.892        | 6.892        | 6.891        | 6.892        |             |             |             |             | 6.892        |   |
| <i>Irrigation</i> |                |                                                  | <b>11.91</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>0.00</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>13.40</b> |   |
| <i>0</i>          |                |                                                  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b> | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b>  | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b>  |   |
| <i>IUA</i>        |                |                                                  | <b>11.91</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>0.00</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>13.40</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>0.00</b> | <b>13.40</b> |   |

There are no surface water tables for IUAs 5, 8 and 9 of the Lower Orange River catchment.

