

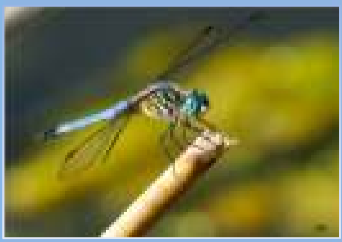


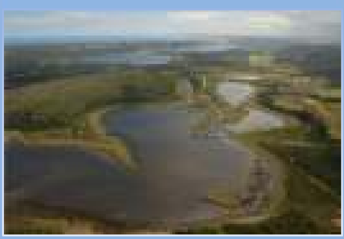


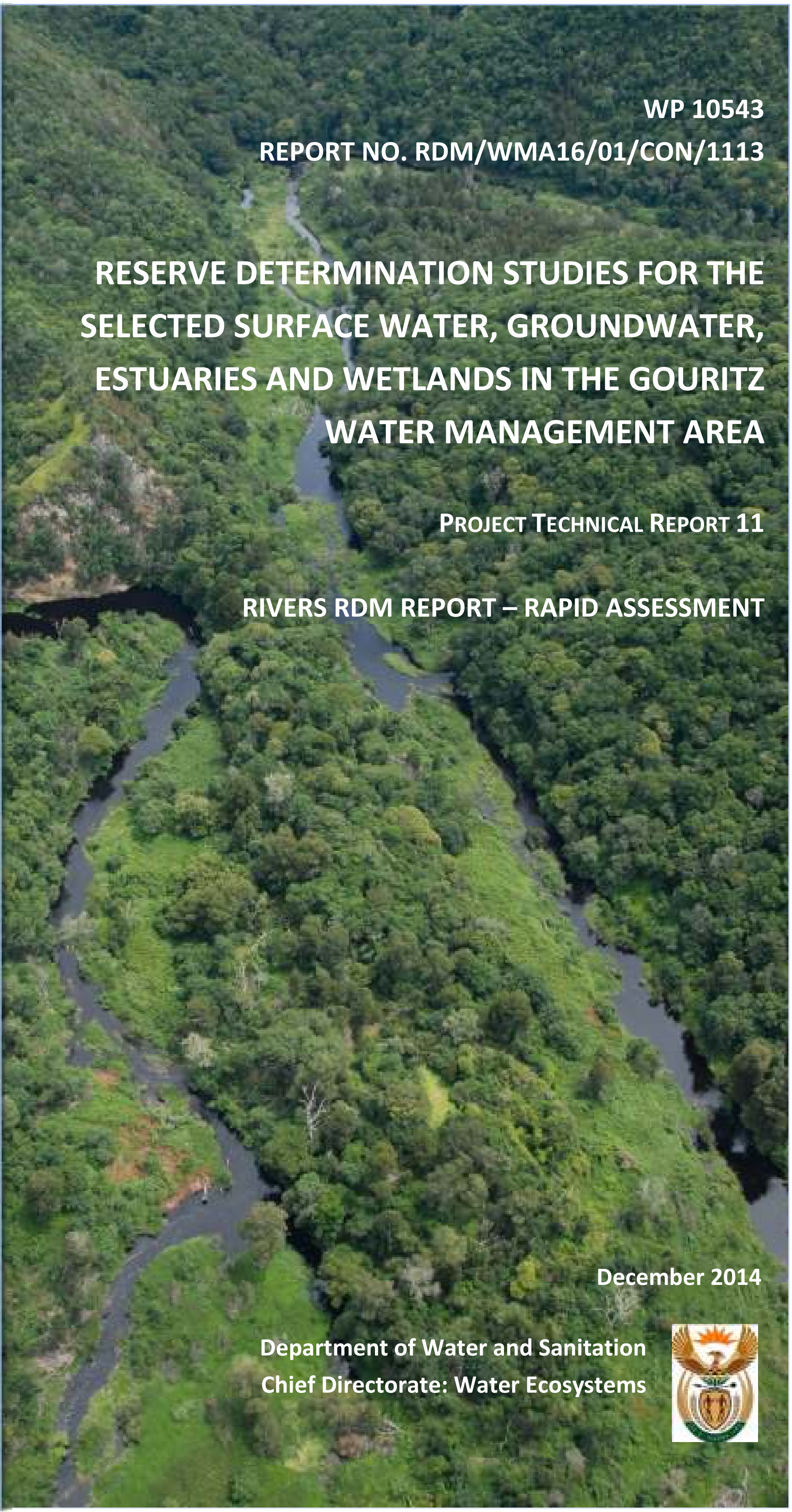

WP 10543

REPORT NO. RDM/WMA16/01/CON/1113

# RESERVE DETERMINATION STUDIES FOR THE SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE GOURITZ WATER MANAGEMENT AREA

## PROJECT TECHNICAL REPORT 11

## RIVERS RDM REPORT – RAPID ASSESSMENT

December 2014

Department of Water and Sanitation
Chief Directorate: Water Ecosystems

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# DOCUMENT INDEX

***Reports as part of this project:***

| INDEX NUMBER | REPORT NUMBER | REPORT TITLE |
|---|---|---|
| Report Number 01 | RDM/WMA16/00/CON/0113 | Inception Report |
| Report Number 02 | RDM/WMA16/00/CON/0213 | Desktop EcoClassification Report |
| Report Number 03, Volume 1 | RDM/WMA16/00/CON/0313, Volume 1 | Delineation Report, Volume 1 (Groundwater, Estuaries and Wetlands) |
| Report Number 03, Volume 2 | RDM/WMA16/00/CON/0313, Volume 2 | Delineation Report, Volume 2 (Rivers) |
| Report Number 04 | RDM/WMA16/02/CON/0413 | Groundwater Report |
| Report Number 05 | RDM/WMA16/03/CON/0513 | Wetland Report |
| Report Number 06, Volume 1 | RDM/WMA16/04/CON/0613, Volume 1 | Estuaries RDM Report – Desktop Assessment |
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| Report Number 12 | RDM/WMA16/00/CON/1213 | Monitoring Report |
| Report Number 13 | RDM/WMA16/00/CON/1313 | Main Report |
| Report Number 14 | RDM/WMA16/00/CON/1413 | Study Closure Report |

**Bold** indicates this report

# APPROVAL

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James Mackenzie undertook the riparian vegetation surveys and set up the VEGRAI for the Doring River.

# REPORT SCHEDULE

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|---|---|
| First draft | December 2014 |
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# EXECUTIVE SUMMARY

## INTRODUCTION

*This report documents the results of the EcoClassification and quantification of the Ecological Water Requirements (EWR) at selected EWR sites in the study area.*

## EWR SITES

*A total of ten EWR sites were selected in the study area. This report documents the results of the EcoClassification and quantification of the EWR at five EWR sites located in the Duiwenhoks, the Goukou, the Doring, the Olifants and the Kammanassie Rivers. Although it was originally proposed to undertake the Rapid III methodology (extended to include floods) on these sites, the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999) was followed with the only deviation from the method being the exclusion of geomorphology. This approach was followed in order to increase the confidence in the results and supply the needs for the estuarine scenarios. These five sites are referred to Rapid sites and a detailed site description is provided in DWA (2014) and listed below:*

### EWR sites

| EWR site name | SQ[1] reach | River | MRU[2] | Latitude | Longitude | Eco-Region (Level II) | Geo[3] Zone | Alt[4] (m) | Quat[5] |
|---|---|---|---|---|---|---|---|---|---|
| H8DUIW-EWR1 | H80E-09314 | Duiwenhoks | MRU Duiwenhoks C | S34.25167 | E20.99194 | 22.02 | E Lower Foothills | 15 | H80E |
| H9GOUK-EWR2 | H90C-09229 | Goukou | MRU Goukou A | S34.09324 | E21.29300 | 22.02 | E Lower Foothills | 87 | H90C |
| J1DORI-EWR7 | J12L-09895 | Doring | | S33.79137 | E20.92699 | 19.07 | E Lower Foothills | 370 | J12L |
| J3OLIF-EWR9 | J31D-08592 | Olifants | MRU Olifants A | S33.43813 | E23.20587 | 19.01 | E Lower Foothills | 621 | J31D |
| J3KAMM-EWR10 | J34C-8869 | Kamma-nassie | MRU Kammanassie A | S33.73286 | E22.69740 | 19.01 | E Lower Foothills | 445 | J34C |

*1 Sub Quaternary* *2 Management Resource Unit* *3 Geomorphic*
*4 Altitude* *5 Quaternary catchment*

## ECOCLASSIFICATION RESULTS

**H8DUIW-EWR1: DUIWENHOKS RIVER**

**EIS: LOW**
*Highest scoring metrics were unique species (new record and distribution for* Redigobius dewaali*); species intolerant to physico-chemical changes (*Pseudobarbus burchelli*); diversity of habitat types and features; and important migration route for the cape shrimp (*Paleamon capensis*), mullet (*Myxus capensis *and* Mugil cephalus*) and R. dewaali. The river is relatively small and sensitive to flow changes.*

**PES: D**

- *Decreased base flows and flooding events with zero flows at times due to abstraction.*
- *Overall deterioration in water quality due to irrigation return flows.*
- *Bank modification and instability due to alien invasive vegetation and agricultural practices in the riparian zones.*
- *Alien fish species occur in the reach.*

| Component | PES[1] and REC[2] |
|---|---|
| IHI Hydrology | B |
| Physico chemical | C |
| Fish | D |
| Macroinvertebrates | D |
| Instream | D |
| Riparian vegetation | C/D |
| **EcoStatus** | D |
| Instream IHI | C |

<table>
<tr><td>

***REC: D***

*The EIS was LOW and no improvement was required. The REC was therefore set to maintain the PES.*

</td><td>

| | |
|---|---|
| *Riparian IHI* | ***C*** |
| ***EIS*** | ***LOW*** |

</td></tr>
<tr><td colspan="2">

***H9GOUK-EWR2: GOUKOU RIVER***

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<tr><td>

***EIS: MODERATE***

*Highest scoring metrics were unique and intolerant riparian/wetland species (Palmiet -* Prinonium serratum*); species intolerant to physico-chemical changes (*P. burchelli *and macroinvertebrate taxa), diversity of habitat types and features which included backwaters and wetland features. The river is relatively small and sensitive to flow changes.*

***PES: C/D***

- *Decreased base flows, flooding events and zero flows at times due to abstraction and upstream dams.*
- *Deteriorated water quality due to the cumulative effects of agriculture and return flows.*
- *Bank modification and instability due to alien invasive vegetation and agriculture in the riparian zones.*
- *Alien fish species also occur in the reach.*
- *Wood removal in the riparian zones.*

***REC: C/D***

*The EIS was MODERATE and the REC was therefore set to maintain the PES.*

</td><td>

| ***Component*** | ***PES and REC*** |
|---|---|
| *IHI Hydrology* | ***B*** |
| *Physico chemical* | ***C/D*** |
| *Fish* | ***D*** |
| *Macroinvertebrates* | ***D*** |
| *Instream* | ***D*** |
| *Riparian vegetation* | ***C*** |
| ***EcoStatus*** | ***C/D*** |
| *Instream IHI* | ***C*** |
| *Riparian IHI* | ***C*** |
| ***EIS*** | ***MODERATE*** |

</td></tr>
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***J1DORI-EWR7: DORING RIVER***

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***EIS: LOW***

*The highest scoring metrics were rare and endangered species (*Pseudobarbus asper *– endangered) occurring in the reach; refugia and critical habitat (deep pools) and species/taxon richness. The river is relatively small and sensitive to flow changes.*

***PES: C/D***

- *Decreased base flows with zero flows at times and decreased floods due to abstraction and upstream dams and flow diversions.*
- *Deteriorated water quality due to polluted agricultural return flows.*
- *Bank modification and instability in the reach due to alien invasive vegetation and agriculture in the riparian zones.*
- *Clearing and overgrazing as well as catchment erosion have also contributed to bank and bed modification.*
- *Alien fish species also occur in the reach.*

***REC: C/D***

*The EIS was LOW and no improvement was required. The REC was therefore set to maintain the PES.*

</td><td>

| ***Component*** | ***PES and REC*** |
|---|---|
| *IHI Hydrology* | ***D*** |
| *Physico chemical* | ***C*** |
| *Fish* | ***C/D*** |
| *Macroinvertebrates* | ***D*** |
| *Instream* | ***C/D*** |
| *Riparian vegetation* | ***C/D*** |
| ***EcoStatus*** | ***C/D*** |
| *Instream IHI* | ***D*** |
| *Riparian IHI* | ***D*** |
| ***EIS*** | ***LOW*** |

</td></tr>
</table>

*1 Present Ecological State      2 Recommended Ecological State*

**J3OLIF-EWR9: OLIFANTS RIVER**

**EIS: MODERATE**
Three endemic riparian species occur at the site and an effective riparian/wetland migration corridor is provided by dense woody vegetation (mostly Acacia karoo and Salsola aphylla) in an otherwise barren and sparse landscape.

**PES: C**
- Baseflows and moderate flood frequency has decreased due to irrigation.
- Water quality deteriorations especially when flows are low leading to high temperatures and low oxygen rates.
- Overgrazing in the riparian zone leading to bank modification and decreased longitudinal connectivity

**REC: C**
The EIS was MODERATE and the REC was therefore set to maintain the PES.

| Component | PES and REC |
|---|---|
| IHI Hydrology | B |
| Water quality | C |
| Macroinvertebrates | C |
| Riparian vegetation | C |
| **EcoStatus** | C |
| Instream IHI | B/C |
| Riparian IHI | C |
| **EIS** | MODERATE |

**J3KAMM-EWR10: KAMMANASSIE RIVER**

**EIS: LOW**
The highest scoring metrics were rare and endangered species (P. asper – endangered) occurring in the reach; refugia and critical habitat (deep pools) and species/taxon richness. The river is relatively small and it is sensitive to flow changes and is an important corridor in a dry environment.

**PES: C/D**
- Decreased base flows with zero flows at times and decreased floods due to irrigation return flows, abstraction and farm dams.
- Deteriorated water quality due to polluted agricultural return flows.
- Reduced pool depth and degraded substrate for biota due to elevated sediment input.
- Alien vegetation in the upper riparian zone and significant Cyperus textillis encroachment in the area. Possibly due to nutrient enrichment and more consistent flows or seepage from return flows during dry times.
- Alien fish species also occur in the reach.

**REC: C/D**
The EIS was LOW and no improvement was required. The REC was therefore set to maintain the PES.

| Component | PES and REC |
|---|---|
| IHI Hydrology | C |
| Physico chemical | C |
| Fish | D |
| Macroinvertebrates | C/D |
| Instream | D |
| Riparian vegetation | C/D |
| **EcoStatus** | C/D |
| Instream IHI | D |
| Riparian IHI | D |
| **EIS** | LOW |

## EWR QUANTIFICATION

*The final flow requirements are expressed as a percentage of the Natural Mean Annual Runoff (nMAR).*

| | | | | Long term mean | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **EWR site** | **EcoStatus** | **nMAR (MCM[1])** | **pMAR[2] (MCM)** | **Low flows (MCM)** | **Low flows (%nMAR)** | **High flows (MCM)** | **High flows (%nMAR)** | **Total flows (MCM)** | **TOTAL (%nMAR)** |
| H8DUIW-EWR1 | PES; REC: D | 83.7 | 79.8 | 14.2 | 17 | 8.2 | 10.2 | 22.7 | 27.1 |
| H9GOUK-EWR2 | PES; REC: C/D | 54.1 | 46 | 7.1 | 13.1 | 4.3 | 13.9 | 11.4 | 21 |
| J1DORI-EWR7 | PES; REC: C/D | 4.52 | 2.01 | 0.386 | 8.5 | 0.644 | 14.3 | 1.03 | 22.8 |
| J3OLIF-EWR9 | PES; REC: C | 13.76 | 11.32 | 0.54 | 3.9 | 3.05 | 22.2 | 3.59 | 26.1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *J3KAMM-EWR10* | *PES; REC: C/D* | *20.6* | *19.6* | *1.8* | *8.9* | *2.8* | *13.5* | *4.6* | *21* |

*1 Million Cubic Metres* *2 Present Day Mean Annual Runoff*

## *CONCLUSIONS AND RECOMMENDATIONS*

*The confidence in the EcoClassification is generally Moderate, which is acceptable for a Rapid assessment. Furthermore, no further work on the EcoClassification is required as it will not influence the EWR determination. However, monitoring is essential to ensure that the ecological objectives in terms of the REC are achieved.*

*The confidence for all the parameters (provided below) is generally Moderate for most sites except J1DORI-EWR7. Low confidence dominates most parameters for J1DORI-EWR7 due to the lack of gauge data which influenced the confidence in setting EWRs. A low confidence for hydrology was achieved at J1DORI-EWR7 and J3OLIF-EWR9. At J1DORI-EWR7 the low confidence in hydrology is linked to the available hydrological model for the Doring River which is out of date. The low confidence for hydrology at J3OLIF-EWR9 is linked to the absence of a reliable gauge in the area and in turn influenced the overall confidence in low flows.*

*Confidence in the hydraulic modelling results overrides the confidence in the biophysical responses and EWR determination. The confidence is generally Moderate for all the EWR sites with High confidence in the high flow determination for H9GOUK-EWR2. The lowest confidence for low flow determination was achieved at H9GOUK-EWR2 and J1DORI-EWR7. This is because all measured flow data used for calibrating the hydraulic model was higher than the low flow EWR determination. Further work to improve the hydraulics would require additional measured calibration at very low flows.*

*The most effective way of improving confidence is linked to monitoring the ecological status of the river and, if required, improving the hydraulics for low flows at selected sites as part of the monitoring programme. No specific studies to improve any confidences other than monitoring are therefore recommended.*

### *Confidence summary*

| **EWR site** | **H8DUIW-EWR1** | **H9GOUK-EWR2** | **J1DORI-EWR7** | **J3OLIF-EWR9** | **J3KAMM-EWR10** |
|---|---|---|---|---|---|
| *Data availability* | *3.3* | *3.1* | *2.3* | *2.3* | *2.5* |
| *EcoClassification* | *3.3* | *3.1* | *3.0* | *2.2* | *3.1* |
| *Low flow EWR (biotic responses)* | *3.2* | *2.8* | *1.8* | *N/A* | *2.5* |
| *High flow EWR (biophysical responses)* | *3.0* | *2.7* | *1.7* | *4.0* | *2.7* |
| *Hydrology* | *3.5* | *2.8* | *1.5* | *1.5* | *2.8* |
| *Hydraulics (low)* | *3* | *2.5* | *2.5* | *N/A* | *3* |
| *Hydraulics (high)* | *2.5* | *4* | *3* | *3.0* | *3* |
| *Overall low flow EWR confidence* | *3.0* | *2.5* | *1.8* | *1.5* | *2.5* |
| *Overall high flow EWR confidence* | *2.5* | *2.7* | *1.7* | *3.5* | *2.7* |

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## ACRONYMS

| | |
|---|---|
| AEC | Alternative Ecological Category |
| Alt | Altitude |
| ASPT | Average Score Per Taxon |
| Ave | Average |
| BBM | Building Block Methodology |
| CEV | Chronic Effects Value |
| CMA | Catchment Management Area/Agency |
| COD | Chemical Oxygen Demand |
| CSIR | Council for Scientific and Industrial Research |
| D:RQIS | Directorate: Resource Quality Information Services |
| DO | Dissolved Oxygen |
| DRIFT | Downstream Response to Imposed Flow Transformation |
| DRM | Desktop Reserve Model |
| DWA | Department of Water Affairs (Name change from DWAF applicable after April 2009) |
| DWAF | Department of Water Affairs and Forestry |
| DWS | Department of Water and Sanitation (Name change from DWA applicable after May 2014) |
| EC | Ecological Category |
| EI | Ecological Importance |
| EI-ES | Ecological Importance and Ecological Sensitivity |
| EIS | Ecological Importance and Sensitivity |
| ES | Ecological Sensitivity |
| EWR | Ecological Water Requirements |
| F | Fluoride |
| FDI | Flow Dependent Macroinvertebrates |
| FibreCo | Fibre Optic data cable |
| FRAI | Fish Response Assessment Index |
| FROC | Frequency of Occurrence |
| GD | Green Drop |
| Geo | Geomorphic |
| HFSR | Habitat Flow Stressor Response method |
| HFSR-RM | Habitat Flow Stressor Response-Reserve Model |
| IERM | Intermediate Ecological Reserve Methodology |
| IHI | Index of Habitat Integrity |
| MAR | Mean Annual Runoff |
| MCM | Million Cubic Metres |
| MIRAI | Macroinvertebrate Response Assessment Index |
| MRU | Management Resource Unit |
| n | Number of samples |
| nMAR | Natural Mean Annual Runoff |
| NWA | National Water Act |
| PAI | Physico-chemical Driver Assessment Index |

| | |
|---|---|
| PD | Present Day |
| PES | Present Ecological State |
| pMAR | Present Day Mean Annual Runoff |
| POSA | Plants of southern Africa |
| PTV | Pollution Tolerant diatom Valve |
| Quat | Quaternary catchment |
| RC | Reference Condition |
| RDRM | Revised Desktop Reserve Model |
| REC | Recommended Ecological Category |
| RHP | River Health Programme |
| SANBI | South African National Biodiversity Institute |
| SANRAL | South African National Roads Agency |
| SASS5 | South African Scoring System version 5 |
| SPI | Specific Pollution sensitivity Index |
| SQ | Sub Quaternary |
| TDI | Trophic Diatom Index |
| TIN | Total Inorganic Nitrogen |
| TWQR | Target Water Quality Range |
| VEGRAI | Riparian Vegetation Response Assessment Index |
| WMA | Water Management Area |
| WR2005 | Water Resources of South Africa, 2005 study |
| WRCS | Water Resource Classification System |
| WWTW | Wastewater Treatment Works |

**Velocity Depth Classes: Fish and Macroinvertebrates**

| | |
|---|---|
| FCS | Fast over Coarse Substrate |
| FD | Fast Deep fish habitat |
| FI | Fast Intermediate fish habitat |
| FS | Fast Shallow fish habitat |
| GSM | Gravel-Sand-Mud |
| MV | Marginal Vegetation |
| SCS | Slow over Coarse Substrate |
| SD | Slow Deep fish habitat |
| SIC | Stones-In-Current |
| SOC | Stones-Out-of-Current |
| SS | Slow Shallow fish habitat |
| VFCS | Very Fast over Coarse Substrate |

# 1 INTRODUCTION

## 1.1 BACKGROUND

The National Water Act (Act No. 36 of 1998) (NWA), Section 3 requires that the Reserve be determined for water resources, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. The Reserve is one of a range of measures aimed at the ecological protection of water resources and the provision of basic human needs (i.e. in areas where people are not supplied directly from a formal water service delivery system and thus directly dependent on the resource according to Schedule 1 of the NWA). Chief Directorate: Water Ecosystems within the Department of Water and Sanitation (DWS) is tasked with the responsibility of ensuring that the Reserve is considered before water allocation and licensing can proceed.

The requirement for detailed Reserve studies in the Gouritz Water Management Area (WMA) became apparent for the following reasons:

- Various licence applications in the area.
- Gaps that have been identified as part of the Outeniqua Reserve determination completed in 2010.
- The conservation status of various priority water resources in the catchment and existing and proposed impacts on them.
- Increasing development pressures and secondary impacts related from the aforementioned and the subsequent impact on the availability of water.

For management and improved governance reasons, South Africa's 19 WMAs have been consolidated into nine (9) WMAs. The Gouritz WMA (previously WMA 16) now forms part of the previous Breede WMA (WMA 8) which now is known as the Breede-Gouritz WMA. It will be governed by the Breede-Gouritz Catchment Management Agency (CMA).

## 1.2 STUDY AREA OVERVIEW

Although it is acknowledged that the Breede and Gouritz WMA have been consolidated, the focus of this study is the Gouritz River and its associated catchments. Therefore the study area has been described in terms of the original WMA; the Gouritz WMA – WMA 16.

The Gouritz WMA (WMA16) is situated on the south coast of the Western Cape, largely falling within the Western Cape Province, and with a surface area of approximately 53 000 km$^2$. It consists of primary drainage region J (approximately 90 quaternary catchments), and part of primary drainage regions K (K1 to K7) and H (H8 to H9). The WMA therefore consists of approximately 100 – 105 quaternary catchments. It consists of the large dry inland area that is comprised of the Karoo and Little Karoo, and the smaller humid strip of land along the coastal belt. The main rivers are the Gouritz and its major tributaries, the Buffels, Touws, Groot, Gamka, Olifants and Kammanassie rivers, with smaller coastal rivers draining the coastal belt. All the inland rivers drain via the Gouritz

River into the Indian Ocean. The mean annual precipitation varies from as high as 865 mm in the coastal areas, which experience all-year-round rainfall, to as little as 160 mm in the drier areas inland to the north, which experience late summer rainfall. A map of the study area is provided below (**Figure 1.1**).

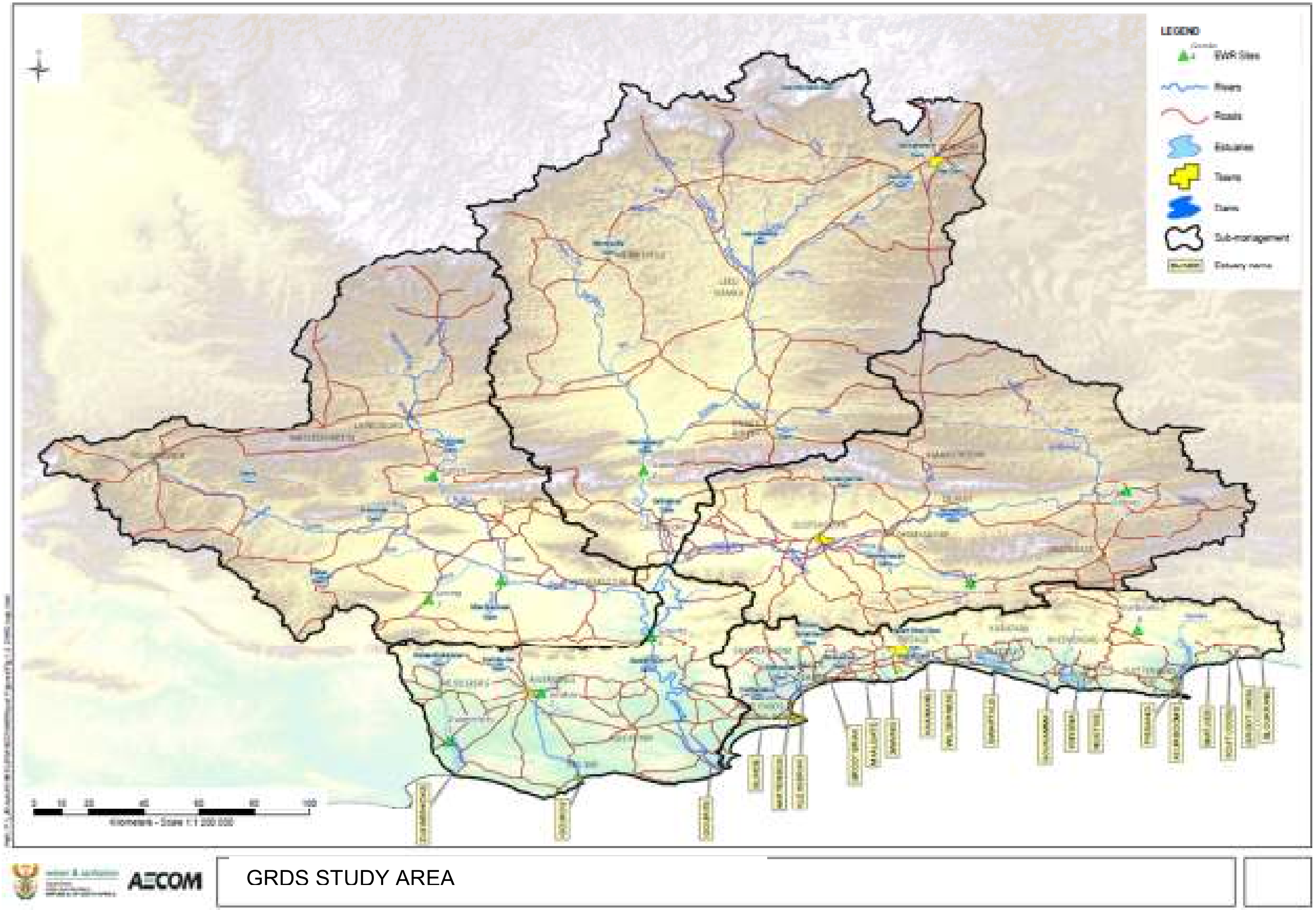



**Figure 1.1 Study area**

## 1.3 EWR SITES

A total of ten EWR sites were selected in the study area. Although it was originally proposed to undertake the Rapid III methodology (extended to include floods) at five EWR sites located in the Duiwenhoks, the Goukou, the Doring, the Olifants and the Kammanassie Rivers, the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999) was followed with the only deviation from the method being the exclusion of geomorphology (see **Chapter 2**). This approach was followed in order to increase the confidence in the results and supply the needs for the estuarine scenarios. These five sites are referred to Rapid sites and a detailed site description is provided in DWA (2014) and listed **Table 1.1**.

### Table 1.1 EWR sites

| EWR site name | SQ[1] reach | River | MRU[2] | Latitude | Longitude | Eco-Region (Level II) | Geo[3] Zone | Alt[4] (m) | Quat[5] |
|---|---|---|---|---|---|---|---|---|---|
| H8DUIW-EWR1 | H80E-09314 | Duiwen-hoks | MRU Duiwenhoks C | S34.25167 | E20.99194 | 22.02 | E Lower Foothills | 15 | H80E |
| H9GOUK-EWR2 | H90C-09229 | Goukou | MRU Goukou A | S34.09324 | E21.29300 | 22.02 | E Lower Foothills | 87 | H90C |
| J1DORI-EWR7 | J12L-09895 | Doring | | S33.79137 | E20.92699 | 19.07 | E Lower Foothills | 370 | J12L |
| J3OLIF-EWR9 | J31D-08592 | Olifants | MRU Olifants A | S33.43813 | E23.20587 | 19.01 | E Lower Foothills | 621 | J31D |
| J3KAMM-EWR10 | J34C-8869 | Kamma-nassie | MRU Kammanassie A | S33.73286 | E22.69740 | 19.01 | E Lower Foothills | 445 | J34C |

1 Sub Quaternary 2 Management Resource Unit 3 Geomorphic
4 Altitude 5 Quaternary catchment

## 1.4 DATA AND INFORMATION AVAILABILITY

Information collated during physical surveys was used to provide the results in this report. The data and information availability is summarised in **Table 1.2.** The confidence score used in this document was based on a scale of 0–5 where:

- A score of 0 – 1.9 suggested that the confidence was low.
- A score of 2 – 3.4: suggested that the confidence was moderate.
- A score of 3.5 – 5: suggested that the confidence was high.

### Table 1.2 Data and information availability

| Data and information availability |
|---|
| **Hydrology**<br>▪ Duiwenhoks River: H8DUIW-EWR1<br>o Natural hydrology: The natural quaternary data based on the Water Resources of South Africa, 2005 study (WR2005) (Middleton and Bailey, 2011) was scaled to obtain representative natural flow at the EWR site. Two flow gauges (Duiwenhoks Dam and H8H001) were used for calibration. Confidence: 4.<br>o Present hydrology: Modelled data were based on the WR2005 hydrological data. Modelled flow data were conservative but similar to the observed data. Confidence 3.<br>o Record period: H8H001 upstream of site (June 1967 to January 2014).<br><br>▪ Goukou River: H9GOUK-EWR2<br>o Natural hydrology: The natural quaternary data were based on the WR2005-study and were scaled to |

| Data and information availability |
|---|
| obtain representative natural flow at the EWR site. There were no rainfall stations in the mountainous areas where the high flows originate. Confidence: 3.<br>o Present hydrology: Flow data were based on the WR2005 hydrological data. There was not enough confidence in information on water use upstream of the EWR point especially the large irrigation demand which was moved upstream of the EWR site with access to water from H90A which was not the case for the WR2005 set-up. However, there was good correlation between the observed and modelled monthly flow. Confidence: 2.5.<br>o Record period: H9H005 upstream of site (May 1969 to January 2014).<br><br>▪ Doring River: J1DORI-EWR7<br>o Natural hydrology: The natural quaternary data were based on the WR2005-study and were scaled to obtain representative natural flow at the EWR site. The natural Mean Annual Runoff (MAR) was only 4.5 million $m^3$/a and a monthly model could not simulate these flows accurately. Confidence: 2.<br>o Present hydrology: There was a 80% reduction in MAR from natural. Flow data based on the WR2005 hydrological data were used. There was not enough confidence in information on water use and dams upstream of the EWR point. It should be investigated as the modelled data show that this river is dry most of the times. The WR2005 set-up of the Tierkloof Dam catchment was a very crude. Confidence 1.<br>o Record period: No reliable gauge as the river was small and a tributary of the Touws River.<br><br>▪ Olifants River: J3OLIF-EWR9<br>o Measured daily flows: None.<br>o Simulated natural hydrology: The natural quaternary data from the WR2005-study were scaled to obtain a representative natural flow record at the EWR site. The catchment area upstream of EWR9 is small with uncertainties regarding the historical agriculture abstractions and groundwater-surface water interaction. Confidence: 1.5.<br>o Simulated PD hydrology: The WRYM model with land-use at the 2004-development level was used to provide PD flow at J3OLIF-EWR9. Surface/groundwater interaction requires more detailed modelling. Abstraction is mostly from groundwater but was modelled as from surface water. Confidence 1.5.<br><br>▪ Kammanassie River: J3KAMM-EWR10<br>o Natural hydrology: The natural quaternary data were based on the WR2005-study and were scaled to obtain representative natural flow at the EWR site. Confidence: 3.<br>o Present hydrology: There was small reduction (less than 5%) in present MAR from natural. Flow data based on the WR2005 hydrological data. There was not enough confidence in information on water use and dams upstream of the EWR point. Confidence 2.5.<br>o Record period: No reliable gauge in the upper reaches upstream of Kammanassie Dam. |
| **Water quality**<br>▪ Duiwenhoks River: H8DUIW-EWR1<br>o DWS gauging weir H8H001Q01 (1967 – 1979; number of samples (n) = 66 - 71, Electrical Conductivity: n = 110).<br>o DWS gauging weir H8H001Q01 (2007 – 2013; n = 69, Fluorine (F) = 48).<br>Confidence: 3.5<br><br>▪ Goukou River: H9GOUK-EWR2<br>o Reference Condition (RC) was represented by the A Category benchmark tables in DWAF (2008), as no other data were available to describe natural state.<br>o DWS gauging weir H9H005Q01 (2007 – 2014; n = 63 - 71, F = 52).<br>Confidence: 3<br><br>▪ Doring River: J1DORI-EWR7<br>o No data were available for the water quality assessment. Land use and available information, diatom data, *in situ* water quality data and survey notes were used to provide an expert opinion and generate a Physico-chemical Assessment Model (PAI) model and integrated water quality category for the site.<br>Confidence: 2<br><br>▪ Olifants River: J3OLIF-EWR9 |

| Data and information availability |
|---|
| o RC: Information available to the water quality specialist on water quality conditions and land-use were available and the A Category benchmark tables in DWAF (2008) were considered unsuitable.<br>o PES: Data were sourced from DWS gauging weir J3H021Q01 (WMS code 102192) was used for the present state assessmen,t located downstream of the EWR site and upstream of Stompdrift Dam. (Data record: 1982 – 1993; n = 127).<br>Confidence: 2.5<br><br>▪ Kammanassie River: J3KAMM-EWR10<br>o No data were available for the water quality assessment. Land use and available information, diatom data, *in situ* water quality data and survey notes were used to provide an expert opinion and generate a PAI model and integrated water quality category for the site.<br>Confidence: 2 |
| **Riparian vegetation**<br>Data were obtained for all the sites from the following sources:<br>Data collected during site visit (June 2014). Other sites visits have been conducted by the vegetation specialist with regard to Environmental Impact Assessment related studies for Wind Farms (on behalf of Council for Scientific and Industrial Research - CSIR, 2012 and 2013), road upgrades for South African National Roads Agency (SANRAL) and the Fibre Optic data cable (FibreCo) connecting Port Elizabeth, George, Uniondale, Willowmore and Riversdale.<br>▪ Historical anecdotal information on the vegetation, mammals and herptofauna collated by the Animal Demography Unit © 2014, Department of Biological Sciences – University of Cape Town.<br>▪ Vegetation Biomes, Bioregions and Vegetation Types (Mucina & Rutherford, 2006).<br>▪ South African National Biodiversity Institute (SANBI) distribution data of plant species (SANBI Plants of southern Africa (POSA) (POSA, 2009).<br>▪ Google Earth © satellite imagery.<br>▪ Hydraulic rating curves and lookup tables for each site.<br>▪ 2013 desktop Present Ecological State (PES), Ecological Importance and Ecological Sensitivity (EI-ES), referred to as the PES/EIS project (DWS, 2014).<br>Confidence:<br>H8DUIW-EWR1: 4<br>H9GOUK-EWR2: 4<br>J1DORI-EWR7: 3<br>J3OLIF-EWR9: 3.5<br>J3KAMM-EWR10: 3 |
| **Fish**<br>▪ Duiwenhoks River: H8DUIW-EWR1<br>o Single site visit (June 2014).<br>o Moderate to good historic data for river system.<br>o Fish catch records from Steve Lamberth (*Pers. comm.*, July 2014).<br>o PES/EIS data (DWS, 2014), list of fish recently found (average fish confidence: 5).<br>o Reference Fish Frequency of Occurrence (FROC) Report (Kleynhans and Louw, 2007a).<br>Confidence: 3<br><br>▪ Goukou River: H9GOUK-EWR2<br>o Single site visit (June 2014).<br>o Moderate to good historic data for river system.<br>o PES/EIS data (DWS, 2014), list of fish recently found (average fish confidence: 5).<br>o Reference FROC Report (Kleynhans and Louw, 2007a).<br>Confidence: 3<br><br>▪ Doring River: J1DORI-EWR7<br>o Single site visit (June 2014).<br>o No historic data for this SQ, thus used fish data for reaches of Gouritz River system which were in a different quaternary.<br>o PES/EIS data (DWS, 2014), had no fish data for the quaternary or abutting quaternary catchments.<br>o Reference FROC Report (Kleynhans and Louw, 2007a) used, but had low confidence.<br>Confidence: 1.5 |

| Data and information availability |
| --- |
| ▪ Kammanassie River: J3KAMM-EWR10<br>o Single site visit (June 2014).<br>o No historic data for this SQ, only for upstream SQ.<br>o PES/EIS data (DWS, 2014), list of fish in upstream SQ (average fish confidence – 1).<br>o Reference FROC Report (Kleynhans and Louw, 2007a).<br>Confidence: 1.5 |
| **Macroinvertebrates**<br>▪ Single site visit to each of the EWR sites (June 2014).<br>▪ All available River Health Programme (RHP) data for the Gouritz catchment obtained DWS: Western Cape Office (five sample sets, all sampling information and macroinvertebrate abundances provided).<br>▪ PES/EIS data (DWS, 2014) for the Breede-Gouritz WMA (Directorate: Resource Quality Information Services (D: RQIS), *pers.comm*, no sampling data or abundances).<br>Confidence:<br>J1TOUW-EWR3, J1BUFF-EWR5, J4GOUR-EWR6, K6KEUR-EWR8:3<br>J3OLIF-EWR9: 2 |
| **Diatoms**<br>▪ Duiwenhoks River: H8DUIW-EWR1<br>o The diatom results were based on one sample collected on 19 January 2014 at the EWR site. No historic or other present data could be sourced for the Duiwenhoks River.<br>Confidence: 1<br><br>▪ Goukou River: H9GOUK-EWR2<br>o The results were based on two samples collected on 20 January 2014 and 24 June 2014 at the EWR site. No historic or other present data could be sourced for the Goukou River.<br>Confidence: 2.5<br><br>▪ Doring River: J1DORI-EWR7<br>o The results were based on two samples collected on 22 January 2014 and 9 April 2014 at the EWR site. No historic or other present data could be sourced for the Doring River.<br>Confidence: 2.5<br><br>▪ Olifants River: J3OLIF-EWR9<br>o The diatom results are based on two samples collected in February and June 2014 respectively at the EWR site. No other data could be sourced for the Olifants River.<br>Confidence: 2<br><br>▪ Kammanassie River: J3KAMM-EWR10<br>o The results were based on two samples collected on 10 February 2014 and on 24 June 2014. No historic or other present data could be sourced for the Kammanassie River.<br>Confidence: 2.5 |
| **Ecohydraulics**<br>Surveys of the river topography at the EWR sites were done between January and June 2014 (for specific dates refer to **Appendix C**, **Table C.1**). During these surveys discharges were measured using the velocity-area method, together with corresponding water levels (stages), and the position of vegetation markers/zones. These data are provided electronically in the supporting information. The methods used to provide hydraulic information to inform the assessment of EWRs has been documented (refer to Birkhead (2010)). The results of these analyses are tabulated in (so-called 'look-up', **Appendix C**) tables that include the following parameters: discharge; average and maximum depth; wetted width and perimeter; average and maximum (2% exceedance) depth-averaged velocity; flow-classes used for assessing the availabilty of hydraulic-habitat for fish and macroinvertebrates. These (modelled) data are also included with the electronic supporting files for the ecohydraulics.<br>Confidence: 3 |

## 1.5 OBJECTIVES OF THE RESERVE STUDY

This report documents the results of the EcoClassification and quantification of the EWR at a selection EWR sites on the Duiwenhoks, the Goukou, the Doring, the Olifants and the Kammanassie rivers.

## 1.6 OUTLINE OF THIS REPORT

The report outline is as follows:

- **Section 1** provides general background to the study.
- **Section 2** outlines the methods followed during the Ecological Reserve process. Summarised methods are provided for the EcoClassification and EWR scenario determination.
- **Section 3, 5, 7** and **9** provides the EcoClassification results for the respective EWR sites. **Section 4, 6, 8** and **10** provide results of different EWR scenarios with respect to low and high flows for the respective EWR sites. Aspects covered in these chapters are component and integrated/stress curves, generating stress requirements, determining high flows and final results.
- **Section 11** summarises the EcoClassification and EWR scenario results and also includes recommendations.
- References are listed in **Section 12**.
- **Appendix A** and **B** are specialist appendices outlining the approach and results of the water quality and diatom assessment undertaken at all the EWR sites.
- **Appendix C** is a specialist appendix which provides more detail regarding the hydraulic data generated for this task and includes a discussion of methods, data collection and results.
- **Appendix D** provides the Revised Desktop Reserve Model (RDRM) output files for all the EWR sites.
- **Appendix E** provides comments from various reviewers.

# 2 APPROACH

It was originally proposed to undertake the Rapid III methodology (extended to include floods) on the selected sites sites. However, to increase the confidence and supply the needs for the estuarine scenarios, the Intermediate method was followed with the only deviation from the method being the exclusion of geomorphology.

## 2.1 ECOCLASSIFICATION

The EcoClassification process was done in accordance with Kleynhans and Louw (2007b). Information provided in the following sections is a summary of the EcoClassification approach. For more detailed information on the approach and suite of EcoStatus methods and models, refer to:

- Physico-chemical Driver Assessment Index (PAI): Kleynhans *et al*. (2005); DWAF (2008).
- Fish Response Assessment Index (FRAI): Kleynhans (2007).
- Macroinvertebrate Response Assessment Index (MIRAI): Thirion (2007).
- Riparian Vegetation Response Assessment Index (VEGRAI): Kleynhans *et al*. (2007).
- Index of Habitat Integrity (IHI): Kleynhans *et al*. (2009).

EcoClassification refers to the determination and categorisation of the PES (condition, health or integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) RC. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES from the RC. This provides the information needed to derive desirable and attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints is considered.

The state of the river is expressed in terms of biophysical components:

- Drivers (physico-chemical and hydrology), which provide a particular habitat template; and
- Biological responses (fish, riparian vegetation and macroinvertebrates).

Different processes are followed to assign a category (A→F; A = Near natural, and F = critically modified) to each component. Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the EcoStatus of a river. The EcoStatus can therefore be defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna (modified from: Iversen *et al*., 2000). This ability relates directly to the capacity of the system to provide a variety of goods and services.

### 2.1.1 Present Ecological State

The steps followed in the EcoClassification process are as follows:

- Determine the RC for each component.
- Determine the PES for each component and the EcoStatus.
- Determine the trend for each component, as well as for the EcoStatus (dependant on available information).
- Determine the reasons for the PES and whether these are flow or non-flow related.

- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitat.
- Considering the PES and the EIS, suggest a realistic REC for each component and the EcoStatus.

The EcoStatus assessment followed an approach between Level 3 and 4 and standard tools were used. The tools required for this assessment are shown in **Figure 2.1** (modified from Kleynhans and Louw, 2007b).

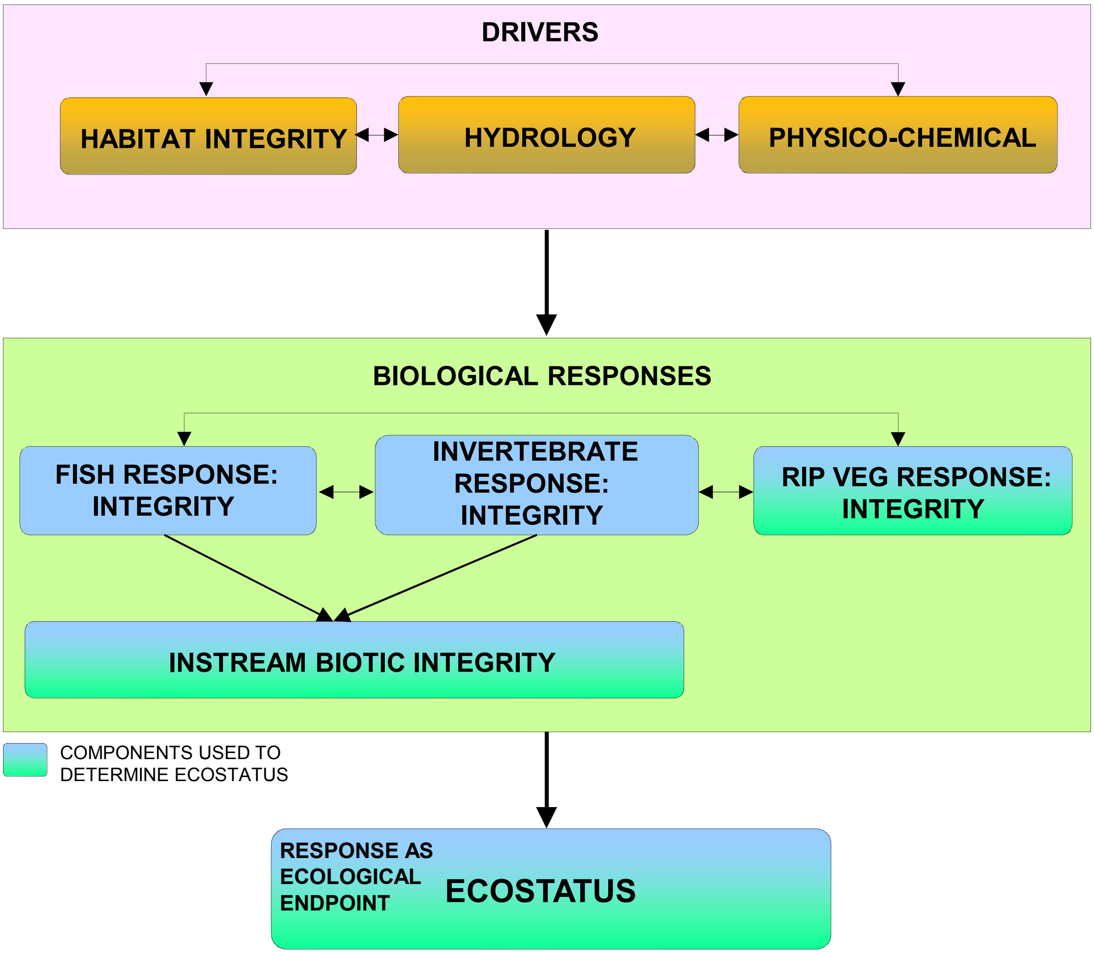



**Figure 2.1 EcoStatus determination (modified from Kleynhans and Louw, 2007b)**

The role of the EcoClassification process is, amongst others, to define the various Ecological Categories (ECs) for which EWRs will be set. It is therefore an essential step in the EWR process. The EWR process is essentially a scenario-based approach and the EWRs determined for a range of ECs are referred to as EWR scenarios. The range of ECs could include the PES, REC (if different from the PES) and the Alternative Ecological Categories (AECs). When designing a scenario that could decrease the PES, flow changes are first to be evaluated. If this, and the response of other drivers, are deemed to be insufficient on its own to change the category, then the current non-flow related impacts are 'increased', or new non-flow related impacts are included. It must be acknowledged, however, that there are many scenarios that could result in a particular EC.

The populated Ecostatus models are provided electronically.

### 2.1.2 Ecological Importance and Sensitivity

The EIS was calculated using a model developed by Dr Kleynhans in 2010, and representing a refinement of the model in Kleynhans and Louw (2007b) and Louw *et al*. (2010). This model estimates and classifies the EIS of the streams in a catchment using:

- The presence of rare and endangered species, unique species (i.e, endemic or isolated populations) and communities, intolerant species and species diversity for both the instream and riparian components of the river.
- Habitat diversity, including specific habitat types such as reaches with a high diversity of habitat types, e.g. pools, riffles, runs, rapids, waterfalls, riparian forests.
- The importance of a river or stretch of river in providing connectivity between different sections of the river, i.e. whether it provided a migration route or corridor for species.
- The presence of conservation, or relatively natural, areas along the river.
- The sensitivity (or fragility) of the biotic and abiotic components of the system and their resilience (i.e. the ability to recover following disturbance) to environmental changes.

The EIS results of the study are summarised in this report and the models are provided electronically. EIS categories are summarised in **Table 2.1**.

**Table 2.1 EIS categories (modified from DWAF, 1999)**

| EIS categories | General description |
|---|---|
| Very high | Quaternaries/delineations that are considered to be unique on a national or even international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use. |
| High | Quaternaries/delineations that are considered to be unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but in some cases, may have a substantial capacity for use. |
| Moderate | Quaternaries/delineations that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually not very sensitive to flow modifications and often have a substantial capacity for use. |
| Low/Marginal | Quaternaries/delineations, which are not unique at any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have a substantial capacity for use. |

### 2.1.3 Recommended Ecological Category

The REC is a recommendation from an ecological perspective that is one of the scenarios considered in the National Water Resource Classification System (NWRCS). This recommendation is based on either maintenance of the PES or an improvement thereon. Improvements are only considered if the EIS is HIGH or VERY HIGH. The guidelines to derive the REC based on the PES and the EIS are indicated in **Table 2.2**. Note that, in all cases, the practicalities of achieving the ecological recommendations are considered.

**Table 2.2 Guideline for REC determination**

| PES | EIS | REC | Comment |
|---|---|---|---|
| A, A/B, B | High or Very High | A, A/B, B | The PES will be maintained as it is already in a good condition that will support the high EIS. |
| B/C | High or Very High | B | As this condition is close to a B, marginal improvement may be required as a B is sufficient to support the high EIS. |
| C | High or Very High | B | Attempts should be made to improve by a Category. |
| C/D | High or Very High | B/C | Attempts should be made to improve by a Category. |
| D | High or Very High | C | Attempts should be made to improve by a Category. |
| D/E, E, E/F, F | n/a | D | Any Category below a D should (if restoration potential still exists) be improved to at least a D to ensure a minimum level of sustainability. This is irrespective of the EIS. It is unlikely though that it would be practical to improve an F river to a D without considerable investment, effort and possibly physical rehabilitation of the river. |

## 2.2 EWR DETERMINATION

The Habitat Flow Stressor Response method (HFSR) (O'Keeffe *et al*., 2002; IWR S2S, 2004; Hughes and Louw, 2010), was used to determine the EWRs. This method is one of the methods used to determine EWRs at a detailed level and a version of this has been built into the RDRM (Hughes *et al*., 2011).

The Reserve level that was followed was the Intermediate Ecological Reserve Methodology (IERM) (Louw and Hughes, 2002) without geomorphological input. Initially, these rivers were targeted to follow a RAPID III approach (DWAF, 1999) but it was upgraded to a level close to the IERM (see above).

To accommodate application of the IERM using the RDRM, additional functionality was added to the model, and this is an ongoing process. The version currently being applied was appropriate for any 'non-desktop' assessment and will be referred to as the 'Habitat Flow Stressor Response – Reserve Model' (HFSR-RM). It allows for, amongst others, specific specialist ecological input to be incorporated into the assessment.

The process to determine EWRs is summarised below:

### 2.2.1 Low flows

**Step A: Determining the stress index**
The basic approach is to compile stress indices for fish and macroinvertebrates. The stress index describes the consequences of flow reduction on flow-dependent biota (or guilds) and is determined

by assessing the response of the critical habitat if an indicator guild to flow reductions in low flows. The stress index therefore describes the habitat conditions and the response of fish and macroinvertebrates over a range of low flows.

The stress index is described as an instantaneous response of habitat to flow in terms of a 0 to 10 index relevant for the specific site where:

- 0 – Optimum habitat with least amount of stress possible for the indicator groups (fixed at the natural maximum base flow which was based on the 20% annual value using separated natural baseflows).
- 2 to 9: Gradual decrease in habitat suitability and increase in stress as a result of decreased discharge.
- 10 – Zero discharge (Note: Surface water may still be present). Maximum stress on indicator group.

A process has been built into the RDRM that includes both hydrological and hydraulic submodels. The hydrological submodel is not very different from that found in the Desktop Reserve Model (DRM), but includes the addition of a used-specified percentage point (exceedance value) for defining the maximum baseflow on the (baseflow) separated natural flow duration curve (i.e*.,* the 20% value, see above). The hydraulic submodel is, however, a new addition, and uses parameters such as slope, geomorphological zone and flood characteristics to model hydraulic relationships and velocity-depth classes (for further detail refer to Hughes *et al*., 2011). These classes are, in-turn, used to define 'desktop' stress-profiles.

Stress profiles (relationships between discharge and stress indices in the range 0 to 10) are prepared for both the fish and macroinvertebrate biotic components. These are integrated to provide a single relationship (the highest discharge for any given stress index), that is directly used in the (HFSR-RM (i.e. it overwrites the 'desktop' profile as used in the RDRM).

**Step B: Determining the low flow EWR**

The stress index is used to convert natural and present day flow time series to natural and present day stress time series. Each stress time series is then converted to a stress duration graph. This then provides the specialist with the information of how much the stress has changed from natural under present conditions due to changes in flow. It would follow that if flow has decreased from natural, stress would increase and vice versa. If specialists disagree with the levels of stress under natural conditions based on their knowledge of the species, the stress indices can be refined to a limited extent.

Stress durations at key points are provided by the fish and invertebrate specialists. The ecological sub-model of the HFSR-RM model generates flow requirements using hydrology, hydraulic and the stress flow index. According to the flow sensitivity of the species that occur in the specific system, the importance of velocity depth categories are also weighted and adjusted according to specialist requirements and to match the requirements set by specialists.

When the HFSR-RM is used in 'desktop' mode, a combination of stress at zero flow and relative weightings for flow (velocity-depth) classes are applied to develop stress-discharge relationships for both the dry and wet seasons. For these intermediate assessments, stress-discharge relationships for the two seasons were supplied by the ecologists and used directly in the HFSR-RM. This effectively bypasses the hydraulic and ecological sub-modules of the RDRM, with these assessments being done externally by ecologists.

The HFSR-RM generated (EWR) flow-durations and stress-durations for the PES categories were then assessed (by ecologists) using the default RDRM 'shifts' (relative to natural and taking cognisance of Present Day (PD), and these were adjusted (based on ecological feedback), if required. In this way, the HFSR-RM is used as a framework for providing EWR results appropriate to an intermediate level of assessment (i.e., it is not applied merely in 'desktop' mode).

### 2.2.2 High flows

The approach to set high flows follows the principles of the Downstream Response to Imposed Flow Transformation (DRIFT; King *et al*., 2003) method and the Building Block Methodology (BBM – King and Louw, 1998). The high flows as part of HFSR are determined as follows:

- Flood ranges for each flood class and riparian vegetation functions are identified and tabled by the relevant specialists.
- These are provided to the instream specialists who indicate:
  - which instream function these floods cater for;
  - whether additional instream functions apart from those provided are required; and
  - whether they require any additional flood classes to the ones identified.
- The number of floods for each flood class is identified as well as where (early, mid, late) in the season they should occur.
- The floods are evaluated by the hydrologist to determine whether they are realistic. A nearby gauge with daily data is used for this assessment. Without this information it is difficult to judge whether floods are realistic.
- The hydrologist then determines the daily average and documents the months in which the floods are spaced.
- The floods are then entered into the RDRM (high flow submodel) to provide the final .rul and .tab files. This process is described below:
  - convert each flood to volume using specified frequency and duration;
  - calculate total volume of all floods together for the specified Category;
  - use HFSR-RM to match volume as close as possible by manipulating the following three variables:
    - a) No high flow when natural high flows <X% total flows.
    - b) Adjust hydrological variability.
    - c) Maximum high flows are X% higher than normal high flows.
  - adjust variable a (above) to exclude flows (selected month) in months you do not require floods (i.e. zero volume).
  - adjust variable b for seasonality.
  - adjust variable c to match calculated volume for specified Category.

### 2.2.3 Final flow requirements

The RDRM produces a report which includes all the changes that were made to parameters by the specialists and provides the EWR rules for all ECs.

# 3 ECOCLASSIFICATION: DUIWENHOKS RIVER – H8DUIW-EWR1

## 3.1 EIS RESULTS

The EIS evaluation resulted in a LOW importance. The highest scoring metrics are:

- Unique species: New record and distribution for *Redigobius dewaali*.
- Species intolerant to physico-chemical changes: *Pseudobarbus burchelli* (one of three fish species likely to be present which was sensitive to water quality).
- Diversity of habitat types and features: Pools, riffles and micro-habitat for macroinvertebrates which included stones-in-current (SIC), marginal vegetation (MV), gravel-sand-mud (GSM) and stones-out-of-current (SOC).
- Migration route: Important for the Cape shrimp (*Paleamon capensis*) and mullet (*Myxus capensis* and *Mugil cephalus*) as well as *R. dewaali*.
- The river is relatively small and it is sensitive to flow changes.

## 3.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 3.1** and water quality and diatom information is provided in **Appendices A** and **B** respectively.

**Table 3.1 H8DUIW-EWR1: Present Ecological State**

| **IHI Hydrology: PES: B, Confidence: 3** |
|---|
| The natural Mean Annual Runoff (nMAR) is 83.67 million cubic metres (MCM) and the Present Day MAR (pMAR) is 79.8 MCM (95.4% of the nMAR). There was a small difference (less than 5%) in MAR between the observed and present day flow. The impact of development was shown on the low flows. The baseflow volumes decreased significantly in volume but not in seasonal distribution and appear to be continuous throughout the year. Base flows decreased mainly due to dams, afforestation, irrigation, grazing and domestic water use. No changes in seasonality were observed for low flows and moderate and large floods have decreased. |
| **Physico-chemical variables: PES: C, Confidence:3.5** |
| The elevated Electrical Conductivity levels at low flows (i.e. from a 95$^{th}$ percentile reference condition of 80 mS/m to a 95$^{th}$ percentile PES value of 272 mS/m), was the major parameter of concern at this site. However, note that this site is at the boundary of the estuary zone and geology also results in high background salinities. Although nutrient data showed low levels in the water column, some nutrients and toxics were expected from fertilizer and pesticide use for irrigation purposes. Stones at the site were also covered in benthic algae, indicating elevated nutrients. According to the Specific Pollution sensitivity Index (SPI) the water quality was Moderate. The ecological classification of van Dam *et al.* (1994) suggested high nutrient levels, organic pollution and salinity levels that were problematic along with moderate oxygenation rates and heavy pollution levels. The diatoms reflected the accumulative effects of farming activities within the reach. |
| **IHI Instream: PES: C, Confidence 2.9 IHI Riparian: PES: C, Confidence 2.4** |
| The instream IHI was mainly impacted by decreased base flow due to abstraction for irrigation which has led to increased sedimentation. Increased nutrient loading within the system has led to increased algal growth. The deteriorated water quality has resulted in bed modification while bank modification was the result of agriculture and alien invasive vegetation.<br>The riparian IHI was mainly impacted by bank structure modification due to agriculture and the presence of alien invasive species which have led to bank instability. |

| Riparian vegetation: PES: C/D, Confidence: 4 |
|---|
| Marginal Zone and Lower Zone: Small to large cobbles with alluvial deposits. These were dominated by non woody sedges downstream of the road crossing. Upstream of the road crossing, the inundation pool created by the road structure had also limited the development of any broad marginal zones. Woody species were few, and those that did occur were all alien *Acacia* (*Acacia mearnsii*). A notable species within the inundated area, created by the ponding, was the presence of *Aponogeton distachyos* (Cape pond weed).<br>Upper Zone and floodplain: Found on alluvial terraces bounded by the steeper valley slopes that were colonised by Thicket, bound by Eastern Ruens Shale Renosterveld (Critically Endangered). The latter was however not affected by river flows and is found only on the upper valley plateaus and not within the river valleys. These areas were colonized by *A. mearnsii* and *Arundo donax,* which created dense stands on both banks.<br>Main impacts at the site were as a result of the alien plants (*A. mearnsii* and *A. donax*). These species created mono-specific stands, which out-compete indigenous species, which would have created bank stability. During flood events the alien plants created bank instability. |
| **Fish: PES: D, Confidence: 2** |
| According to the recent PES/EIS Study (DWS, 2014) at least four indigenous fish species have a high to definite probability of occurrence under reference conditions within this SQ reach in the lower Duiwenhoks River. However, only three estuarine-dependent and/or catadromous species, namely *M. capensis* (predicted), *M. cephalus* and *R. dewaalii*, as well as the non-indigenous banded tilapia, *Tilapia sparrmanii* were captured during the survey in June 2014. The presence of these three species was expected due to the close proximity (probably < 500 m) of H8DUIW-EWR1 to the head of the estuary. The three indigenous species predicted, but not found, namely the longfin eel (*Anguilla mossambica*), Breede River redfin (*Pseudobarbus burchelli*) and the Cape kurper (*Sandelia capensis*) were thought to be present in this reach, but at a low FROC. The main reasons for the reduced FROC were considered to be:<br>▪ The deterioration in water quality due to effluent from dairy farms and enriched agricultural return flows (probably significant during low summer flows).<br>▪ Competition and predation (on eggs and fry) by alien *T. sparrmanii.*<br>▪ A decrease in base flows and reduced habitat availability during dry periods in summer, when the river may even stop flowing (anecdotal evidence).<br>▪ Elevated sediment input resulting in loss of substrate cover for fish. |
| **Macroinvertebrates: PES: D, Confidence: 2.5** |
| The reference or 'natural' condition was based on:<br>▪ Data from five historic sample sets compiled by DWS Western Cape for the RHP site at the same locality, H8DUIW_LOWE (3 sets: 2009, 2010, 2012) and the nearby downstream site H8DUIW_VERMA (5 sets: 1995, 2003, 2005, 2012). These data included all sampling details, and macroinvertebrate abundances.<br>▪ Data sourced from the PES/EIS Project (DWS, 2014) for the Breede-Gouritz WMA, specifically for the upstream site H8DUIW_UNBB2 and for the same site, H8DUIW-LOWE. These data were highly summarised and do not include sampling details or macroinvertebrate abundances, but did provide details of all known macroinvertebrates collected at this site historically.<br>The reference condition was slightly modified on the basis of discrepancies in habitat between the selected reference site and the sampling site, and on specialist experience. The derived condition indicated that in the vicininity of 39 taxa could possibly have occurred at this site in the natural state.<br><br>The South African Scoring System (SASS) score for the single sampling on 23 June 2014 was 78, with 14 taxa collected and an Average Score Per Taxon (ASPT) of 5.6. Flow sensitive taxa present in the sample included teloganodid and baetid mayflies, hydropsychid caddisflies and elmid beetles. Teloganodid mayflies were the only taxa present with a high requirement for very good water quality. The greatest deviation from the expected macroinvertebrate community (> 60%) was found in cobble habitat in fast flowing (> 0.6 m/s) and moderately fast flowing water (0.3 - 0.6 m/s), and in vegetation. Macroinvertebrates expected, but absent from the former habitat included heptageniid and leptophlebiid mayflies, notonemourid stoneflies, and polycentropodid and Philopotamidae craneflies. All of these macroinvertebrates also require moderate to good water quality. A number of more commonplace hemipterans and coleopterans were expected, but absent from the sample. The sample yielded less than 20% of the taxa that would be expected if the water quality were excellent, and 35% of the taxa expected in moderate water quality. |

The major causes of the alteration in the community were – in order of importance - the altered hydrology of the site (a reduction in baseflows and extended periods of no surface water), the deterioration in habitat quality, and the reduction in water quality. The sources of the hydrological changes were both the upstream Duiwenhoksrivier River Dam, and upstream abstraction practices. The habitat deterioration results (largely) from poor land-use practices and increased sedimentation in the catchment. The water quality deterioration was the result of agricultural practices and return-flows.

The PES EcoStatus is a D EC and the EcoStatus models are provided electronically. The major issues that have caused the change from reference condition were mainly flow and some non-flow related issues. Abstraction has resulted in decreased base flows and possibly zero flows at times. Irrigation return flows have resulted in elevated nutrients and salinity and an overall deterioration in water quality. Alien invasive vegetation and agricultural practices in the riparian zones have led to bank modification and instability in the reach while alien fish species also occur in the reach.

## 3.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability thereof. As the EIS was LOW, no improvement was required. The REC was therefore set to maintain the PES. No AEC was assessed as the instream components were already in a D EC.

## 3.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 3.2**.

**Table 3.2 H8DUIW-EWR1: Summary of EcoClassification results**

| Component | PES and REC |
|---|---|
| IHI Hydrology | B |
| Physico chemical | C |
| Fish | D |
| Macroinvertebrates | D |
| Instream | D |
| Riparian vegetation | C/D |
| **EcoStatus** | D |
| Instream IHI | C |
| Riparian IHI | C |
| **EIS** | LOW |

As there was a level of correlation between the instream REC and the riparian vegetation REC, the flows were set to maintain the REC EcoStatus of a D EC.

# 4 EWR REQUIREMENTS: DUIWENHOKS RIVER – H8DUIW-EWR1

## 4.1 FLOW VS STRESS RELATIONSHIP

The HFSR-RM generated a stress flow index which was reviewed and adjusted to specialist requirements. The fish and macroinvertebrate stress flow index is provided in **Figures 4.1** and **4.2**. The integrated stress curve is illustrated on both curves. A description of the habitat and response associated with the key stress is provided in **Tables 4.1** and **4.2**.

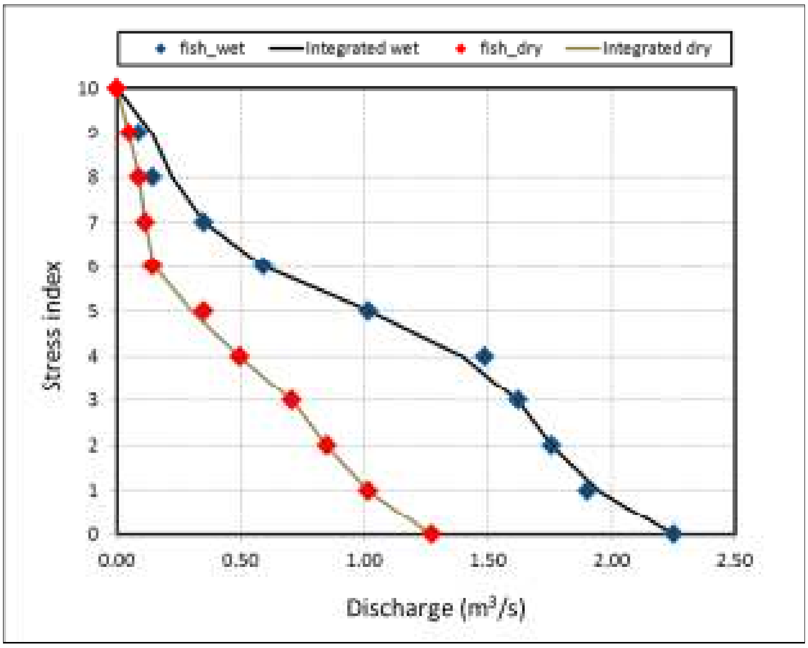



**Figure 4.1 H8DUIW-EWR1: Fish and integrated stress index**

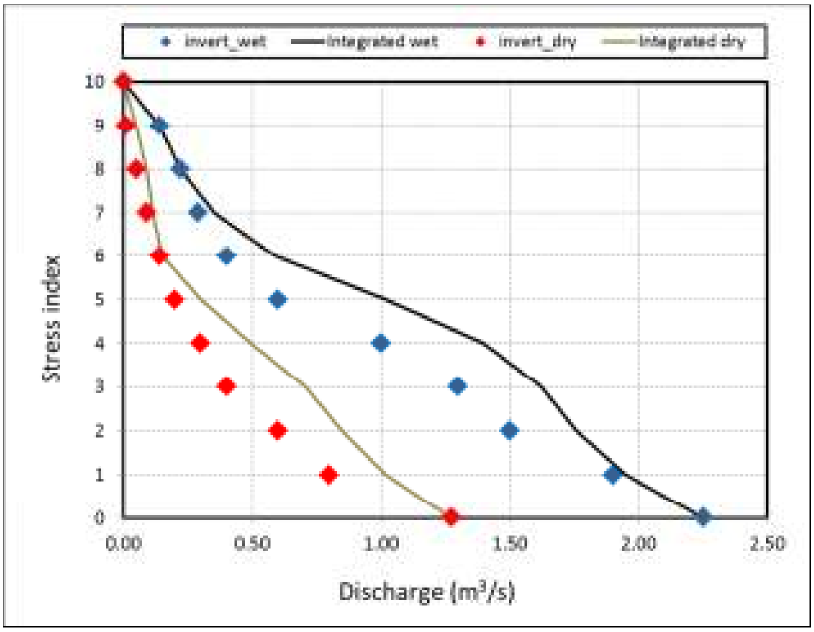



**Figure 4.2 H8DUIW-EWR1: Macroinvertebrate and integrated stress index**

**Table 4.1 H8DUIW-EWR1: Summarised habitat/biotic responses for the dry and wet season for fish**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 1 | 1.017 | Flow and depths suitable for all species, but slightly limiting in terms of amount of Fast Deep (FD) habitat available for eels. | 1.9 | Adequate breeding habitat among inundated marginal vegetation for *S. capensis*, as well as sufficient velocity-depth categories for *P. burchelli* spawning and for fish migration and eel habitat in riffles. |
| 5 | 0.35 | Adequate depths in riffles for migration of all catadromous species and a moderate amount of habitat for eels, although flow related water quality may still be somewhat limiting. | 1.11 | Some inundation of marginal vegetation allowing limited breeding habitat for *S. capensis.* All velocity-depth categories well represented in riffle to allow for migration and preferred eel habitat, as well as moderate *P. burchelli* spawning areas and eel habitat in riffles. |
| 6 | 0.14 | Presence of some Fast Intermediate (FI), notable improvement in water quality migration of catadromous species, some suitable habitats for eels. | 0.59 | |
| 7 | | | 0.35 | All velocity-depth categories represented, limited spawning habitat for *P. burch*elli. Some suitable habitat (rapids/riffles) for juvenile eels. Water quality a potential problem. |
| 8 | 0.089 | 8% fast habitat. First suitable (rapid/riffle) habitat for juvenile eels. Limited fish and eel passage possible over riffle due to shallow depths. Limited improvement in water quality. | 0.14 | All velocity-depth categories represented except FD, very limited if any spawning habitat for *P. burchelli*. Limited suitable habitat (rapids/riffles) for juvenile eels. Poor water quality anticipated. |
| 9 | 0.048 | 4% Fast habitat, very limited migration of catadromous species (depth) possible past riffle at this flow, poor water quality expected. | 0.089 | Depth will allow very limited migration with high predation, water quality of low suitability and virtually no suitable spawning habitat of *P. burchelli*, very low suitability for juvenile eels. |

**Table 4.2 H8DUIW-EWR1: Summarised habitat/biotic responses for the dry and wet season for macroinvertebrates**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 0 | 1.27 | This is the flow at which the river was sampled in June 2014. At this flow, all habitats relevant to macroinvertebrates are activated and maintained. All normal mid-summer (February) requirements are met by this condition. There is adequate depth and velocity in the critical flow areas to support a community which includes a number of | 2.25 | Associated depth and velocities create a diverse, good quality habitat allowing for all typical early summer requirements (development, breeding) and favouring abundant Flow Dependent Macroinvertebrates (FDIs). Vegetation inundated (>10 cm) and provides ample cover for developing juveniles (e.g. Baetidae): |

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| | | Flow Dependent Macroinvertebrates (FDIs): Baetidae, Telagonodidae, Elmidae, Hemiptera, Gastropoda, and Diptera:<br>▪ Average (Ave) depth: 0.34 m.<br>▪ Ave velocity: 0.43 m/s.<br>▪ Fast over Coarse Substrate (FCS): 28%.<br>▪ Very Fast over Coarse Substrate (VFCS): 17%. | | ▪ Ave depth: 0.45 m.<br>▪ Ave velocity: 0.5 m/s.<br>▪ FCS: 27%; VFCS: 24%. |
| 3 | 0.4 | These conditions will sustain the majority of the macroinvertebrate population in its current state and provides adequate habitat and flow to ensure the habitats are maintained for developing juveniles:<br>▪ Ave depth: 0.23 m.<br>▪ Ave velocity: 0.23 m/s.<br>▪ FCS: 16%; FCS: 3%. | 1.3 | This is the flow at which the river was sampled in June 2014. At this flow, all habitats are activated and maintained, and there is adequate depth and velocity in the critical flow areas to support a community which includes a number of FDIs (Baetidae, Telagonodidae, and Elmidae).<br>▪ Ave depth: 0.34 m.<br>▪ Ave velocity: 0.43 m/s.<br>▪ FCS: 28%; VFCS: 17%. |
| 7 | 0.09 | There is a significant loss in depth and a reduction in average velocity. At these flows the abundances of individual taxa are diminished, and some taxa may even disappear. Marginal vegetation is exposed. While there is still flow in FCS, this is largely between or under the cobbles, and many surfaces are exposed:<br>▪ Ave depth: 0.13 m.<br>▪ Ave velocity: 0.13 m/s.<br>▪ FCS: 64%; VFCS: 6%. | 0.29 | A loss of depth over the coarse substrate results in some loss and compromise of macroinvertebrate habitat and the potential for water quality to start deteriorating. Associated with this, there is likely to be a reduction in abundances of flow- and water quality- reliant taxa such as the teloganodid mayfly:<br>▪ Ave depth: 0.2 m.<br>▪ Ave velocity: 0.34 m/s.<br>▪ FCS: 11%; VFCS: 2%. |
| 9 | 0.01 | Surface water only, all but the most resilient taxa will be lost:<br>▪ Ave depth: 0.04 m.<br>▪ Ave velocity: 0.05 m/s.<br>▪ VFCS: 0%; FCS: 0%. | 0.14 | No fast flow habitat remains, however there is adequate slow flow over coarse substrates to maintain the majority of the non flow-dependent taxa in a robust condition:<br>▪ Ave depth: 0.16 m.<br>▪ Ave velocity: 0.14 m/s.<br>▪ FCS: 8%; VFCS: 0%.<br>▪ Slow over Coarse Substrate (SCS): 62%. |

## 4.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as October and February respectively. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow).

## 4.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generated the stress (and flow) requirements for different ECs. Once specialists were satisfied that these results were adequate to maintain the river at the appropriate EC, descriptions were provided for key stress points (**Table 4.3**). Note that in this case the fish requirement was mostly the highest and drove the final EWR (green shaded cells). The macroinvertebrate requirements are provided in the table for possible future use if scenarios need to be assessed in future.

**Table 4.3 H8DUIW-EWR1: Stress requirements and habitat and instream biota description**

| Dry season | | | Wet season | | |
|---|---|---|---|---|---|
| Flow ($m^3/s$)* | | Description | Flow ($m^3/s$) | | Description |
| Macroinvertebrates | Fish | | Macroinvertebrates | Fish | |
| **Duration: 95% (Drought)** | | | | | |
| 0.005 | ***0.009*** | Fish will be notably stressed (9.8), but conditions are similar to PD flows. Since no rheophilic species occur, the fish guild should be able to survive these extreme conditions during droughts. No fast habitats will be available, no migration will be allowed and water quality will be poor. | 0.09 | ***0.3*** | Fish stress will be moderate to high (7.2), but adequate habitat diversity, including availability of fast habitats, will be maintained. All fast velocity-depth categories will be represented, adequate spawning habitats for *P. burchelli* will be provided and habitats will also be suitable for juvenile eels:<br>▪ 2% FS, 13% FI, 0.5% FD. |
| **Duration: 60%** | | | | | |
| ***0.14*** | ***0.13*** | Fish will be under moderate stress (6.4), but habitat diversity and abundance would be adequate to maintain the fish in its PES. Some FI will be maintained, water quality will be adequate, depth will allow unrestricted migration and some suitable habitat for eels would be available:<br>▪ 8% FS, 1% FI, 0% FD. | 0.4 | ***0.57*** | Fish stress will be moderate (6), but adequate habitat diversity and abundance should be available to maintain the fish in the PES. All species should be able to breed successfully and migration and water quality should not be a limiting factor.<br>▪ 5% FS, 4.5% FI, 21% FD. |

* Final HFSR-RM model output values.

## 4.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Only two marginal plant species were observed during this assessment and based on the known tolerances these species would persist under low conditions either through direct inundation of the marginal zone that would occur during the wet low periods or through infiltration of water into the river banks in the dry periods. Due to the sandy nature of the sediments of the study area, infiltration of water into these areas would still be able to maintain the soil moisture content of the marginal zone to maintain the observed plant species. Therefore, the low flows determined will maintain the marginal vegetation in its C/D PES and overall D PES.

## 4.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in **Table 4.4** and final high flow results are provided in **Table 4.5**.

**Table 4.4 H8DUIW-EWR1: Identification of instream functions addressed by the identified floods for riparian vegetation**

| Flood Class Flood Range (Peak in $m^3/s$) | Riparian vegetation motivation | Fish flood functions | | | | | | Macroinvertebrate flood functions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Migration cues and spawning | Migration habitat (depth etc.) | Clean spawning substrate | Create nursery areas | Resetting water quality | Inundate vegetation for spawning | Breeding and hatching cues | Clear fines and surface algae | Scour substrate | Reach or inundate specific areas | Reset and remobilize cobble and rock | Transport vegetative material and biota |
| Class I (3-5) | Required to inundate the overall extent of the marginal zone (height 0.7 m). This keeps this area free of woody vegetation and promotes the colonisation of these areas by emergent vegetation (instream and riverbank sedges). Optimal periods would be early summer. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Class II (16 – 20) | These flows will inundate the lower zone and any secondary channels that were colonised by obligate species, while reducing any woody cover (height 1.48 m). Optimal periods late spring | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | ✓ |
| Class III (28) | Inundation of upper zone (height 2.10 m). Removal of dominant woody species (although limited currently by the alien vegetation). Spring/Summer. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| Class IV (40) | These floods seem to occur annually and would result in the removal of large woody trees in particular and encourage removal of excess sediments (sand bars) that would be colonised by reeds within the instream areas. Height 2.58 - 2.84 m. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |

The high flow peaks (daily average) and durations were recommended by the specialists (refer to Table 4.5). The validity of events is best assessed using observed data, and DWS Gauge H8001, located at the EWR site was used for this purpose. The DWS gauge H8001 was present in the reach and used to verify high flows.

**Table 4.5 H8DUIW-EWR1: The recommended number of high flow events required**

| Flood class (Peak in $m^3/s$) | Flood requirements* | Months | Daily ave. | Duration (days) |
|---|---|---|---|---|
| CLASS I (3 – 5) | 3 | June, March, October | 2.7 | 3 |
| CLASS II (16 - 20) | 1 | August | 13 | 5 |
| CLASS III (28) | 1:2 | September or November | 21 | 6 |
| CLASS IV (40) | 1:3 | October | 30 | 8 |

* Refers to frequency of occurrence per year, i.e. how often will floods occur per year where e.g. 1:3 means once every three years.

Daily and peak discharge records for DWS gauge, H8H001 was used in this study to:

- 'inform' (since ecological requirements are also taken into consideration to a point) the assessment of typical (natural) durations for various flood magnitudes (classes); and
- to develop a characteristic relationship between instantaneous peak (as assessed by the ecologists – specifically for riparian vegetation for this study, but for which the adequacy was also confirmed for fish and macroinvertebrate requirements) and average daily peak as applied in the high flow volume calculations.

It must be noted that the RDRM distributed the annual high flow volume monthly, according to the natural distribution. Specialists did, however, identify the months where no flood volumes are required.

## 4.6 EWR RESULTS

The results are provided as an EWR table (**Table 4.6**) and an EWR rule (**Table 4.7**). Flow duration graphs are supplied as **Figures 4.3** and **4.4**. Detailed results are provided in the model-generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 4.8**.

**Table 4.6 H8DUIW-EWR1: EWR table ($m^3/s$) for a PES and REC: D**

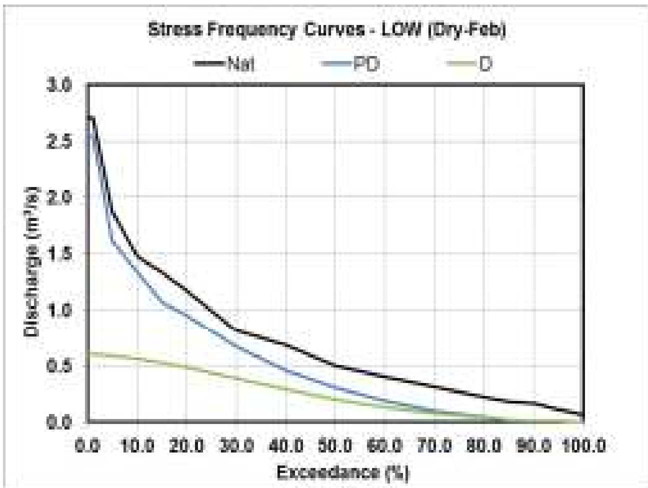
| Month | Low flows | | | High flows ($m^3/s$) | |
|---|---|---|---|---|---|
| | Drought (90%) ($m^3/s$) | 60% ($m^3/s$) | 50% ($m^3/s$) | Daily average ($m^3/s$) | Duration (days) |
| October | 0.391 | 0.573 | 0.666 | 2.7; 30 (1:3)* | 3; 8 |
| November | 0.340 | 0.531 | 0.650 | | |
| December | 0.143 | 0.342 | 0.432 | | |
| January | 0.016 | 0.166 | 0.243 | | |
| February | 0.009 | 0.131 | 0.203 | | |

| | | | | | |
|---|---|---|---|---|---|
| March | 0.037 | 0.205 | 0.293 | 2.7 | 3 |
| April | 0.052 | 0.240 | 0.334 | | |
| May | 0.094 | 0.269 | 0.368 | | |
| June | 0.120 | 0.302 | 0.393 | 2.7 | 3 |
| July | 0.174 | 0.356 | 0.453 | | |
| August | 0.297 | 0.452 | 0.535 | 13 | 5 |
| September | 0.337 | 0.504 | 0.590 | 21 (1:2) | 6 |

* Refers to frequency of occurrence per year, i.e. how often the floods occur per year where e.g. 1:3 means once every three years.

**Table 4.7 H8DUIW-EWR1: Total low flow assurance rules ($m^3/s$) for Instream PES and REC: D**

| Month | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 99% |
|---|---|---|---|---|---|---|---|---|---|---|
| October | 1.036 | 0.965 | 0.872 | 0.768 | 0.666 | 0.573 | 0.496 | 0.435 | 0.391 | 0.361 |
| November | 0.970 | 0.861 | 0.794 | 0.741 | 0.650 | 0.531 | 0.428 | 0.417 | 0.340 | 0.262 |
| December | 0.764 | 0.637 | 0.589 | 0.529 | 0.432 | 0.342 | 0.262 | 0.178 | 0.143 | 0.025 |
| January | 0.608 | 0.497 | 0.435 | 0.349 | 0.243 | 0.166 | 0.106 | 0.057 | 0.016 | 0.007 |
| February | 0.561 | 0.486 | 0.391 | 0.292 | 0.203 | 0.131 | 0.079 | 0.043 | 0.009 | 0.005 |
| March | 0.605 | 0.554 | 0.512 | 0.420 | 0.293 | 0.205 | 0.114 | 0.061 | 0.037 | 0.005 |
| April | 0.686 | 0.592 | 0.537 | 0.453 | 0.334 | 0.240 | 0.161 | 0.083 | 0.052 | 0.035 |
| May | 0.730 | 0.587 | 0.520 | 0.468 | 0.368 | 0.269 | 0.172 | 0.131 | 0.094 | 0.072 |
| June | 0.660 | 0.588 | 0.533 | 0.474 | 0.393 | 0.302 | 0.203 | 0.149 | 0.120 | 0.095 |
| July | 0.718 | 0.615 | 0.594 | 0.553 | 0.453 | 0.356 | 0.282 | 0.202 | 0.174 | 0.151 |
| August | 0.892 | 0.779 | 0.733 | 0.643 | 0.535 | 0.452 | 0.422 | 0.315 | 0.297 | 0.297 |
| September | 0.925 | 0.826 | 0.787 | 0.713 | 0.590 | 0.504 | 0.455 | 0.404 | 0.337 | 0.316 |



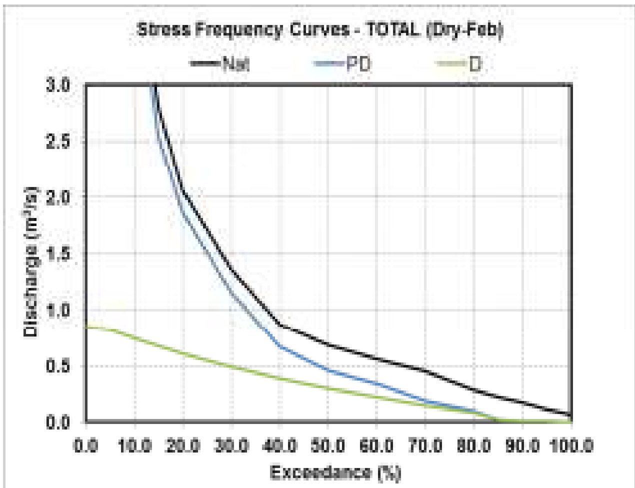




**Figure 4.3 H8DUIW-EWR1: Flow duration graph for the dry season low flows (left), total flows (right)**

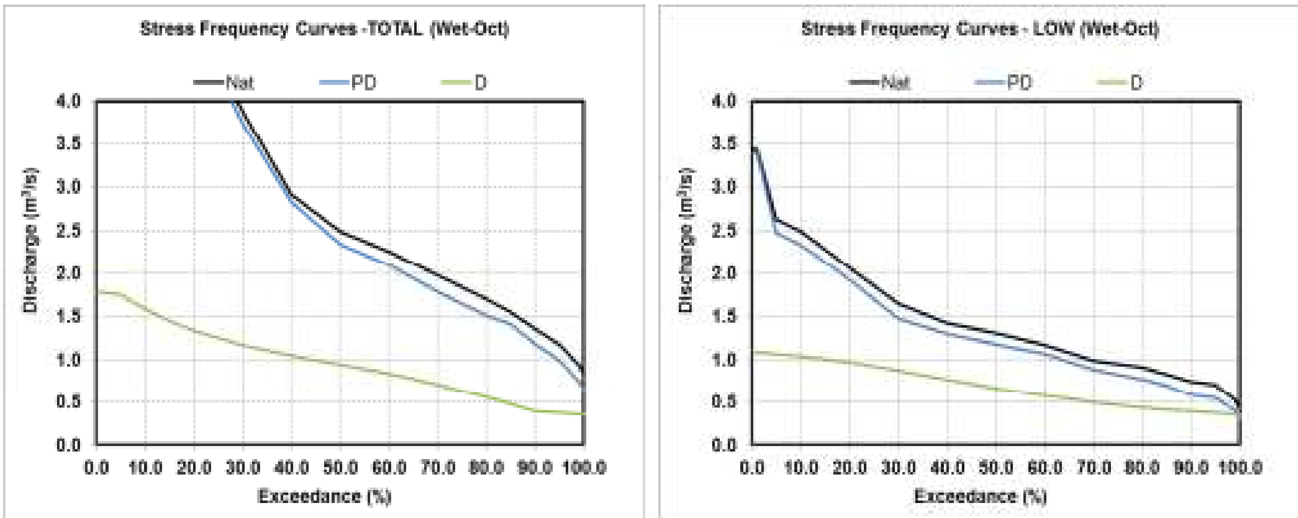



**Figure 4.4 H8DUIW-EWR1: Flow duration graph for the wet season low flows (left), total flows (right)**

**Table 4.8 H8DUIW-EWR1: Summary of results as a percentage of the nMAR**

| EcoStatus | nMAR (MCM) | pMAR (MCM) | Low flows (MCM) | Low flows (%) | High flows (MCM) | High flows (%) | Total flows (MCM) | Total (%) |
|---|---|---|---|---|---|---|---|---|
| PES; REC: D | 83.7 | 79.8 | 14.2 | 17 | 8.2 | 10.2 | 22.7 | 27.1 |

# 5 ECOCLASSIFICATION: GOUKOU RIVER – H9GOUK-EWR2

## 5.1 EIS RESULTS

The EIS evaluation resulted in a MODERATE importance. The highest scoring metrics were:

- Species intolerant to physico-chemical changes: *P. burchelli* and macroinvertebrate taxa.
- Diversity of habitat types and features: Backwaters and wetland features.
- The river is relatively small and it is sensitive to flow changes.
- Unique and intolerant riparian/wetland species: Palmiet (*Prinonium serratum*). Although this species is not protected nor has any conservation concern, agricultural pressures on the numerous catchments within its distribution range, has resulted in erosion, scour or bank instability and limits its natural development. This is also coupled to alien plant invasion that further limits/impacts the present distribution of this species.

## 5.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 5.1** and water quality and diatom information is provided in **Appendices A** and **B** respectively.

**Table 5.1 H9GOUK-EWR2: Present Ecological State**

| **IHI Hydrology: PES: B, Confidence: 3.3** |
|---|
| The nMAR is 54.1 MCM and the pMAR is 46.04 MCM (85.8% of the nMAR). There was a small difference in MAR between the observed and present day flow. The observed and present flows both showed that zero flows occur. The observed record is from the late 1960's up to date and land-use practices have changed little during this period. Baseflows have decreased significantly in volume with flows during the summer months (Nov to Mar) showing a larger decrease than the flows in winter. Natural seasonal distribution has changed and the reduction in flow volume is more during the summer months. This is mainly due to farm dams, afforestation, irrigation; grazing and domestic water use. Moderate and large floods have decreased. |
| **Physico-chemical variables: PES: C/D, Confidence: 3.5** |
| Water quality at the site was dominated by high Electrical Conductivity and phosphate levels. Toxics were expected due to extensive irrigation and associated pesticide use in the area. The SPI score for diatoms (n = 2) indicated that salinity, nutrients and organic pollution levels were increasing. Note that the increased occurrence of zero flows indicated the exacerbation of water quality issues at low flows, including oxygen and temperature levels. |
| **IHI Instream: PES: C, Confidence 2.8 IHI Riparian: PES: C, Confidence 3.3** |
| The instream IHI was mainly impacted by a decreased base flow due to abstraction for irrigation. Deteriorated water quality due to agricultural return flows has resulted in bed modification (sedimentation and algae) while bank modification was the result of agriculture and alien invasive vegetation.<br>The riparian IHI indicated that the bank structure was modified due to agriculture, cattle grazing and the presence of alien invasive species, which have led to bank instability. |
| **Riparian vegetation: PES: C, Confidence: 3.6** |
| Marginal Zone and Lower Zone: Alien Acacia (*A. mearnsii*) was removed from the reach by the farmer. These areas were thus being colonised by ruderral/primary species, with only three indigenous marginal species being observed during the time of the assessment. The remainder of the species, grasses, were common/ubiquitous species associated with moist environments and not only riverine/riparian |

| |
|---|
| environments (e.g. *Stenotaphrum secundatum*).<br>Indicator riparian species in this zone included *Cyperus marginatus, Ficinia lateralis* and *P. serratum* (Palmiet). The farmer did indicate that the Palmiet previously did colonise most of the reach up until the most recent floods (although it is uncertain if these floods occurred in 2014).<br>Upper Zone and floodplain: These areas were transformed and converted to fodder/ grazing areas. The left bank was in a better condition as it is fed by seeps that have created a large wetland area. This was colonized by *Juncus rigidus* and *Phragmites australis*. The wetland area ran parallel to the river reach, with an outflow that joins as a tributary further below the study area. |
| **Fish: PES: D, Confidence: 2** |
| The recent PES/EIS Study (DWS, 2014) predicted that at least five indigenous fish species with a high to definite probability of occurrence under reference conditions should be present within this SQ reach of the Goukou River. However, only one indigenous species, the catadromous Cape Moony *Monodactylus falciformis* was captured, in addition to the predatory alien largemouth bass *Micropterus salmoides*. The four indigenous species predicted but not found were *P. burchelli*, Cape galaxias *Galaxias zebratus*, long-fin eel *A. mossambica* and Cape kurper *S. capensis*. These fish were probably present in other reaches at low FROCs. The main reasons for these reduced FROCs were considered to be related to:<br>▪ predation by largemouth bass; and<br>▪ the loss of fish habitat and cover such as instream and riparian (marginal) vegetation, overhanging vegetation and root wads due to siltation and bank collapse.<br>A further important impact included the deterioration in water quality (probably significant during low summer flows) due to polluted return flows from agriculture (elevated nutrients, salts and some toxicity). The poor water quality would be aggravated by lower base flows in summer resulting from water abstraction. The unnaturally low river levels also reduce the availability and quality of fish habitat and protective cover making fish more vulnerable to predation by alien bass. |
| **Macroinvertebrates: PES: D, Confidence: 2.5** |
| The reference or 'natural' condition for this site was derived on the basis of:<br>▪ Data from historic sample sets compiled by DWS Western Cape for a downstream RHP site in SQ H90D-09318, H9GOUK_KLPFN (8 sets: 2003, 2004, 2005, 2010, and 2012). This was in the same Ecoregion Level II as the sampling site. The data included all sampling details, and macroinvertebrate abundances.<br>▪ Data sourced from the PES/EIS project (DWS, 2014) for the Breede-Gouritz WMA, specifically for the same downstream site H9GOUK_KLPFN. The data were highly summarised and do not include sampling details or macroinvertebrate abundances, but did provide details of all known macroinvertebrates collected at this site historically.<br>The reference condition was slightly modified on the basis of discrepancies in habitat between the selected reference site and the sampling site, and on specialist experience. The derived condition indicated that in the vicinity of 36 taxa could possibly have occurred at this site in the natural state, with an ASPT of > 6.2. It should be noted that some of these taxa were only collected once in the many sampling sets.<br>The SASS5 score for the site was 113, with 17 taxa collected and an ASPT of 6.6. Heptageniid mayflies, five different species of baetid mayflies and > 2 hydropsychid species were present. These collectively indicated relatively good quality water. Other reasonably high-scoring macroinvertebrates included leptophlebiid mayflies. Sensitive taxa that could be expected on the basis of the derived reference condition were notonemourid stoneflies, teloganodid mayflies, barbarochthonid, glossosomatid, hydroptilid, petrothrincid and pisullid caddisflies, athericid dipterans, gomphid dragonflies, helodid beetles, and corixid and naucorid hemipterans. The habitats that were most affected by the alterations in the system were the cobbles in moderate and fast flowing water, in which 30% of the expected taxa were absent, and vegetation, in which 60% of the expected taxa were absent.<br>The change in the macroinvertebrate community was attributed to – in order of influence:<br>▪ Altered hydrology – particularly the extended periods of no-flow under PD (abstraction, irrigation by centre-pivot, and the effects of the upstream Korintepoort Dam).<br>▪ Change in water quality (cumulative effects of agriculture and return flows – e.g. elevated nutrients, salts and some toxicity).<br>▪ Habitat deterioration and reduced diversity due to poor catchment land-management (sedimentation), alien vegetation in the catchment (bank effects, sedimentation). |

The PES EcoStatus is a C/D EC and the EcoStatus models are provided electronically. The major issues that have caused the change from reference condition were mainly flow and some non-flow related. Abstraction and upstream farm dams have resulted in decreased base flows and zero flows at times. The cumulative effects of agriculture and return flows, e.g. elevated nutrients, salts and some toxicity has resulted in deteriorated water quality. Alien invasive vegetation and agriculture in the riparian zones have led to bank modification and instability in the reach. Alien fish species also occur in the reach. Wood removal in the riparian zones occurs.

## 5.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was MODERATE, no improvement was required. The REC was therefore set to maintain the PES. No AEC was set as the instream components were already in a D EC.

## 5.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 5.2**.

**Table 5.2 H9GOUK-EWR2: Summary of EcoClassification results**

| Component | PES and REC |
|---|---|
| IHI Hydrology | **B** |
| Physico chemical | **C/D** |
| Fish | **D** |
| Macroinvertebrates | **D** |
| Instream | **D** |
| Riparian vegetation | **C** |
| **EcoStatus** | **C/D** |
| Instream IHI | **C** |
| Riparian IHI | **C** |
| **EIS** | **MODERATE** |

Both the instream REC and the riparian vegetation REC was impacted on by flows as well as anthropogenic impacts. The EWRs was therefore be set to maintain the REC EcoStatus of a C/D EC.

# 6 EWR REQUIREMENTS: GOUKOU RIVER – H9GOUK-EWR2

## 6.1 FLOW VS STRESS RELATIONSHIP

The HFSR-RM generated a stress flow index which was reviewed and adjusted to specialist requirements. The fish and macroinvertebrate stress flow index is provided in **Figures 6.1** and **6.2**. The integrated stress curve is illustrated on both curves. A description of the habitat and response associated with the key stress is provided in **Table 6.1** and **6.2**.

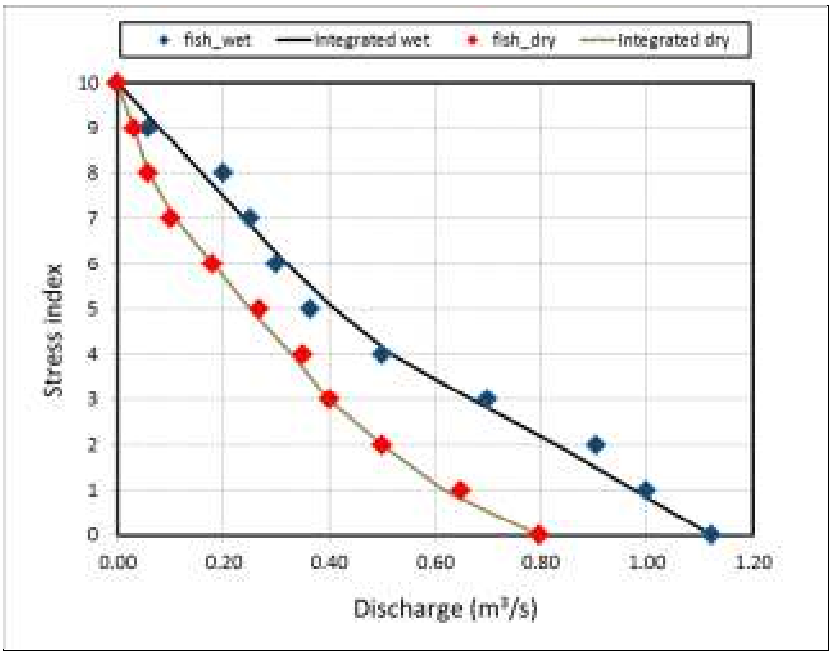



**Figure 6.1 H9GOUK-EWR2: Fish and integrated stress index**

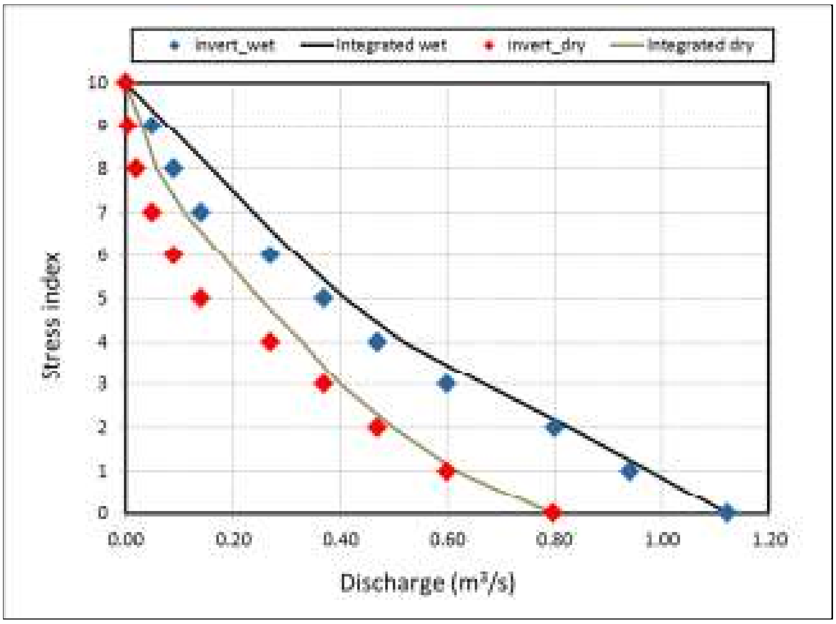



**Figure 6.2 H9GOUK-EWR2: Macroinvertebrate and integrated stress index**

**Table 6.1 H9GOUK-EWR2: Summarised habitat/biotic responses for the dry and wet season for fish**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 1 | 0.65 | All velocity-depth categories available (except FD) thus suitable habitats present for all species and to allow migration. Good water quality expected. | | |
| 2 | | | 0.994 | All velocity-depth categories will be represented with minimal stress on fish assemblage, including good water quality, optimal migration depth, and suitable fast habitats in riffles for *P. burchelli* spawning and inundated marginal vegetation for *S. capensis* spawning. |
| 5 | 0.27 | Most habitat aspects will be of moderate condition to support all fish species in the dry season, including adequate depths for some migration. Slight deterioration in water quality due to reduced flushing. | 0.365 | Good diversity of habitats (up to FI), adequate depth to allow unrestricted migration, and water quality should be adequate. Limited spawning habitat available. |
| 8 | 0.058 | Some FS habitat becomes available, shallow depths will allow limited migration but water quality still expected to be poor. | | |
| 9 | 0.031 | No or very limited migration possible (shallow depths in riffles), water quality still very poor and only very shallow fast habitat available. Poor water quality anticipated. | 0.058 | High stress on fish assemblage. Presence of some FS may allow minimum spawning of *P. burchelli*, very limited migration may be possible (depth) and very limited fast habitats created for juvenile eels. Poor water quality aggravated by elevated temperatures ispredicted. |

**Table 6.2 H9GOUK-EWR2: Summarised habitat/biotic responses for the dry and wet season for macroinvertebrates**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 3 | 0.47 | | 0.80 | Plentiful diverse, good quality habitat and adequate depths to maintain all FDIs and other fauna. Marginal vegetation habitat sufficiently inundated to provide habitat and shelter. |
| 4 | 0.37 | This flow is associated with adequate depth and velocity to provide diverse habitat, which will support all taxa in a healthy and abundant condition. The dominant habitat is VFCS. Marginal vegetation is inundated, providing cover | 0.60 | |

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| | | and fairly dense habitat. | | |
| 6 | 0.14 | Much of cobble habitat exposed, MV only functional as overhanging vegetation. Heptageniidae reduced in abundance and some Baetidae species reduced in abundance.<br>▪ Ave depth: <0.1 m. | 0.37 | |
| 7 | 0.09 | | 0.27 | This flow provides just sufficient depth over the cobble habitat to sustain the habitat required by FDI taxa. Velocities are adequate to maintain the more sensitive elements of the fauna (5 Baetidae species, > 2 Hydropsychidae species, and Heptageniidae). Water quality is maintained.<br>▪ Ave depth: 0.11 m (max 0.2 m).<br>▪ Ave velocity: 0.5 m/s, max 1.4 m/s. |
| 10 | 0.004 | Likely trickling flow only. Depth inadequate to support flow habitats (cobbles, gravel, MV). Continuity may be lost and pools only remain. | 0.05 | Depths are insufficient to provide depth over rocks, although cobble dwelling macroinvertebrates reduced in number. Few FDIs will remain (depending on duration of conditions). Vegetation is largely exposed, and overhanging grasses provide a small amount of cover.<br>▪ Ave depth: 0.06 m.<br>▪ Max depth: 0.12 m. |

## 6.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as October and July, respectively. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow).

## 6.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generated the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the appropriate EC, descriptions are provided for key stress points (**Table 6.3**). Note that in this case the fish and macroinvertebrate requirements were mostly similar.

**Table 6.3 H9GOUK-EWR2: Stress requirements and habitat and instream biota description**

| Dry season | | Wet season | |
|---|---|---|---|
| **Flow* ($m^3/s$)** | **Description** | **Flow ($m^3/s$)** | **Description** |
| **Duration: 95% (Drought)** | | | |
| 0.05 | **Fish stress: 9.2.** Low water temperatures, little fish movement or migration possible due to shallow depths at riffles (no fast habitats) acceptable. Fish will be notably stressed (9.2), but conditions are similar to present day drought flows. Water quality will be poor. Since no rheophilic species occur, the fish guild should be able to survive these extreme conditions during droughts, but elevated mortalities occur. **Macroinvertebrate stress: 7.** The maximum depth associated with this flow (0.12 m) is not adequate to provide depth over the larger substrates (rocks, cobbles). Cobble dwelling macroinvertebrates will be reduced in number. There will be little vegetation available. The majority of the D Category macroinvertebrate taxa will survive for 5% of the time during the dry season under these conditions. In the deepest areas, the velocities (ave: 0.2 m/s, max 0.8 m/s) will support heptageniid and leptophlebiid mayflies, but in the shallow areas these taxa will probably be lost. | 0 | **Fish stress: 10.** No flows in summer under present day condition due to abstraction for irrigation in the catchment. All fish species under severe stress (10) due to very poor water quality and reduction in suitable fish habitats and cover. No fish movement between pools is possible. Increase in mortalities of all species due to predation as well as disease due to poor water quality, but current PES can be maintained. **Macroinvertebrate stress: 0.** Only surface water will be present. Aerial taxa may relocate and resilient taxa will survive. Juveniles and adults of the more sensitive taxa will most likely be lost (depending on duration of these conditions, in days). Eggs may persist depending on the duration of the condition. High flows and floods will transport macroinvertebrates and eggs to the site from upstream. |
| **Duration: 60%** | | | |
| 0.141 | **Fish stress: 6.4.** Fish will be under moderate stress but habitat diversity and abundance would be adequate to maintain the fish in its PES. Some FI will be maintained, water quality will be adequate, and depth will allow unrestricted migration. Possibly some suitable habitat for eels would be available. **Macroinvertebrate stress: 5.5.** At the depth associated with this flow (0.18 $m^3/s$; final flows), much of the cobble habitat is exposed, and most of the useful MV habitat is lost. The more sensitive FDIs will be maintained for short periods, but will gradually be lost at the higher stresses, which will occur for up to 40% of the time. | 0.24 | **Fish stress: 7.2.** Fish stress will be moderate but adequate habitat diversity and abundance should be available to maintain the fish in the present PES. All species should be able to breed successfully and migration and water quality should not be a limiting factor. **Macroinvertebrate stress: 6.** At this flow (0.25 $m^3/s$, final flows) the average depth of 0.11 m (max 0.2 m) provides just sufficient depth over the cobble habitat to sustain the habitat required by FDI taxa. Velocities (average 0.5 m/s, max 1.4 m/s) are adequate to maintain the more sensitive elements of the fauna (5 baetid species, > 2 hydropsychid species and Heptageniidae). Water quality is maintained. This stress or lower for 60% of the time will maintain the macroinvertebrates in a D Category. Lower flows (higher stresses) for 40% of the time will be survived by the more resilient of the FDIs. |

* Final HFSR-RM model output values.

## 6.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

As with the majority of EWR sites assessed in this study, the abundance of marginal species, dependent on low flows was limited to four obligate species. These species would persist under low conditions either through direct inundation of the marginal zone during the wet low flow periods or through infiltration of water still in the main channel into the river banks and cobbles during the dry periods, i.e. these species do not require inundation for survival, only a high soil moisture content. Thus due to the sandy nature of the sediments of the study area, infiltration of water into these areas would still be able to maintain the soil moisture content of the marginal zone to maintain the observed plant species with a PES of C and an overall PES of C/D.

## 6.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in **Table 6.4** and final high flow results are provided in **Table 6.5**.

**Table 6.4 H9GOUK-EWR2: Identification of instream functions addressed by the identified floods for riparian vegetation**

| Flood Class<br>Flood Range (Peak in $m^3/s$) | Riparian vegetation motivation | Fish flood functions | | | | | | Macroinvertebrate flood functions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Migration cues and spawning | Migration habitat (depth etc.) | Clean spawning substrate | Create nursery areas | Resetting water quality | Inundate vegetation for spawning | Breeding and hatching cues | Clear fines and surface algae | Scour substrate | Reach or inundate specific areas | Reset and remobilize cobble and rock | Transport vegetative material and biota |
| Class I (2.8) | This will allow inundation of a small terrace in the lower zone that contains non-woody riparian species (sedges). This will aid in recruitment/activation of this area while removing any woody species. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| Class II (6.8) | Activation of a channel/bench that contains mostly hygrophillous grasses and sedges in these areas, while reducing woody cover. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Class III (10.8) | Inundation of the upper zone that would allow for the maintenance of any facultative riparian species (woody and non-woody). | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| Class IV (19.2) | These large floods would increase the removal/scour of any sediment preventing any reed/Palmiet encroachment, thus allowing for an increase in habitat diversity. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |

The DWS gauge H9H005 was present in the reach and used to verify high flows.

**Table 6.5 H9GOUK-EWR2: The recommended number of high flow events required**

| Flood class (Peak in $m^3/s$) | Flood requirements* | Months | Daily ave. | Duration (days) |
|---|---|---|---|---|
| CLASS I (2) | 3 | September, October, February | 2.6 | 3 |
| CLASS II (6.8) | 2 | September, January | 6 | 4 |
| CLASS III (10.8) | 1 | October, November | 9 | 5 |
| CLASS IV (19.2) | 1:3 – 1:5 | May | 15.2 | 6 |

* Refers to frequency of occurrence per year, i.e. how often the floods occur per year where e.g. 1:3 means once every three years.

Daily and peak discharge records for DWA gauge H9H005 was used in this study to:

- 'inform' (since ecological requirements are also taken into consideration to a point) the assessment of typical (natural) durations for various flood magnitudes (classes); and
- to develop a characteristic relationship between instantaneous peak (as assessed by the ecologists – specifically for riparian vegetation for this study but for which the adequacy was also confirmed for fish and macroinvertebrate requirements) and average daily peak as applied in the high flow volume calculations

It must be noted that the RDRM distributed the annual high flow volume monthly, according to the natural distribution. Specialists did, however, identify the months where no flood volumes are required.

## 6.6 EWR RESULTS

The results are provided as an EWR table (**Table 6.6**) and an EWR rule (**Table 6.7**). Flow duration graphs are supplied as **Figures 6.3** and **6.4**. Detailed results are provided in the model-generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 6.8**.

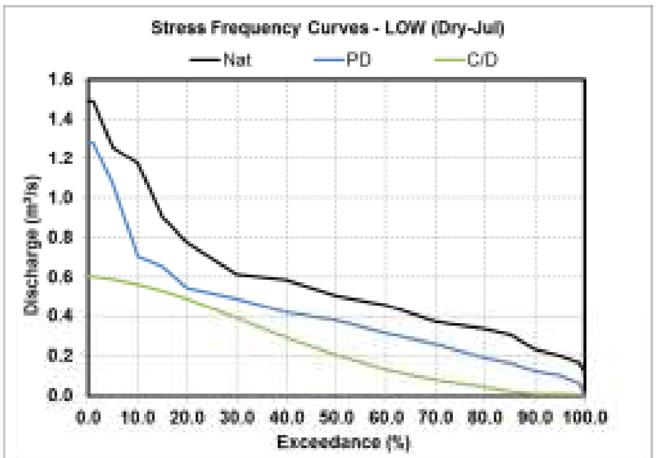
**Table 6.6 H9GOUK-EWR2: EWR table ($m^3/s$) for a PES and REC: C/D**

| Month | Low flows | | | High flows ($m^3/s$) | |
|---|---|---|---|---|---|
| | Drought (90%) ($m^3/s$) | 60% ($m^3/s$) | 50% ($m^3/s$) | Daily average ($m^3/s$) | Duration (days) |
| October | 0.000 | 0.252 | 0.315 | 2.6; 9 | 3; 5 |
| November | 0.000 | 0.250 | 0.313 | 9 | 5 |
| December | 0.000 | 0.000 | 0.068 | | |
| January | 0.000 | 0.000 | 0.000 | 6 | 4 |
| February | 0.000 | 0.000 | 0.061 | 2.6 | 3 |
| March | 0.000 | 0.210 | 0.273 | | |
| April | 0.054 | 0.213 | 0.282 | | |
| May | 0.058 | 0.194 | 0.259 | 15.2 (1:3–1:5)* | 5 |
| June | 0.043 | 0.191 | 0.245 | | |
| July | 0.067 | 0.181 | 0.225 | | |
| August | 0.075 | 0.229 | 0.274 | | |
| September | 0.077 | 0.236 | 0.268 | 2.6; 6 | 3; 4 |

* Refers to frequency of occurrence per year, i.e. how often the flood will occur per year where e.g. 1:3 means once every three years.

**Table 6.7 H9GOUK-EWR2: Total low flow assurance rules ($m^3/s$) for PES and REC: C/D**

| Month | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 99% |
|---|---|---|---|---|---|---|---|---|---|---|
| October | 0.503 | 0.478 | 0.434 | 0.379 | 0.315 | 0.252 | 0.187 | 0.128 | 0.000 | 0.000 |
| November | 0.469 | 0.450 | 0.426 | 0.380 | 0.313 | 0.250 | 0.183 | 0.000 | 0.000 | 0.000 |
| December | 0.353 | 0.352 | 0.333 | 0.301 | 0.068 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| January | 0.329 | 0.321 | 0.296 | 0.186 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| February | 0.336 | 0.335 | 0.310 | 0.246 | 0.061 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| March | 0.394 | 0.394 | 0.377 | 0.333 | 0.273 | 0.210 | 0.119 | 0.000 | 0.000 | 0.000 |
| April | 0.425 | 0.404 | 0.371 | 0.330 | 0.282 | 0.213 | 0.142 | 0.083 | 0.054 | 0.000 |
| May | 0.397 | 0.391 | 0.364 | 0.325 | 0.259 | 0.194 | 0.137 | 0.081 | 0.058 | 0.000 |
| June | 0.342 | 0.333 | 0.328 | 0.286 | 0.245 | 0.191 | 0.131 | 0.081 | 0.043 | 0.007 |
| July | 0.323 | 0.312 | 0.293 | 0.262 | 0.225 | 0.181 | 0.135 | 0.096 | 0.067 | 0.047 |
| August | 0.433 | 0.418 | 0.370 | 0.313 | 0.274 | 0.229 | 0.172 | 0.121 | 0.075 | 0.044 |
| September | 0.441 | 0.439 | 0.394 | 0.331 | 0.268 | 0.236 | 0.180 | 0.121 | 0.077 | 0.000 |



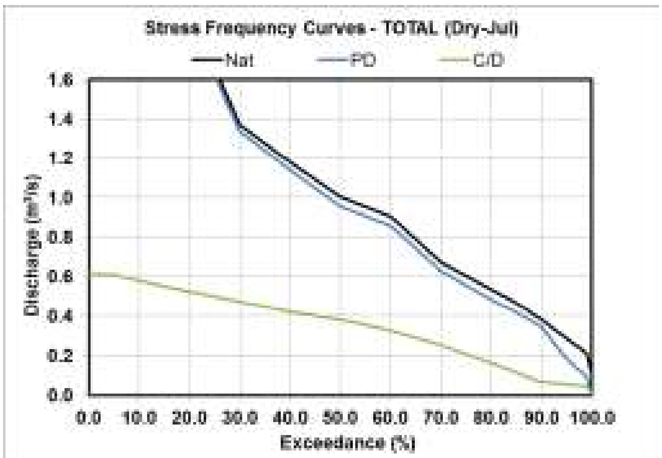



**Figure 6.3 H9GOUK-EWR2: Flow duration graph for the dry season low flows (left), total flows (right)**

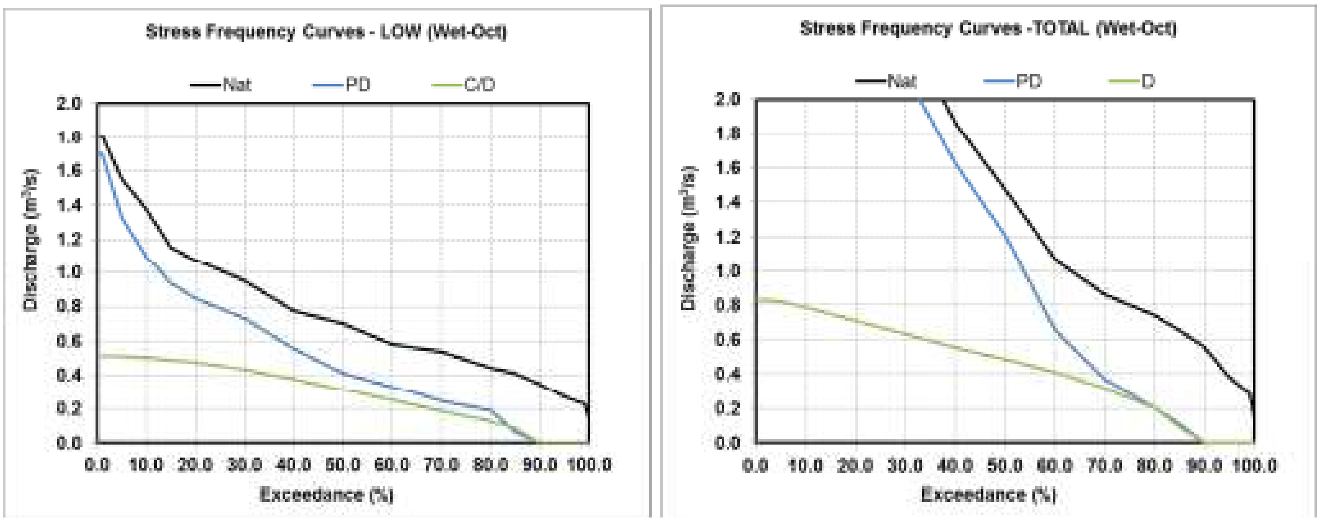



**Figure 6.4 H9GOUK-EWR2: Flow duration graph for the wet season low flows (left), total flows (right)**

**Table 6.8 H9GOUK-EWR2: Summary of results as a percentage of the nMAR**

| EcoStatus | nMAR (MCM) | pMAR (MCM) | Low flows (MCM) | Low flows (%) | High flows (MCM) | High flows (%) | Total flows (MCM) | Total (%) |
|---|---|---|---|---|---|---|---|---|
| PES; REC: C/D | 54.1 | 46 | 7.1 | 13.1 | 4.3 | 13.9 | 11.4 | 21 |

# 7 ECOCLASSIFICATION: DORING RIVER – J1DORI-EWR7

## 7.1 EIS RESULTS

The EIS evaluation resulted in a LOW importance. The highest scoring metrics were:

- Rare and endangered species: The endangered *Pseudobarbus asper* occurs in the reach.
- Refugia and critical habitat: Deep pools present.
- The river is relatively small and it is sensitive to flow changes.
- Species/taxon richness.

## 7.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 7.1** and water quality and diatom information is provided in **Appendices A** and **B** respectively.

**Table 7.1 J1DORI-EWR7: Present Ecological State**

| **IHI Hydrology: PES: D, Confidence: 1.1** |
|---|
| The nMAR is 4.52 MCM and the pMAR is 2.01 MCM (44.4% of the nMAR). There is no available observed data. Baseflows have decreased significantly in volume due to Tierpoort Dam, farms dams, irrigation, and grazing. Decreased flow appears to be continuous throughout the year. The seasonal distribution has changed with peak flows now in March instead of May. Distribution of monthly flows is flattened throughout the year. These changes are mainly due to Tierpoort Dam, farm dams, irrigation and grazing. Small floods have changed due to dams and irrigation. Note that there is low confidence in the hydrology (reasons provided in Chapter 8). There is however substantial anacdotal evidence that the river has stopped flowing and that some pools have even dried up in recent years (Withers Environmental Consultants, 2012). |
| **Physico-chemical variables: PES: C, Confidence: 2** |
| Water quality at the site shows elevated salts and nutrients, with some impact on turbidity, oxygen and temperatures at low flows, exacerbated by abstraction and excavation activities in the Doring and Lemoenshoek tributary. The biological water quality, as indicated by diatoms, was Moderate to Poor, with nutrient levels, organic pollution and salinity high and problematic for both sampling efforts. High salt and nutrient levels are linked to land use, i.e. irrigation return flows and livestock. Cultivation of fruit and vineyards also indicate herbicide and fertilizer use, and probable toxicant load. |
| **IHI Instream: PES: D, Confidence 2.1 IHI Riparian: PES: D, Confidence 2.7** |
| The instream IHI is mainly impacted by decreased base flows due to abstraction for irrigation. Deteriorated water quality due to agricultural return flows has resulted in bed modification (sedimentation and algae) while bank and structure modification is the result of agriculture and alien invasive vegetation.<br>The riparian IHI is mainly impacted by bank and structure modification due to agriculture, cattle grazing and the presence of alien invasive species which have led to bank instability. There has been vegetation clearing, terracing of banks and clearing of floodplains. |
| **Riparian vegetation: PES: C/D, Confidence: 3.7** |
| Marginal Zone and Lower Zone: This was found to be a narrow zone, colonised by a small number of riparian obligate species such as; *J. rigidus* and *Gymnosporia buxifolia*. The sand bars are been colonised by *P. australis* (Common Reed). These areas are at risk of being encroached by this species as evident in reaches observed upstream and downstream of the site. The vegetation type within the region includes the Western Little Karoo vegetation type (Succulent Karoo Biome: Rain Shadow Valley Bioregion), which is listed as Least Concern. |

| |
|---|
| Upper Zone and floodplain: These areas have been transformed and converted to fodder/ grazing areas/orchards.<br>Thus, the main impacts within the site are related to the conversion of the floodplains to agriculture, numerous farm dams with cut-off drains/diversion channels. Several of the areas, also have berms/ levees that separate the channels from floodplain areas. The agricultural activities would also seem to have resulted in sedimentation/erosion of areas that have created areas for the reedbeds to establish. |
| **Fish: PES: C, Confidence: 2** |
| A total of four indigenous species are potentially expected at this site, namely *Labeo umbratus*, *Barbus anoplus*, *P. asper* and *S. capensis*. As no fish data for this SQ reach or adjacent reaches are available, the species expected at the site were extrapolated from distribution data elsewhere in the catchment and is thus of low confidence. Only one of the expected species *S. capensis* was captured during the June 2014 survey, in addition to the alien *T. sparrmanii*.<br>Main impacts causing the current low FROCs or possible absence of *Labeo umbratus*, *Barbus anoplus* and *P. asper* are considered due to:<br>▪ a degradation and reduction of Slow Deep (SD) habitat due to sediment input resulting from catchment erosion and bank collapse;<br>▪ loss of fish cover in the form of overhanging vegetation, substrate and root wads in both SD and Slow Shallow (SS) habitats, due to bank collapse and overgrazing; and<br>▪ deterioration in water quality due to polluted return flows from irrigation, which is exacerbated during low flows due to abstraction by farmers during the dry summer months. |
| **Macroinvertebrates: PES: D, Confidence: 1.5** |
| The reference or 'natural' condition for this site was derived on the basis of:<br>▪ Data from historic sample sets compiled by DWS Western Cape for a RHP site in the Touws River upstream of its confluence with the Doring River, J1TOUW-BOOKE in SQ J12L-8831.<br>▪ Six data sets (2004, 2005, 2009, and 2010), and the same Ecoregion Level II as the sampling site. The data include all sampling details, and macroinvertebrate abundances.<br>▪ Data sourced from the PES/EIS project (DWS, 2014) for the Breede-Gouritz WMA, specifically for the same site on the Touws, J1TOUW-BOOKE. The data are highly summarised and do not include sampling details or macroinvertebrate abundances, but do provide details of all known Macroinvertebrates collected at this site historically.<br>The reference condition is established on the assumption that at this site, natural flows were perennial. The condition is slightly modified on the basis of discrepancies in habitat between the selected reference site and the sampling site, and on specialist experience. The derived condition indicates that in the vicinity of 34 taxa could possibly have occurred at this site in the natural state, with an ASPT of > 5.5. It should be noted that some of the taxa included in the reference state occurred only once in the actual sampling sets.<br>The SASS5 score for the site was 93 with 20 taxa and an ASPT of 4.7. There were no sensitive taxa (scoring >8) in the sample. The fauna collected comprised resilient taxa, and this sort of community is indicative of a system which is exposed to fluctuations in water level and to zero flows for reasonable periods of time (>2 weeks at a time). A number of the expected taxa were absent, including ephemerid and platycnemid mayflies, psephenid and helodid beetles, dixid dipterans, and naucorid hemipterans. The largest change in the macroinvertebrate community relative to natural was in the absence of taxa with a preference for unmodified or moderately modified water quality ('serious' change from reference condition). In terms of habitat, the fast and moderately fast flowing habitats had low percentages of expected taxa, and the vegetation, GSM and water column habitats were similarly lacking.<br>The major cause of the change in the system appears to be the significantly altered hydrology of this upper section of the river, and the periodic zero flow. This change has been attributed in part to flow diversions and in part to small dams and abstractions for irrigation. The deterioration in water quality which has affected the overall sensitivity of the macroinvertebrate community is attributable to pesticides, herbicides, possibly metals, and raised nutrients and salt in this water. The presence of *T. sparrmanni*, an alien predatory fish, may also account for the lack of macroinvertebrates scoring between 6 and 10 (these form part of the diet of these fish). In addition to these major changes, clearing for agriculture has altered the riparian zone significantly, and lower and middle zone riparian vegetation has been impacted. |

The PES EcoStatus is a C/D EC and the EcoStatus models are provided electronically. The major issues that have caused the change from reference condition were mainly flow and some non-flow related issues. Abstraction and upstream dams as well as flow diversions have resulted in decreased base flows and zero flows at times. Deterioration in water quality is mainly due to agricultural return flows. Alien invasive vegetation occurs in the lower and upper zones. Alien fish species also occur in the reach. Clearing and overgrazing as well as catchment erosion have also contributed to bank and bed modification.

## 7.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was LOW, no improvement was required. The REC was therefore set to maintain the PES. No AEC was set as the Macroinvertebrates were already in a D category.

## 7.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 7.2**.

**Table 7.2 J1DORI-EWR7: Summary of EcoClassification results**

| Component | PES and REC |
|---|---|
| IHI Hydrology | D |
| Physico chemical | C |
| Fish | C/D |
| Macroinvertebrates | D |
| Instream | C/D |
| Riparian vegetation | C/D |
| **EcoStatus** | C/D |
| Instream IHI | D |
| Riparian IHI | D |
| **EIS** | LOW |

As there is a correlation between the instream REC and the riparian vegetation REC, the flows will be set to maintain the REC EcoStatus of a C/D EC.

# 8 EWR REQUIREMENTS: DORING RIVER – J1DORI-EWR7

## 8.1 FLOW VS STRESS RELATIONSHIP

The HFSR-RM generated a stress flow index which was reviewed and adjusted to specialist requirements. The fish and macroinvertebrate stress flow index is provided in **Figures 8.1** and **8.2**. The integrated stress curve is illustrated on both curves. A description of the habitat and response associated with the key stress is provided in **Tables 8.1** and **8.2**.

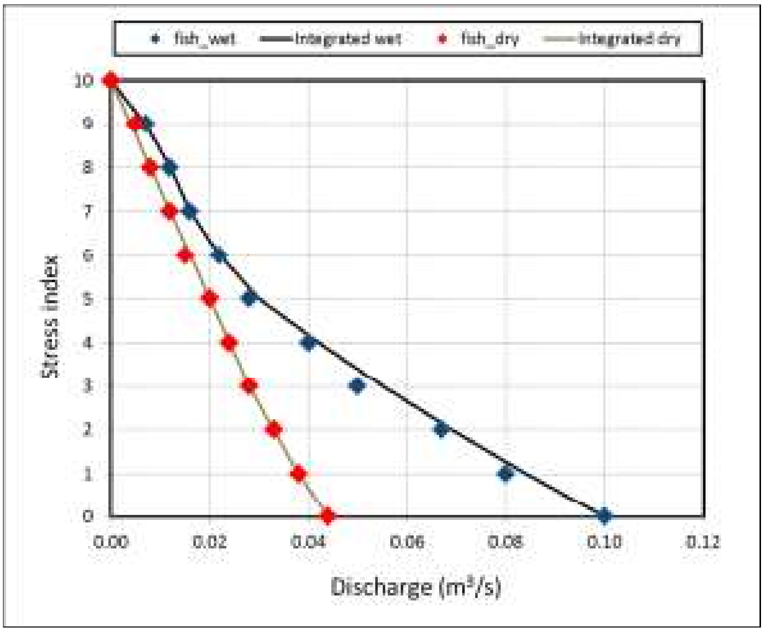



**Figure 8.1 J1DORI-EWR7: Fish and integrated stress index**

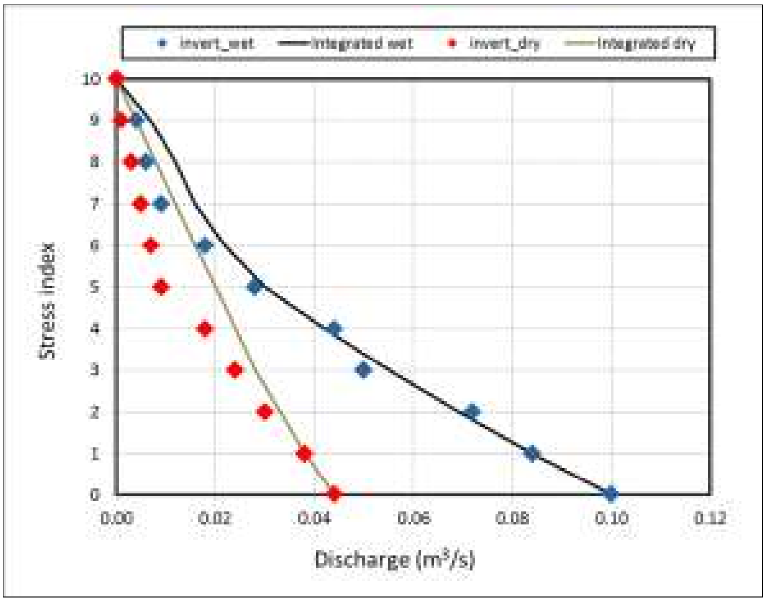



**Figure 8.2 J1DORI-EWR7: Macroinvertebrate and integrated stress index**

**Table 8.1 J1DORI-EWR7: Summarised habitat/biotic responses for the dry and wet season for fish**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 0 | 0.04 | Low temperatures and sufficient flows to ensure excellent water quality and all available habitats for both species, including for movement between pools. | 0.1 | Sufficient flows to ensure good water quality and all available habitats for both species, including for migration and spawning. |
| 2 | 0.03 | Sufficient flows to ensure good water quality, but some limitation of movement over riffle areas. | 0.07 | Optimal riffle spawning habitat for *P. asper* slightly decreased, but good habitat and cover available as well as depths for migration over riffles |
| 5 | 0.02 | Limited fast flows and shallow depths in riffles limit fish movement and increase mortalities due to predation. | 0.03 | Limited riffle spawning habitat and shallow depths in riffles restricts safe fish migrations. Slight deterioration in water quality. |
| 9 | 0.005 | Only limited fast very shallow habitat in riffles, not allowing any movement between pools. Water quality deteriorates, increasing mortalities due to disease and loss of cover. | 0.007 | Only fast very shallow habitat present in riffles, thus no migration or spawning habitat available. Water quality deteriorates and decrease in fish cover results in elevated mortalities. |

**Table 8.2 J1DORI-EWR7: Summarised habitat/biotic responses for the dry and wet season for macroinvertebrates**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 0 | 0.1 | Plentiful FCS and VFCS. All biota supported and MV provides shelter to developing juveniles. These flows will also support expected taxa (e.g. increased no of baetid spp, simuliid blackflies). | 0.04 | |
| 4 | 0.04 | VFCS almost absent. Maximum depth of 0.12 m provides just adequate cover over the cobbles to maintain this habitat for the FDI taxa collected (none of which are highly sensitive) and also provides for expected taxa such as simuliid blackflies. | 0.02 | At this flow the maximum depth is 0.1 m, which is the minimum or threshhold requirement for provision of some depth over the cobble habitat, which is essential to its functionality. The associated velocities (ave. 0.15 m/s, max. 0.48 m/s) should sustain all elements of the fauna, but more sensitive expected FDI taxa are unlikely to occur. |
| 7 | 0.009 | This is a shallow flow (max. depth 0.08 m), but the velocities (ave. 0.1 m/s, max. 0.3 m/s) are adequate to maintain taxa with a preference for moderately fast flows (ecnomids and tabanids) and also make provision for taxa which are expected to occur (e.g. ephemerid mayflies). | 0.005 | |

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 8 | 0.006 | | 0.003 | All habitats are shallow and there is trickling flow if any. If this condition persists (> 2 weeks), taxa scoring >5 are likely to relocate, be reduced in abundance, or may disappear altogether. |
| 9 | 0.004 | Trickling flow present, if any. Water quality will deteriorate as the surface water loses longitudinal connectivity. If this condition persists (> 2 weeks), taxa scoring >5 are likely to relocate, be reduced in abundance, or may disappear altogether. | 0.001 | |

## 8.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as April and July respectively. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow).

**Hydrological information for the Doring and Kammanasie EWR sites**

The natural hydrology used is the WR2005 modelled monthy timeseries for the periods 1920 to 2004. These set-ups were also used for modelling the PD conditions which are the 2004 land use and latest available domestic abstractions with the WRYM-MF. For both J1DORI-EWR7 and J3KAMM-EWR10, there are no local gauges that could be used to assess the reliability of the PD information. Given this, and the low naturalised MAR for J1DORI-EWR7 (viz. 5.52 MCM), the modelled PD hydrologies are of low confidence. For example, the initial modelling of the PD hydrology (using the WR2005 set-up) at J1DORI-EWR7 resulted in extended periods (up to 15 years) of no flow. For the Doring River, information on PD low flow hydrology was obtained from a local farmer to inform the assessment of the EWR, and two flow measurements were made for this study (January and April 2014) corresponding to flow during a wet year. The PD hydrology was subsequently revised for the J1DORI-EWR7 (it reduces to a 'trickle' but seldom below 1 litre/sec), but is nonetheless of low confidence. It is for this reason that the EWR results (flow-assurance rules and timeseries) for the Doring and Kammanasie EWR sites (J1DORI-EWR7 and J3KAMM-EWR10) have not been constrained to be equal/lower than the PD hydrology.

## 8.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the appropriate EC, descriptions are provided for key stress points (**Table 8.3**). Note that in this case the fish and macroinvertebrate requirements were mostly similar.

## Table 8.3 J1DORI-EWR7: Stress requirements and habitat and instream biota description

| Dry season | | Wet season | |
|---|---|---|---|
| **Flow* ($m^3/s$)** | **Description** | **Flow ($m^3/s$)** | **Description** |
| **Duration: 95% (Drought)** | | | |
| 0 | **Fish stress: 10.** Fish in survival mode and confined to pools. Elevated mortalities occur due to disease (poor water quality) and sparse fish habitat and cover due to reduced water levels (predation). | 0 | **Fish stress: 10.** Fish in survival mode and confined to pools. Elevated mortalities due to disease (poor water quality and high temperatures) and sparse fish habitat and cover due to lowered water levels in pools (increased predation). |
| **Duration: 80%** | | | |
| 0.001 | **Fish stress: 9.7.** Very slight improvement in water quality and levels maintained in pools, but elevated mortalities. | 0.002 | **Fish stress: 9.7.** Higher water temperatures in wet season thus more flow required to maintain water quality than in dry (winter) season. No movement between pools and no spawning of either fish species (*P.afer* and *S. capensis*) possible. Elevated mortalities due to disease.<br>**Macroinvertebrate stress: 9.5.** Surface water with no flow. If this condition persists for >2 weeks, the majority of taxa scoring >5 will be reduced in abundance or will disappear. |
| **Duration:50%** | | | |
| 0.006 | **Fish stress: 8.6.** Very limited fast very shallow habitat in riffles, allowing very limited fish movement. No migration or fish spawning habitat available. Poor to moderate water quality.<br>**Macroinvertebrate stress: 6.5.** These flows are associated with shallow water (<0.08 m ave.) and trickling flows. This condition supports the non flow-dependent elements of the fauna for a period, until water quality deteriorates to an unmanageable state. This is sustainable during the dry season for a fair proportion of the time assuming that floods occur during this period. | 0.01 | **Fish stress: 8.3.** 5% Fast very shallow habitat in riffles, allowing limited spawning of *P. asper* and some vegetation for sticky eggs of *S. capensis* in pools.<br>**Macroinvertebrate stress: 7.** This is a shallow flow (max. depth 0.08 m), which only just covers the smaller cobbles. Velocities (ave. 0.1 m/s, max. 0.3 m/s) are adequate to maintain taxa with a preference for moderately fast flows and also make provision for the less sensitive FDI taxa which are expected to occur (e.g. simuliid blackflies). Abundances will be low. |
| **Duration: 20%** | | | |
| 0.017 | **Macroinvertebrate stress: 4.** At this flow the maximum depth is 0.1 m, which is adequate to provide some depth over the cobble habitat. The associated velocities (ave. 0.15 m/s, max. 0.48 m/s) should sustain all elements of the current fauna, and possibly the expected simuliids, but more sensitive expected FDI taxa are unlikely to occur. | 0.029 | **Macroinvertebrate stress: 5.** This flow is associated with an average depth of 0.08 m, a maximum depth of 0.12 m, and a maximum velocity of 0.6 m/s. These conditions are suited to the maintenance of the current community and will support additional expected taxa with a preference for moderate to fast flows (e.g. Simuliidae, additional baetid species and psephenid beetle larvae). |

* Final HFSR-RM model output values.

## 8.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The low flows for both the dry and wet seasons, would maintain the present PES of C/D and an overall PES of C/D. This would be due to the marginal habitat being either inundated or soils being moist at any of the low flow. Although it could be argued that this would be a negative impact on this reach, allowing for further encroachment of the instream areas by reed species (*P. australis*), species should no high flows/floods occur to scour the main channel areas.

## 8.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in **Table 8.4** and final high flow results are provided in **Table 8.5**.

**Table 8.4 J1DORI-EWR7: Identification of instream functions addressed by the identified floods for riparian vegetation**

| Flood Class<br>Flood Range (Peak in m³/s) | Riparian vegetation motivation | Fish flood functions | | | | | | Macroinvertebrate flood functions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Migration cues & spawning | Migration habitat (depth etc.) | Clean spawning substrate | Create nursery areas | Resetting water quality | Inundate vegetation for spawning | Breeding and hatching cues | Clear fines and surface algae | Scour substrate | Reach or inundate specific areas | Reset and remobilize cobble + rock habitats | Transport vegetative material and biota |
| Class I (0.41) | Required to inundate areas at the 0.25 m height, which would be important to scour/reduce sedimentation which would otherwise be colonised by Common reeds (*P. australis*). | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| Class II (0.84) | Activation of a channel/bench that contains mostly hygrophilous grasses and sedges in these areas, while reducing woody cover. This will also reduce excessive sedimentation of the cobble areas found within this area. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Class III (2.1) | Floods in this range would activate the lower zone that is currently colonised by hygrophilous species and is still dependent on inundation by the river (left bank) as opposed to seepage (height of 0.5 m). | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| Class IV (7.2) | These floods would serve to remove any woody species within the Lower/Upper zone, to prevent "bush encroachment" by species such as *A. karroo*. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ |

There are no local gauges that could be used to verify the high flows and specifically the flood durations. Gauge records used for H8DUIW-EWR1 and H9GOUK-EWR2 as well as gauge data for the Brand River in the adjacent catchment of J1DORI-EWR7 were used to:

- 'inform' (since ecological requirements are also taken into consideration to a point) the assessment of typical (natural) durations for various flood magnitudes (classes); and

- to develop a characteristic relationship between instantaneous peak (as assessed by the ecologists – specifically for riparian vegetation for this study, but for which the adequacy is also confirmed for fish and invertebrate requirements) and average daily peak as applied in the high flow volume calculations.

**Table 8.5 J1DORI-EWR7: The recommended number of high flow events required**

| Flood class (Peak in $m^3/s$) | Flood requirements* | Months | Daily ave. | Duration (days) |
|---|---|---|---|---|
| Class I (0.41) | 2 | October, November, January | 0.4 | 2 |
| Class II (0.84) | 1 | Spring/Summer | 0.8 | 3 |
| Class III (2.1) | 1:2 | Spring/Summer | 2 | 3.5 |
| Class IV (7.2) | 1:5 | Spring/Summer | 6.1 | 5 |

* Refers to frequency of occurrence per year, i.e. how often the floods occur per year where e.g. 1:3 means once every three years.

It must be noted that the RDRM distributes the annual high flow volume monthly, according to the natural distribution. Specialists did, however, identify the months where no flood volumes are required.

## 8.6 EWR RESULTS

The results are provided as an EWR table (**Table 8.6**) and an EWR rule (**Table 8.7**). Flow duration graphs are supplied as **Figures 8.3** and **8.4**. Detailed results are provided in the model-generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 8.8**.

### Table 8.6 J1DORI-EWR7: EWR table for PES and REC: C/D EC

| Month | Low Flows | | | High Flows ($m^3/s$) | |
|---|---|---|---|---|---|
| | Drought (90%) ($m^3/s$) | 60% ($m^3/s$) | 50% ($m^3/s$) | Daily average ($m^3/s$) | Duration (days) |
| October | 0.000 | 0.007 | 0.010 | 0.4 | 2 |
| November | 0.000 | 0.007 | 0.013 | 0.4 | 2 |
| December | 0.000 | 0.007 | 0.011 | 6.1 (1:5) | 5 |
| January | 0.000 | 0.005 | 0.007 | 0.4 | 2 |
| February | 0.000 | 0.005 | 0.006 | | |
| March | 0.000 | 0.006 | 0.009 | 2 (1:2)[1] | 3.5 |
| April | 0.000 | 0.007 | 0.010 | 0.8 | 3 |
| May | 0.000 | 0.006 | 0.010 | | |
| June | 0.000 | 0.004 | 0.008 | | |
| July | 0.000 | 0.004 | 0.006 | | |
| August | 0.001 | 0.005 | 0.007 | | |
| September | 0.000 | 0.005 | 0.007 | | |

* Refers to frequency of occurrence per year, i.e. how often the floods occur per year where e.g. 1:3 means once every three years.

### Table 8.7 J1DORI-EWR7: Total low flow assurance rules ($m^3/s$) for PES and REC: C/D

| Month | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 99% |
|---|---|---|---|---|---|---|---|---|---|---|
| October | 0.041 | 0.028 | 0.022 | 0.015 | 0.010 | 0.007 | 0.004 | 0.002 | 0.000 | 0.000 |
| November | 0.037 | 0.032 | 0.028 | 0.020 | 0.013 | 0.007 | 0.004 | 0.002 | 0.000 | 0.000 |
| December | 0.038 | 0.027 | 0.019 | 0.015 | 0.011 | 0.007 | 0.004 | 0.002 | 0.000 | 0.000 |
| January | 0.028 | 0.020 | 0.012 | 0.010 | 0.007 | 0.005 | 0.003 | 0.002 | 0.000 | 0.000 |
| February | 0.029 | 0.019 | 0.011 | 0.009 | 0.006 | 0.005 | 0.002 | 0.001 | 0.000 | 0.000 |
| March | 0.037 | 0.019 | 0.013 | 0.011 | 0.009 | 0.006 | 0.003 | 0.001 | 0.000 | 0.000 |
| April | 0.043 | 0.029 | 0.019 | 0.014 | 0.010 | 0.007 | 0.003 | 0.002 | 0.000 | 0.000 |
| May | 0.037 | 0.028 | 0.020 | 0.015 | 0.010 | 0.006 | 0.003 | 0.002 | 0.000 | 0.000 |
| June | 0.025 | 0.020 | 0.014 | 0.011 | 0.008 | 0.004 | 0.003 | 0.002 | 0.000 | 0.000 |
| July | 0.023 | 0.017 | 0.013 | 0.009 | 0.006 | 0.004 | 0.002 | 0.001 | 0.000 | 0.000 |
| August | 0.035 | 0.021 | 0.014 | 0.011 | 0.007 | 0.005 | 0.003 | 0.002 | 0.001 | 0.000 |
| September | 0.029 | 0.024 | 0.015 | 0.010 | 0.007 | 0.005 | 0.003 | 0.002 | 0.000 | 0.000 |

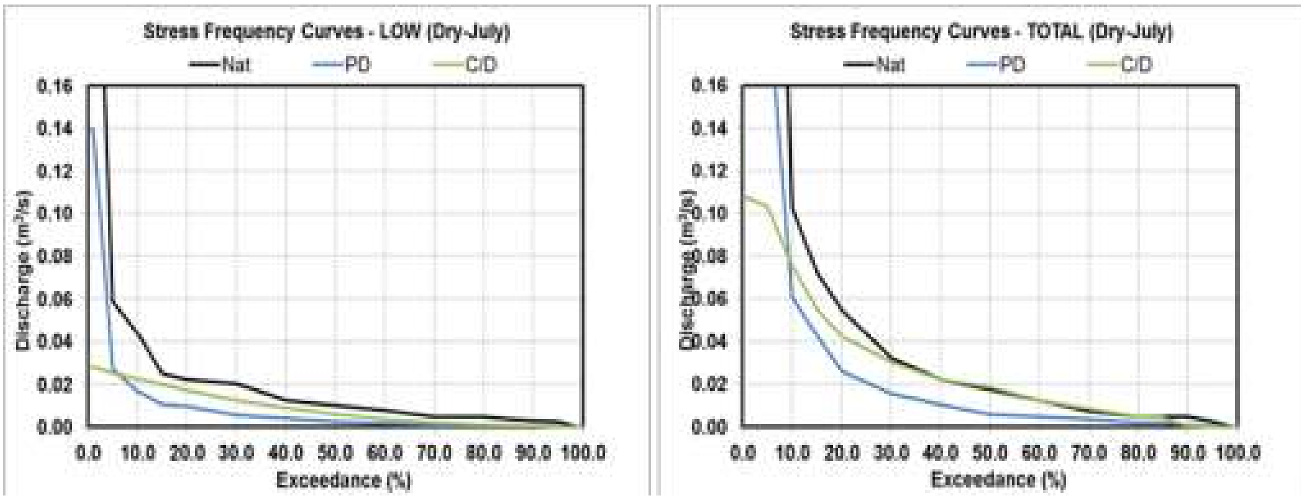



**Figure 8.3 J1DORI-EWR7: Flow duration graph for the dry season low flows (left), total flows (right)**

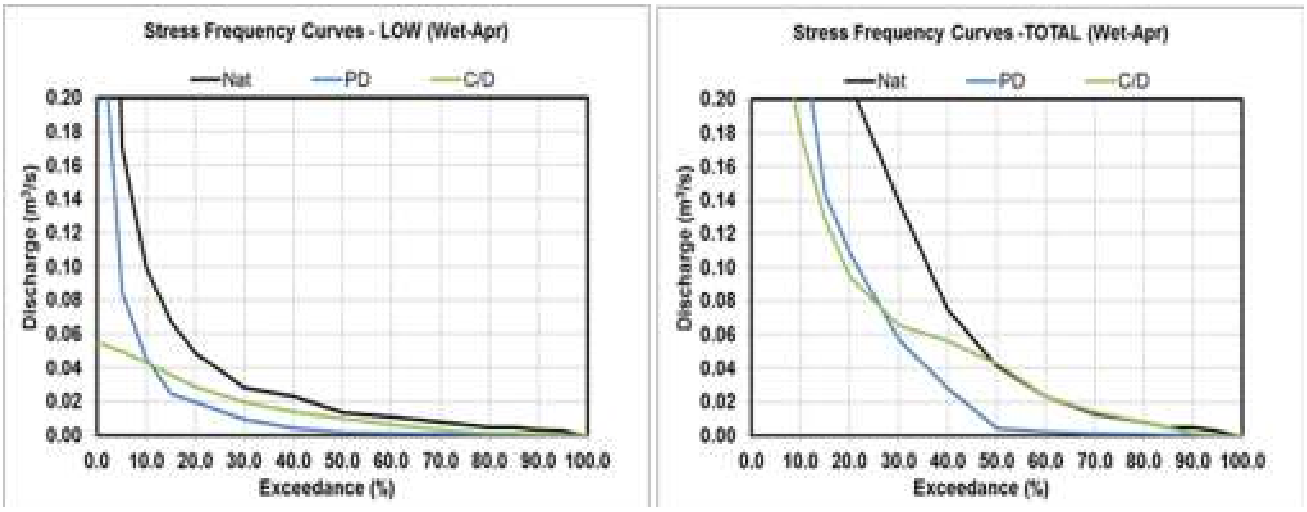



**Figure 8.4 J1DORI-EWR7: Flow duration graph for the wet season low flows (left), total flows (right)**

**Table 8.8 J1DORI-EWR7: Summary of results as a percentage of the nMAR**

| EcoStatus | nMAR (MCM) | pMAR (MCM) | Low flows (MCM) | Low flows (%) | High flows (MCM) | High flows (%) | Total flows (MCM) | Total (%) |
|---|---|---|---|---|---|---|---|---|
| PES; REC: C/D | 4.52 | 2.01 | 0.386 | 8.5 | 0.644 | 14.3 | 1.03 | 22.8 |

# 9 ECOCLASSIFICATION: OLIFANTS RIVER – J3OLIF-EWR9

## 9.1 EIS RESULTS

The EIS evaluation resulted in a **MODERATE** importance. The highest scoring metrics are:

- Unique riparian/wetland species: Three endemic riparian species occur at the site*: Cyperus thunbergii, Nymania capensis* and *Salsola aphylla.*
- Riparian/wetland migration corridor: An effective corridor is provided by dense woody vegetation (mostly *A. karoo* and *S. aphylla*) in an otherwise barren and sparse landscape.

## 9.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 9.1** and water quality and diatom information is provided in **Appendix A** and **B**, respectively.

**Table 9.1 J3OLIF-EWR9: Present Ecological State**

| |
|---|
| **IHI Hydrology: PES: B, Confidence: 1.6** |
| The nMAR is 13.76 MCM and the pMAR is 11.32 MCM (82.3% of the nMAR). Baseflows have decreased from natural although timing and distribution have remained the same. These changes seem continuous throughout the year due to irrigation and farm dams. |
| **Water quality: PES: C (75.9%), Confidence: 2** |
| Salt levels are elevated, which is also linked to the high natural levels expected due to the geology of the region. Of concern is the high sulphate levels recorded. Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes, with temperature and oxygen impacts expected when little flow is present. Note that irrigation activities are limited in this area, with livestock farming being the predominant land-use activity. |
| **IHI Instream: PES: B/C (80%) Confidence 2.6 IHI Riparian: PES: C (75%), Confidence 2.7** |
| The instream IHI is mainly impacted by decreased base flow due to abstraction for irrigation. Deteriorated water quality due to agricultural return flows has resulted in bed modification (sedimentation and algae) while nutrient and salinity levels are elevated.<br>The riparian IHI is mainly impacted by bank structure modification due to cattle grazing which have led to bank instability and substrate exposure. Lateral connectivity has also been impacted due to overgrazing in marginal and non-marginal areas. |
| **Riparian vegetation: PES: C (75.8%), Confidence: 3.1** |
| The site occurs within Eastern Little Karoo which refers to a terrestrial vegetation type dominated by dense succulent Karoo shrub lands. (Mucina and Rutherford, 2006).<br><br>On 16 December 1797, J Barrow describes the Olifants River as follows: "The long drought had completely deprived the Olifant's River of its waters... indeed along each side of the bed of the river where the mimosas [*A. karoo*], now full of golden blossoms, still retained their verdure..." (Barrow, 1801, in Skead, 2009). Google Earth images show no noticeable change since 2006.<br><br>The marginal zone was restricted to the channel floor, about 10 m wide and sandy and likely always wet (not necessarily flowing). Severe algae cover (>50%) was present. Dominant species included *Cotula*, *Panicum* and several sedges. Vegetation in the sub-zone was sparse, overgrazed, short and dominated by non-woody vegetation. Woody encroachment was not evident in the sub-zone, likely an indication that larger floods occur sufficiently.<br>The lower zone consisted of a well-defined flood bench with no erosion observed. The sub-zone was overgrazed, with 80 - 100% grass cover and very little sedge cover. *Agrostis* was the dominant grass with a few *Gomphocarpus fruticosus* individuals.<br>The upper zone was similar to the lower zone (higher up in profile) with additional grass species (dominated by *C.* |

| |
|---|
| *dactylon*) and more cover by *G. fruticosus*.<br><br>The Macro Channel Bank (MCB) was narrow, alluvial and dominated by low shrubs and some trees. Dominant species were *Salsola aphylla, Tarconanthus, Lycium cinereum, L. hirsuta* and some young *A. karoo* were encroaching into the sub-zone. Flood debris was observed, the effect of which could have been recent especially for lower sub-zones.<br><br>Beyond the levee the floodplain was dominated by woody thicket (same species as MCB). A dense older (larger) population of *A. karoo* existed, likely because large floods are less destructive on the floodplain but recruitment was distinctly absent (likely due to grazing of seedlings seeds).<br>The main impacts were overgrazing. The trend is likely stable. |
| **Macroinvertebrates: PES: C (69%), Confidence: 1.5** |
| The RC was derived from data received from DWS: Western Cape for seven sampling trips to the RHP site J3KAMM-UNION, between 2003 and 2012. This site is located in the Holdrif River, a tributary in the upper reaches of the Kammanassie River. The site occurs in an adjacent quaternary (J34A) to the Olifants, but in the same EcoRegion Level II. This site is likely to have perennial flow, whereas J3OLIF-EWR9 is seasonal or ephemeral and most flow seems to have groundwater origins.<br><br>In addition the PES/EIS project (DWA, 2013) data for nearby sub-quaternary J31D-8592 were consulted, however only 'expected' taxa (no actual) were included. The data were thus not used in compiling the RC.<br><br>The site is upstream of a large dam. Water use is typically abstraction of groundwater through boreholes. It is not certain whether or not this deep aquifer abstraction affects the groundwater levels. The hydrology at EWR9 is very low confidence, which makes it difficult to estimate the nature and duration of surface water conditions under both natural and PD scenarios. It is equally difficult to assess what taxa may be present under these conditions. This further complicated the derivation of the RC. As a precautionary measure, only taxa collected at J3KAMM-UNION and scoring less than10 were selected for the RC.<br><br>The SASS5 score for the site was 84, with 17 taxa and an ASPT of 4.9. The ASPT for the derived RC was 5. The fauna at EWR 9 was dominated by gomphid dragonfly larvae, which occur naturally in the alluvial river bed and are capable burrowers. The numerous age cohorts of this dragonfly collected in a single sample suggested that this group is successful and in abundance year round, in different age tiers, which indicates the persistence of hyporheic water (water in the zone between surface - and ground water).<br><br>The main discrepancy between the invertebrate fauna of the RC and the sample appears to be in the taxa with a preference for moderately fast flow, cobble or gravel/sand habitat, and moderate water quality (elmids, leptocerids, hydraenids, potamonautids, aeshnids, hydropsychids absent, inter alia). These conditions most likely represent seasonal conditions during natural times and this is an indication that these conditions no longer persist for the same duration. |

The PES is a C and the EcoStatus models are provided electronically. The major issues that have caused the change from RC are both flow and non-flow related issues. Baseflows and moderate flood frequency have decreased due to irrigation while water quality deteriorates especially when flows are low leading to high temperatures and low oxygen rates. Overgrazing also occurs in the riparian zone leading to bank modification and decreased longitudinal connectivity.

## 9.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC is determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS is MODERATE, no improvement is required and set to maintain the PES.

## 9.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 9.2**.

**Table 9.2 J3OLIF-EWR9: Summary of EcoClassification results**

| Component | PES and REC |
|---|---|
| IHI Hydrology | **B** |
| Water quality | **C** |
| Macroinvertebrates | **C** |
| Riparian vegetation | **C** |
| **EcoStatus** | **C** |
| Instream IHI | **B/C** |
| Riparian IHI | **C** |
| **EIS** | **MODERATE** |

Both the instream REC and the riparian vegetation REC is impacted on by flows as well as anthropogenic impacts. The EWRs will therefore be set to maintain the REC of a C.

# 10 EWR REQUIREMENTS: OLIFANTS RIVER – J3OLIF-EWR9

No low flow requirements were directly set by the specialists for fish or Macroinvertebrates. However, the hydrological modelling and baseflow separation suggests that there were baseflows at the site all the time under natural conditions (i.e. perennial conditions), but this has been reduced to 30% and 60% of the time under PD conditions (driest and wettest months, respectively) (**refer to Figure 10.1 and 10.2**). Specialist opinion is, however, that the river is most unlikely to have displayed perennial (surface) flow under natural conditions. At the time of a site visit (February 2014), surface flow of 50 l/s was measured at the site (which is located at a bedrock drift) with no flow noted a few kilometres further downstream. This suggests a considerable downstream discharge in the alluvial sands which is forced to the surface by local geological conditions. It needs to be noted, however, that the hydrological analyses are of low-confidence (refer to **Table 13.6**), although such (subsurface) flows in the alluvial sediments would in any event be modelled as non-zero – inferring (surface) perenniality.

In Skead (2009) J. Barrow described the Olifants River as "completely deprived ... of its waters" during December 1797. By the way it is written the author may be suggesting that the Olifants was dry due to a drought, but this term was used loosely throughout documentation. He also describes the vegetation in detail and it exactly matches the lower, upper, MCB and floodplain zones of today. Then in February 1839 the Olifants is again described as "completely dry" by F. Krauss but he also mentions springs in certain areas.

These descriptions, as well as current day vegetation strongly suggest a seasonal river during natural circumstances and probably ephemeral in terms of surface flows present. Some river sections may show seasonal river flow nature due to the presence of springs.

Since the RDRM requires a stress profile (between zero and maximum baseflow), the simplest linear variation was applied (as for J4GOUR-EWR6), and subsequent shifts were applied to align the stress-duration for the PES with that inferred from the PD hydrological modelling. Note that these flows are small, and do not occur for very much of the time. They constitute only 3.9% of the naturalised MAR (**Table 10.5**) and only occur for months following substantial rainfall in the catchment, whereas high flows make up 22.2%.

## 10.1 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in **Table 10.1** and final high flow results are provided in **Table 10.2.**

**Table 10.1 J3OLIF-EWR9: Identification of instream functions addressed by the identified floods for riparian vegetation**

| Motivations |
|---|
| **CLASS I (2.8)**[1] |
| **Riparian vegetation:** Floods the marginal and lower zones and begins to flood the *G. fruticosus* population. It keeps the marginal and lower zones free from *G. fruticosus* and woody aliens. It also floods 100% of marginal vegetation as well as sedges and will prevent the establishment of woody species in these zones. |
| **CLASS II (10 - 15)** |
| **Riparian vegetation:** Floods the upper zone and may scour marginal zone vegetation, including algae. It will also maintain openness and prevent terrestrialisation of the macro channel bed. |
| **CLASS III (>50)** |
| **Riparian vegetation:** Floods the MCB and begins to flood the floodplain. It prevents encroachment of trees towards the channel and maintains woody population dynamics on the floodplain. |

1 (Peak in $m^3/s$)

No reliable gauges were present to verify high flows.

**Table 10.2 J3OLIF-EWR9: Recommended flood events**

| Flood Class (Peak in $m^3/s$) | Flood requirements* | Months | Daily Ave. | Duration (days) |
|---|---|---|---|---|
| **PES** | | | | |
| Class I (2.8) | 1 | March - April | 2.3 | 3 |
| Class II (10 - 15) | 1:3 | March - April | 6.8 | 5 |
| Class III (>50 | 1:10 | March - April | 37 | 6 |

*Refers to frequency of occurrence per year, i.e. how often will the flood occur per year.

The RDRM model distributes the high flow volumes across the wet period months according to the natural distribution. The months provided by specialists are therefore those in which floods are recommended, but there will be naturally-determined variations in the final EWR high flow time series results.

## 10.2 EWR RESULTS

The results are provided as an EWR table (**Table 10.3**) and an EWR rule (**Table 10.4**). Flow duration graphs are supplied as **Figure 10.1** and **10.2**. Detailed results are provided in the model generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 10.4**.

### Table 10.3 J3OLIF-EWR9: EWR table for PES and REC: C EC

| Month | Low Flows ($m^3/s$) | | High Flows | |
|---|---|---|---|---|
| | Drought (90%) ($m^3/s$) | 60% ($m^3/s$) | Daily average ($m^3/s$) | Duration (days) |
| October | 0.000 | 0.000 | | |
| November | 0.000 | 0.000 | | |
| December | 0.000 | 0.000 | 2.3 | 3 |
| January | 0.000 | 0.000 | 6.8 | 5 |
| February | 0.000 | 0.000 | | |
| March | 0.000 | 0.000 | | |
| April | 0.000 | 0.000 | | |
| May | 0.000 | 0.000 | | |
| June | 0.000 | 0.000 | | |
| July | 0.000 | 0.000 | | |
| August | 0.000 | 0.000 | | |
| September | 0.000 | 0.000 | | |

### Table 10.4 J3OLIF-EWR9: Low flow Assurance rules ($m^3/s$) PES and REC: C/D

| Month | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 99% |
|---|---|---|---|---|---|---|---|---|---|---|
| October | 0.284 | 0.128 | 0.053 | 0.037 | 0.020 | 0.010 | 0.001 | 0.001 | 0.000 | 0.000 |
| November | 0.430 | 0.204 | 0.059 | 0.039 | 0.008 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 |
| December | 0.284 | 0.133 | 0.067 | 0.004 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| January | 0.047 | 0.035 | 0.020 | 0.016 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| February | 0.049 | 0.040 | 0.028 | 0.014 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| March | 0.047 | 0.031 | 0.017 | 0.004 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| April | 0.049 | 0.025 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| May | 0.091 | 0.049 | 0.010 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| June | 0.112 | 0.085 | 0.053 | 0.022 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| July | 0.070 | 0.063 | 0.041 | 0.017 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| August | 0.064 | 0.049 | 0.017 | 0.013 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| September | 0.049 | 0.041 | 0.013 | 0.012 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

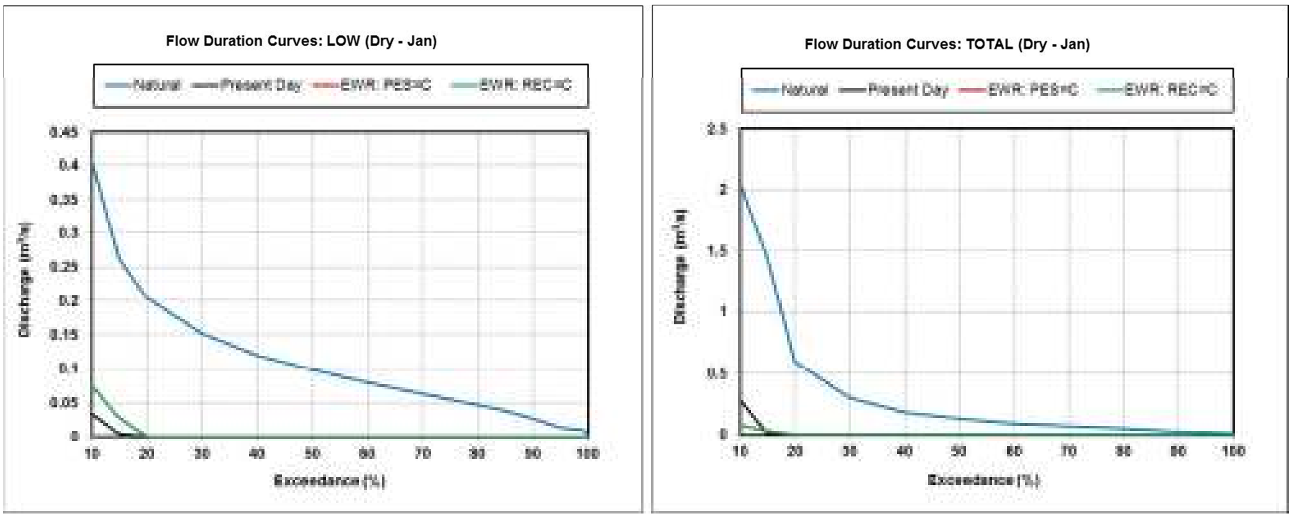



**Figure 10.1 J3OLIF-EWR9: Flow duration graph for the dry season (low flows left, total flows right)**

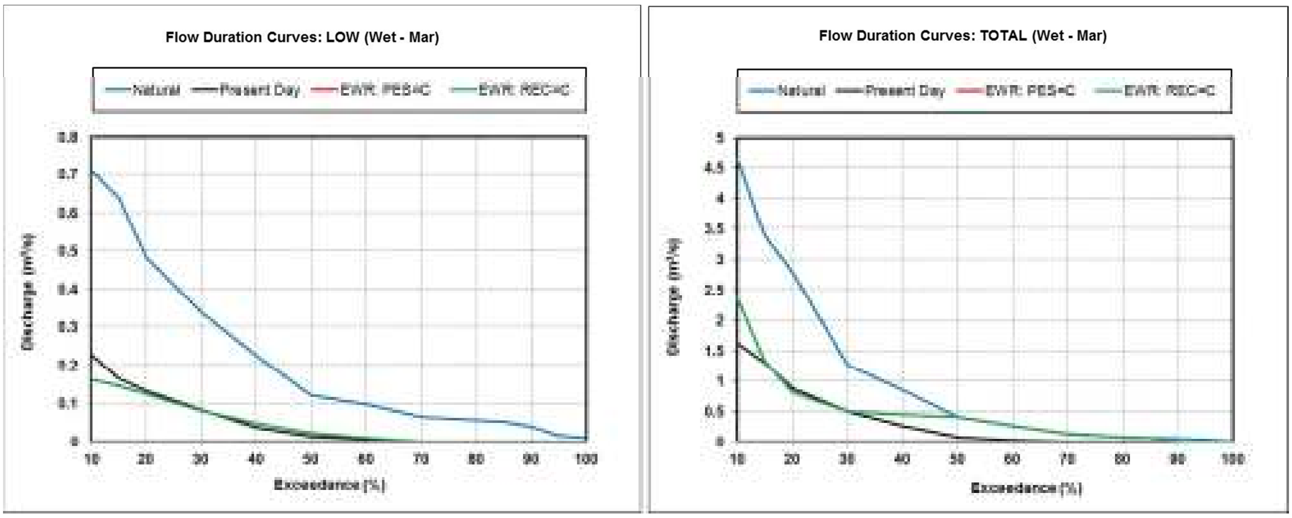



**Figure 10.2 J3OLIF-EWR9: Flow duration graph for the wet season (low flows left, total flows right)**

**Table 10.5 J3OLIF-EWR9: Summary of results as a percentage of the nMAR**

| EcoStatus | nMAR (MCM) | pMAR (MCM) | Low flows (MCM) | Low flows (%) | High flows (MCM) | High flows (%) | Total flows (MCM) | Total (%) |
|---|---|---|---|---|---|---|---|---|
| PES; REC: C | 13.76 | 11.32 | 0.54 | 3.9 | 3.05 | 22.2 | 3.59 | 26.1 |

# 11 ECOCLASSIFICATION: KAMMANASSIE RIVER – J3KAMM-EWR10

## 11.1 EIS RESULTS

The EIS evaluation resulted in a LOW importance. The highest scoring metrics are:

- Rare and endangered species: The endangered *P. asper* occurs in the reach.
- Refugia and critical habitat: Deep pools present.
- The river is relatively small and it is sensitive to flow changes.
- Species/taxon richness.
- Refugia and critical wetland habitat: Corridor in dry environment.

## 11.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 11.1** and water quality and diatom information is provided in **Appendices A** and **B** respectively.

**Table 11.1 J3KAMM-EWR10: Present Ecological State**

| **IHI Hydrology: PES: C, Confidence: 1.1** |
|---|
| The nMAR is 20.57 MCM and the pMAR is 19.63 MCM (95.4% of the nMAR). No observed flow record was available. Inflow at Kamanassie Dam (J3R001) is measured downstream of J3KAMM-EWR10. Inflows at dams are, however, not a good indication of low flow. Baseflows have decreased significantly from natural and these changes seem continuous and the river is often dry. Although the modelled natural hydrology indicates natural perenniality, it is likely that in these quite dry areas that the river could have stopped flowing during droughts. Changes in present hydrology are mainly due to farm dams, irrigation along the river and livestock watering. Seasonality has not changed. |
| **Physico-chemical variables: PES: C, Confidence: 2** |
| Land uses are irrigated farming along river margins and livestock farming. The biological water quality (as indicated by diatoms) at this site was Moderate. Nutrient levels, organic pollution and salinity were elevated with salinity and organic pollution levels becoming problematic. Low to no flows at times result in impacts on oxygen and temperature levels. Although water was clear at the site, there was instream silt when disturbed, so a small impact on turbidity is also expected. |
| **IHI Instream: PES: D Confidence 2.1 HI Riparian: PES: D, Confidence 2.2** |
| The instream IHI is mainly impacted by decreased base flow due to abstraction for irrigation. Deteriorated water quality due to agricultural return flows has resulted in bed modification (sedimentation and algae) while bank modification changes are the result of agriculture and alien invasive vegetation.<br>The riparian IHI is mainly impacted by bank structure modification due to agriculture, cattle grazing and the presence of alien invasive species which have led to bank instability and substrate exposure. |
| **Riparian vegetation: PES: C/D, Confidence: 3.6** |
| Marginal Zone and Lower Zone: The marginal zone was limited toa very narrow zone, dominated/encroached by *Cyperus textilis*, bound by steeper valley slopes that are colonised the Eastern Little Karoo vegetation type (Succulent Karoo Biome: Rain shadow Valley Bioregion).<br>Upper Zone and floodplain: These areas have been transformed through the invasion of the alien vegetation listed below, with localised areas colonised by remaining indigenous species, namely grasses and sedges (*C. dactylon*, and *C. textilis*).<br>Main impacts at the site are as a result of the alien plants, namely wattles, Willows and Brambles (*A. mearnsii*, *Salix mucronata* and *Rubus* spp.). These species created mono-specific stands, which out-DRM (high flow submodel) compete indigenous species that create bank stability. During flood events the |

| |
|---|
| alien plants create bank instability. |
| **Fish: PES: D, Confidence: 2** |
| No fish distribution data for this SQ reach are available, but the recent PES/EIS study (DWS, 2014) predicts with low confidence that the SQ reach immediately upstream of EWR 10 has two indigenous fish species present, namely *S. capensis* and the smallscale redfin *P. asper* that should occur under reference conditions. However, only the alien largemouth bass *M. salmoides* was captured during the June 2014 survey at EWR 10. This predatory species could be responsible for the apparent demise of the two indigenous species in this reach, which are both small and very vulnerable to predation, particularly during low flows. Additional reasons for the absence or very low numbers of indigenous fish are probably related to:<br>▪ Elevated sediment input reducing pool depth and degrading the substrate providing fish cover.<br>▪ A deterioration in water quality due to polluted agricultural return flows (probably significant during low summer flows); and<br>▪ a decrease in base flows during summer due to excessive abstraction for agricultural purposes. |
| **Macroinvertebrates: PES: C/D, Confidence: 2** |
| The reference or 'natural' condition for this site was derived on the basis of:<br>▪ Eight sets of data from the RHP site J3KAMM-CDIEP, upstream in the adjacent SQ (8937, PES B) and same Ecoregion Level II. Eight sets of data from DWS: Western Cape and all PES/EIS data for the same site. SASS5 Score/No. of Taxa/ Average Score per Taxon for the 8 samplings: Maximum 267/43/6.2; Maximum142/21/6.8; Median 89/16/5.8.<br>▪ Data from historic sample sets compiled by DWS Western Cape for an upstream RHP site in adjacent SQ J34C-08869, J3KAMM-CDIEP (8 sample sets: 2003, 2004, 2005, and 2012). This is in the same Ecoregion Level II as the sampling site. The data include all sampling details, and macroinvertebrate abundances.<br>▪ Data sourced from DWS: PES/EIS project (DWS, 2014) for the Breede-Gouritz WMA, specifically for the same upstream site J3KAMM-CDIEP. The data are highly summarised and do not include sampling details or macroinvertebrate abundances, but do provide details of all known Macroinvertebrates collected at this site historically.<br>The reference condition is slightly modified on the basis of discrepancies in habitat between the selected reference site and the sampling site, and on specialist experience. The derived condition indicates that >20 taxa could possibly be have occurred at this site in the natural state, with an ASPT of >5.8. It should be noted that some of these taxa were only collected once in the many sampling sets.<br>The SASS5 score of the sample was 113, with 23 taxa present, and an ASPT of 4.9. Overall, the sample comprised resilient taxa scoring <8, with low preferences for both fast/moderately fast flowing water, and or for good or moderately good water quality. The following taxa were expected, but absent in the sample: leptophlebiid and teloganodid mayflies, pisullid caddisflies, helodid and psephenid beetles, and athericid dipterans. The largest changes in the sampled versus the expected taxa were in the absences of taxa with a high sensitivity to water quality or fast flow, in the paucity of taxa occupying the water column, and in the reduced numbers of families collected in the vegetation habitat.<br>It is likely that the major impacts to this system are caused by altered hydrology and water quality. The former is largely the result of the return flows from agriculture which keep flows regulated in this section of the river, resulting in the encroachment of the *S. mucronata* upstream of the causeway and of *Cyperus* sp. downstream of it. It is possible that some of the inter-year floods have been reduced in volume because of the abstractions in the catchment, and this also results in the continued densities of particularly the *Cyperus* downstream of the bridge. Water quality deterioration would appear to be mainly increased nutrients and salts, with some organic enrichment. The farming practices in the catchment are likely to also have led to some sedimentation which has provided the right environment for the proliferation of the bankside *Cyperus* spp. Finally, it is possible that certain elements of the macroinvertebrate fauna (e.g. Odonata) are being reduced in abundance by the (alien) largemouth bass. Other issues in the catchment are alien vegetation and poor land-use practice. |

The PES EcoStatus is a C/D EC and the EcoStatus models are provided electronically. The major issues that have caused the change from reference condition were mainly flow and some non-flow related issues. Irrigation return flows, abstraction and farm dams have resulted in decreased base flows with zero flows at times. Intensive farming result in impacts on water quality due to irrigation return flows. Elevated sediment input reduces pool depth and degrades the substrate for biota. Alien vegetation occurs in the upper riparian zone whereas the indigenous *C. textillis* (Flat Sedge) has encroached significantly in area. This is possibly due to nutrient enrichment and more consistent flows or seepage from return flows during dry times. Alien fish species also occur in the reach.

## 11.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was LOW, no improvement was required. The REC was therefore set to maintain the PES. No AEC was set as the instream condition was already in a D EC.

## 11.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 11.2**.

**Table 11.2 J3KAMM-EWR10: Summary of EcoClassification results**

| Component | PES and REC |
|---|---|
| IHI Hydrology | C |
| Physico chemical | C |
| Fish | D |
| Macroinvertebrates | C/D |
| Instream | D |
| Riparian vegetation | C/D |
| **EcoStatus** | C/D |
| Instream IHI | D |
| Riparian IHI | D |
| **EIS** | LOW |

Both the instream REC and the riparian vegetation REC are impacted on by flows as well as anthropogenic impacts. The EWRs will therefore be set to maintain the REC EcoStatus of a C/D EC.

# 12 EWR REQUIREMENTS: KAMMANASSIE RIVER – J3KAMM-EWR10

## 12.1 FLOW VS STRESS RELATIONSHIP

The HFSR-RM generated a stress flow index which was reviewed and adjusted to specialist requirements. The fish and macroinvertebrate stress flow index is provided in **Figures 12.1** and **10.2**. The integrated stress curve is illustrated on both curves. A description of the habitat and response associated with the key stress is provided in **Tables 12.1** and **12.2**.

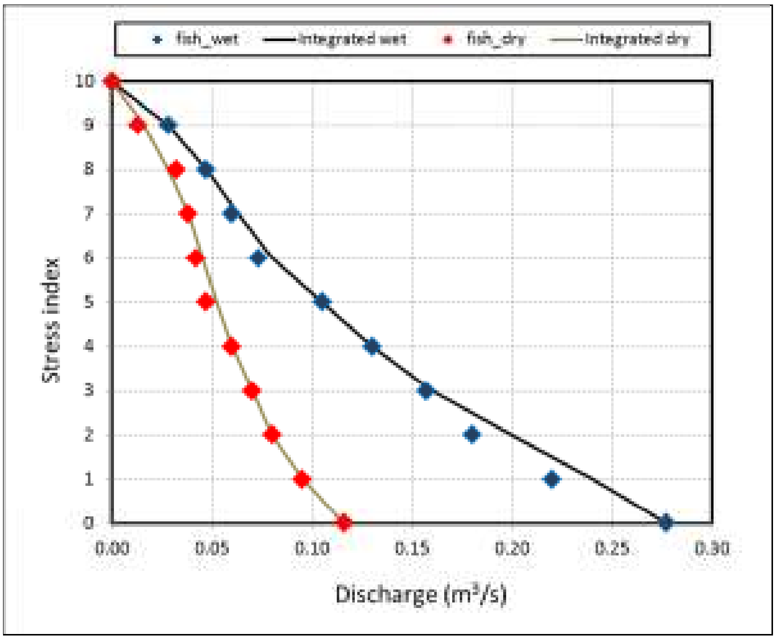



**Figure 12.1 J3KAMM-EWR10: Fish and integrated stress index**

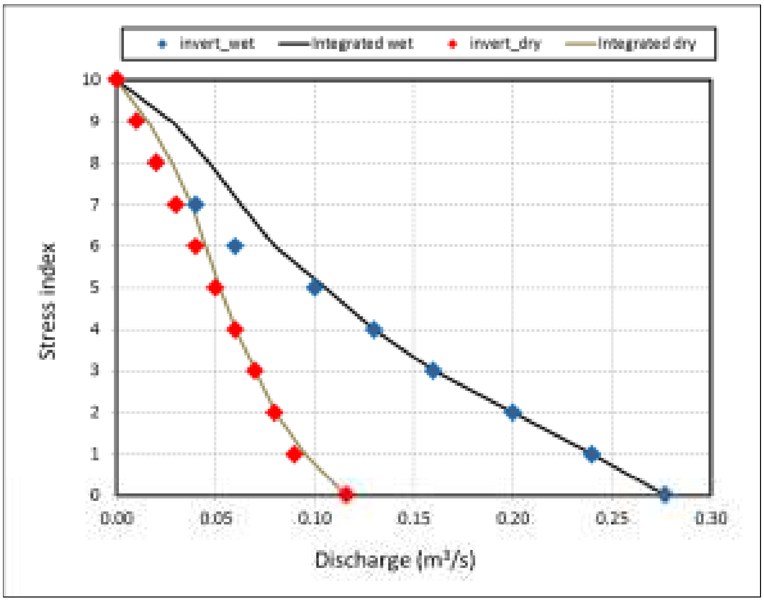



**Figure 12.2 J3KAMM-EWR10: Macroinvertebrate and integrated stress index**

**Table 12.1 J3KAMM-EWR10: Summarised habitat/biotic responses for the dry and wet season for fish**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 9 | 0.013 | Warm temperatures are exacerbated by low flows. Limited fish movement is possible through riffles. Water quality should be poor to very poor and no flushing of fines and no fast habitats are available. Elevated mortalities occur due to predation and disease expected. | 0.028 | First flows with some limited representation of fast velocity depth categories, slight improvement in water quality expected and adequate depth to allow some longitudinal migration. But elevated stress is present due to disease (water quality related) and predation due to reduced fish cover. |
| 8 | 0.028 | First flows where fast habitats will become available and hence water quality will improve notably (compared to lower flows), and depth will allow migration of fish over riffles. | 0.047 | Some fast intermediate habitat will become available, resulting in improved habitat diversity, adequate water quality and depths for migration, as well as some spawning habitat for *P. asper* in riffles. |
| 5 | 0.047 | All of the expected velocity-depth categories will be represented and therefore habitat diversity will be adequate to maintain all expected fish species. Water quality will be moderate and depth will be adequate to allow fish migration over riffles. | 0.11 | Adequate fast habitats for, unrestricted migration and moderate spawning habitats. Flushing should ensure suitable water quality will be provided. Moderate to low habitat stress for all fish species. |
| 3 | 0.07 | Limited stress on both fish species as adequate water quality and wide range of habitats available, as well as unrestricted fish movement over critical riffle areas. | 0.16 | Presence of all expected fast velocity depth categories for unrestricted fish passage over riffles and good spawning habitat for *P. asper* and *S. capensis*. Good water quality at these flows. Limited habitat stress expected. |

**Table 12.2 J3KAMM-EWR10: Summarised habitat/biotic responses for the dry and wet season for macroinvertebrates**

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| 5 | 0.11 | FDIs (none of which are sensitive) are maintained by the 8% FCS. Average depth of 0.18 m (max. 0.29 m) and average velocities of 0.18 (max. 0.6 m/s) sustain the upstream riffle and its community (baetids, hydropsychids, and aeshnids) upstream of the bridge. | 0.05 | No VFCS and 4% FCS. FDIs will be reduced in number and abundance. |
| 6 | 0.08 | Very fast flow habitat (VFCS) is lost and little FCS remains. FDIs will be reduced in number and abundance. | 0.04 | |
| 7 | 0.04 | | 0.03 | |
| 8 | 0.02 | FCS lost and FDIs will diminish in number. Depth (0.1 - 0.2 m) is adequate | 0.02 | No fast flow habitat remains, and no stems are inundated at this depth. MV |

| Stress | Dry season | | Wet season | |
|---|---|---|---|---|
| | Flow ($m^3/s$) | Habitat and stress description | Flow ($m^3/s$) | Habitat and stress description |
| | | to cover the riffle and maintain connectivity. | | comprises largely roots and overhanging vegetation, and does not provide a great deal of cover. The community is gradually reduced to the more resilient individuals and taxa. |
| 9 | 0.01 | At a max depth of 0.1 m and average velocities of 0.03 m/s, all habitat supporting macroinvertebrates scoring 5 or more will be lost and only the more resilient individuals will survive. | 0.01 | |

## 12.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as September and February, respectively. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow). Refer to **Section 8.2** for further hydrological information and considerations.

## 12.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the appropriate EC, descriptions are provided for key stress points (**Table 12.3**). Note that in this case the fish and macroinvertebrate requirements were mostly similar.

**Table 12.3 J3KAMM-EWR10: Stress requirements and habitat and instream biota description**

| Dry season | | Wet season | |
|---|---|---|---|
| Flow* ($m^3/s$) | Description | Flow ($m^3/s$) | Description |
| **Duration: 95% (Drought)** | | | |
| 0 | **Fish stress: 10.** Reflects natural hydrology with extended zero flow periods. Fish is under severe stress, but hardy species adapted to zero flow or very low flow conditions are present. High mortalities due to predation related to reduced cover and elevated disease due to poor water quality. | 0.01 | **Fish stress: 9.6.** Reflects natural hydrology for near perennial system for which fish are adapted, but high mortalities due to reduced habitat and cover, with limited migration and no breeding habitats available. **Macroinvertebrate stress: 10.** At a maximum depth of 0.1 m and average velocities of 0.03 m/s (trickling flow), the majority of habitat supporting macroinvertebrates scoring >8 or higher will be minimal, and only the more resilient individuals will persist for a period. This situation should only persist for a limited time (preferably < 2 weeks) during wet months. |
| **Duration: 60%** | | | |
| 0.02 | **Fish stress: 8.6.** Moderate mortalities occur due to high temperatures and | 0.05 | **Fish stress: 7.8.** Fast flowing riffle habitats provide limited spawning for *P.afer* and |

| Dry season | | Wet season | |
|---|---|---|---|
| **Flow* ($m^3/s$)** | **Description** | **Flow ($m^3/s$)** | **Description** |
| | poor water quality, but pool depths are maintained. No fast flowing habitats are present in riffle, but depths allow limited movement of fish between reaches. **Macroinvertebrate stress: 8.** At this flow there is no fast flow habitat, and no stems are inundated. MV comprises largely roots and overhanging vegetation, and does not provide a great deal of cover. The community is gradually reduced to the more resilient individuals and taxa. Lower stresses are required for a large proportion of the time during the dry season (40%). | | some MV for *S. capensis* spawning. Fish movement between pools is possible. Reduced mortalities occur due to cover availability and improved water quality. **Macroinvertebrate stress: 6.8.** This flow is associated with a paucity of flow (largely slow flow). The less sensitive of the FDIs will persist but gradually be reduced in number and abundance. |
| **Duration: 50%** | | | |
| 0.04 | **Fish stress: 7.** Some fast flowing habitats in riffle area become available, allowing movement over riffle areas. There is more habitat created and improvement in water quality, which result in reduced mortalities. Marginal spawning habitat for *P.afer* in riffles and inundated vegetation for *S. capensis* in pools. | | |
| **Duration:40%** | | | |
| 0.05 | **Macroinvertebrate stress: 5.5**. No VFCS and 4% FCS. FDIs will be reduced in number and abundance. | 0.09 | **Macroinvertebrate stress: 5.5.** Very fast flow habitat (VFCS) is lost, and little FCS remains. FDIs will be reduced in number and abundance. 60% of the time conditions will be better than this during the wet season. |

* Final HFSR-RM model output values

## 12.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Low flows would have the greatest impact on the cover and species diversity of the marginal zone. Currently, the observed Cyperaceae species (*C. textilis*) has dominated the marginal zone, out-competing all other species and has encroached on the marginal zone and the instream areas. The low flows for both the dry and wet seasons, would maintain the present PES of C/D and an overall PES of C/D. This would be due to the marginal habitat being either inundated or soils being moist. Although it could be argued that this would be a negative impact on this reach, allowing for further encroachment of the instream areas by *Cyperus* species should high flows/floods not occur to scour the main channel areas.

## 12.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in **Table 12.4** and final high flow results are provided in **Table 12.5**.

**Table 12.4 J3KAMM-EWR10: Identification of instream functions addressed by the identified floods for riparian vegetation**

| Flood Class Flood Range (Peak in $m^3/s$) | Riparian vegetation motivation | Fish flood functions | | | | | | Macroinvertebrate flood functions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Migration cues & spawning | Migration habitat (depth etc.) | Clean spawning substrate | Create nursery areas | Resetting water quality | Inundate vegetation for spawning | Breeding and hatching cues | Clear fines and surface algae | Scour substrate | Reach or inundate specific areas | Reset and remobilize cobble + rock habitats | Transport vegetative material and biota |
| Class I (0.7) | This will allow inundation of the lower zone that contains non-woody riparian species (sedges). This will aid in recruitment/activation of this area while removing any woody species. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Class II (3) | Activation of a channel/bench that contains mostly hygrophillous grasses and sedges in these areas, while reducing woody cover. This will also reduc excessive sedimentation of the cobbled areas found within this area. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | ✓ |
| Class III (7.5) | Inundation of the upper zone, that would allow for the maintenace of any facultative riparian species (woody and non-woody), while reducing pontential encroachment of the terrestrial vegetation that bounds this upper zone. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| Class IV (10) | These floods would scour any areas of sediment deposition and minimse the areas for colonisation by the Cyperaceae that have dominated the instream and marginal areas. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |

**Table 12.5 J3KAMM-EWR10: The recommended number of high flow events required**

| Flood class (Peak in $m^3/s$) | Flood requirements* | Months | Daily ave. | Duration (days) |
|---|---|---|---|---|
| Class I (0.7) | 3 | October, November, February | 0.7 | 3 |
| Class II (3) | 2 | July | 3 | 4 |
| Class III (7.5) | 1 | Mid Summer | 6.4 | 5 |
| Class IV (10) | 1:3 | Late Summer | 8.3 | 6 |

* Refers to frequency of occurrence per year, i.e. how often the floods occur per year where e.g. 1:3 means once every three years.

Daily and peak discharge records for two DWS gauges, namely H8H001 and H9H005 (see J1DORI-EWR 7 for more information), were used in this study to:

- 'inform' (since ecological requirements are also taken into consideration to a point) the assessment of typical (natural) durations for various flood magnitudes (classes); and
- to develop a characteristic relationship between instantaneous peak (as assessed by the ecologists – specifically for riparian vegetation for this study, but for which the adequacy is also

confirmed for fish and invertebrate requirements) and average daily peak as applied in the high flow volume calculations

It must be noted that the RDRM distributes the annual high flow volume monthly, according to the natural distribution. Specialists do, however, identify the months where no flood volumes are required.

## 12.6 EWR RESULTS

The results are provided as an EWR table (**Table 12.6**) and an EWR rule (**Table 12.7**). Flow duration graphs are supplied as **Figures 12.3** and **12.4**. Detailed results are provided in the model-generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 12.8**.

**Table 12.6 J3KAMM-EWR10: EWR table for PES and REC: C/D EC**

| Month | Low flows | | | High flows ($m^3/s$) | |
|---|---|---|---|---|---|
| | Drought (90%) ($m^3/s$) | 60% ($m^3/s$) | 50% ($m^3/s$) | Daily average ($m^3/s$) | Duration (days) |
| October | 0.009 | 0.052 | 0.081 | 0.7 | 3 |
| November | 0.009 | 0.052 | 0.083 | 0.7 | 3 |
| December | 0.013 | 0.048 | 0.061 | | |
| January | 0.003 | 0.027 | 0.047 | 6.4 | 5 |
| February | 0.000 | 0.020 | 0.037 | 0.7 | 3 |
| March | 0.002 | 0.022 | 0.034 | 8.3 (1:3)[1] | 6 |
| April | 0.000 | 0.021 | 0.035 | | |
| May | 0.002 | 0.022 | 0.040 | | |
| June | 0.003 | 0.025 | 0.046 | | |
| July | 0.007 | 0.034 | 0.058 | 3 | 4 |
| August | 0.012 | 0.049 | 0.071 | | |
| September | 0.015 | 0.054 | 0.068 | | |

* Refers to frequency of occurrence per year, i.e. how often the floods occur per year where e.g. 1:3 means once every three years.

**Table 12.7 J3KAMM-EWR10: Total low flow assurance rules ($m^3/s$) for PES and REC: C/D**

| Month | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 99% |
|---|---|---|---|---|---|---|---|---|---|---|
| October | 0.142 | 0.142 | 0.119 | 0.102 | 0.081 | 0.052 | 0.026 | 0.016 | 0.009 | 0.005 |
| November | 0.144 | 0.143 | 0.122 | 0.102 | 0.083 | 0.052 | 0.026 | 0.017 | 0.009 | 0.005 |
| December | 0.109 | 0.109 | 0.099 | 0.080 | 0.061 | 0.048 | 0.034 | 0.023 | 0.013 | 0.004 |
| January | 0.081 | 0.081 | 0.069 | 0.059 | 0.047 | 0.027 | 0.011 | 0.007 | 0.003 | 0.001 |
| February | 0.067 | 0.063 | 0.057 | 0.048 | 0.037 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 |
| March | 0.085 | 0.074 | 0.062 | 0.044 | 0.034 | 0.022 | 0.006 | 0.006 | 0.002 | 0.001 |
| April | 0.092 | 0.078 | 0.060 | 0.049 | 0.035 | 0.021 | 0.006 | 0.002 | 0.000 | 0.000 |
| May | 0.141 | 0.106 | 0.082 | 0.056 | 0.040 | 0.022 | 0.009 | 0.006 | 0.002 | 0.000 |
| June | 0.127 | 0.097 | 0.080 | 0.063 | 0.046 | 0.025 | 0.011 | 0.007 | 0.003 | 0.001 |
| July | 0.121 | 0.114 | 0.090 | 0.078 | 0.058 | 0.034 | 0.018 | 0.013 | 0.007 | 0.001 |
| August | 0.148 | 0.134 | 0.118 | 0.090 | 0.071 | 0.049 | 0.031 | 0.020 | 0.012 | 0.004 |
| September | 0.148 | 0.129 | 0.109 | 0.085 | 0.068 | 0.054 | 0.040 | 0.029 | 0.015 | 0.007 |

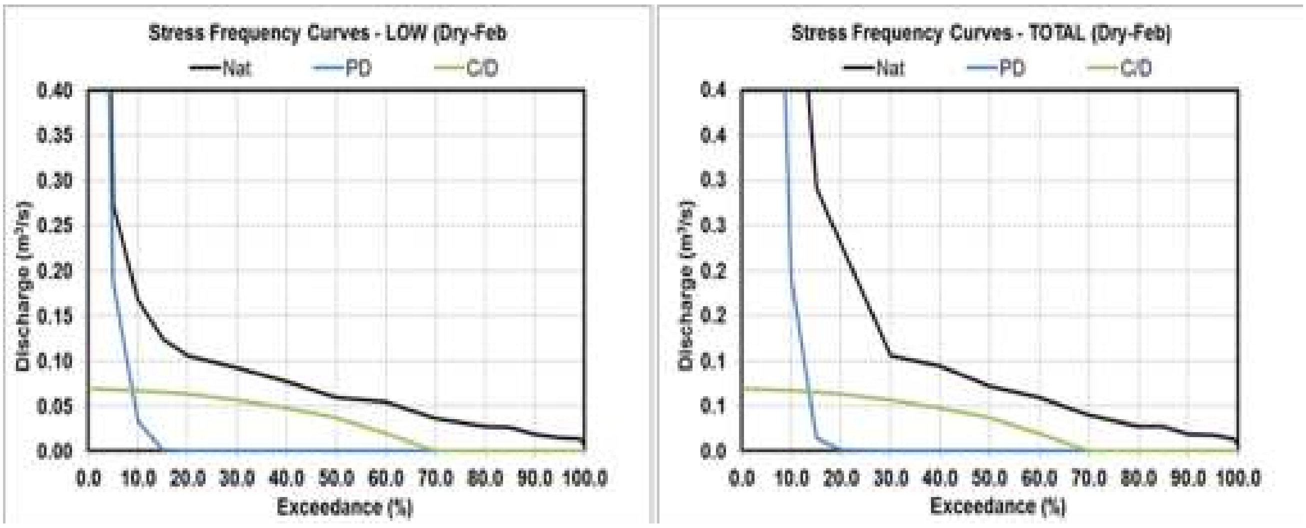
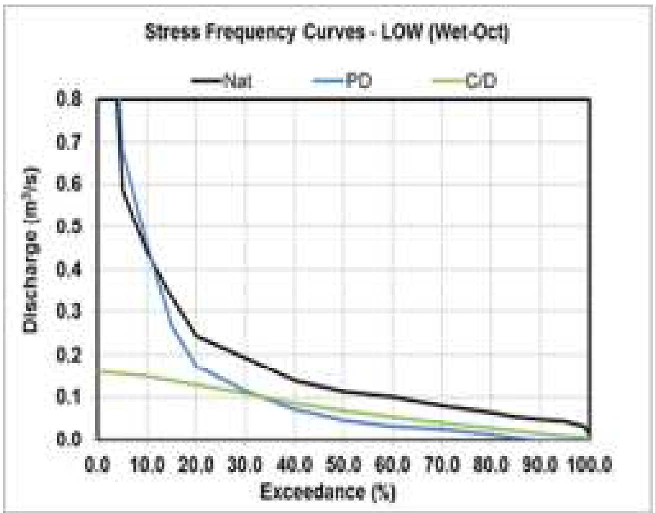



**Figure 12.3 J3KAMM-EWR10: Flow duration graph for the dry season low flows (left), total flows (right)**



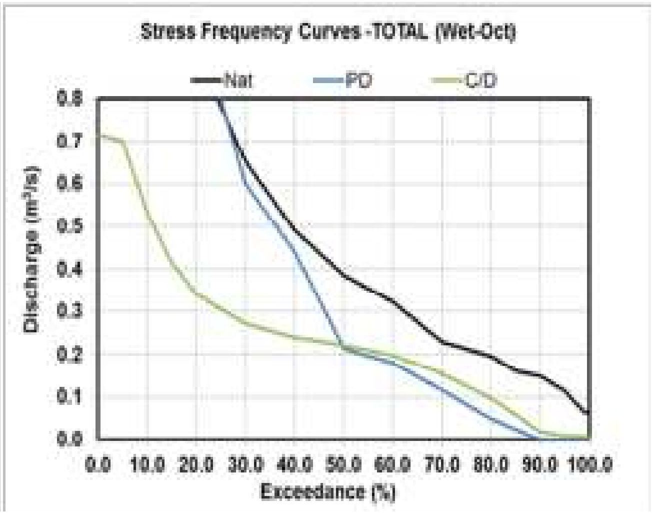




**Figure 12.4 Kammanassie_EWR10: Flow duration graph for the wet season low flows (left), total flows (right)**

**Table 12.8 J3KAMM-EWR10: Summary of results as a percentage of the nMAR**

| EcoStatus | nMAR (MCM) | pMAR (MCM) | Low flows (MCM) | Low flows (%) | High flows (MCM) | High flows (%) | Total flows (MCM) | Total (%) |
|---|---|---|---|---|---|---|---|---|
| PES; REC: C/D | 20.6 | 19.6 | 1.8 | 8.9 | 2.8 | 13.5 | 4.6 | 21 |

# 13 CONCLUSIONS AND RECOMMENDATIONS

## 13.1 ECOCLASSIFICATION

The EcoClassification results for the five rivers assessed by means of IERM, bar geomorphology, are summarised in **Table 13.1**.

**Table 13.1 EcoClassification results summary**

**H8DUIW-EWR1: DUIWENHOKS RIVER**

**EIS: LOW**
Highest scoring metrics were unique species (new record and distribution for *Redigobius dewaali*); species intolerant to physico-chemical changes (*Pseudobarbus burchelli*); diversity of habitat types and features; and important migration route for the cape shrimp (*P. capensis*) and mullet (*Myxus capensis* and *Mugil cephalus*) as well as *R. dewaali*. The river is relatively small and it is sensitive to flow changes.

**PES: D**

- Decreased base flows and flooding events with zero flows at times due to abstraction.
- Overall deterioration in water quality due to irrigation return flows.
- Bank modification and instability due to alien invasive vegetation and agricultural practices in the riparian zones.
- Alien fish species occur in the reach.

**REC: D**
The EIS was LOW and no improvement was required. The REC was therefore set to maintain the PES.

| Component | PES and REC |
|---|---|
| IHI Hydrology | B |
| Physico chemical | C |
| Fish | D |
| Macroinvertebrates | D |
| Instream | D |
| Riparian vegetation | C/D |
| **EcoStatus** | D |
| Instream IHI | C |
| Riparian IHI | C |
| **EIS** | LOW |

**H9GOUK-EWR2: GOUKOU RIVER**

**EIS: MODERATE**
Highest scoring metrics were unique and intolerant riparian/wetland species: Palmiet (*Prinonium serratum*); species intolerant to physico-chemical changes (*Pseudobarbus burchelli*) and macroinvertebrate taxa and diversity of habitat types and features which included backwaters and wetland features. The river is relatively small and it is sensitive to flow changes.

**PES: C/D**

- Decreased base flows and flooding events and zero flows at times due to abstraction and upstream dams.
- Deteriorated water quality due to the cumulative effects of agriculture and return flows.
- Bank modification and instability due to alien invasive vegetation and agriculture in the riparian zones.
- Alien fish species also occur in the reach.
- Wood removal in the riparian zones.

**REC: C/D**
The EIS was MODERATE and the REC was set to maintain the PES.

| Component | PES and REC |
|---|---|
| IHI Hydrology | B |
| Physico chemical | C/D |
| Fish | D |
| Macroinvertebrates | D |
| Instream | D |
| Riparian vegetation | C |
| **EcoStatus** | C/D |
| Instream IHI | C |
| Riparian IHI | C |
| **EIS** | MODERATE |

## J1DORI-EWR7: DORING RIVER

**EIS: LOW**

The highest scoring metrics were rare and endangered species (*Pseudobarbus asper* – endangered) occurring in the reach; refugia and critical habitat (deep pools) and species/taxon richness. The river is relatively small and it is sensitive to flow changes.

**PES: C/D**

- Decreased base flows with zero flows at times and decreased floods due to abstraction and upstream dams and flow diversions.
- Deteriorated water quality due to polluted agricultural return flows.
- Bank modification and instability in the reach due to alien invasive vegetation and agriculture in the riparian zones.
- Clearing and overgrazing as well as catchment erosion have also contributed to bank and bed modification.
- Alien fish species also occur in the reach.

**REC: C/D**

The EIS was LOW and no improvement was required. The REC was therefore set to maintain the PES.

| Component | PES and REC |
|---|---|
| IHI Hydrology | D |
| Physico chemical | C |
| Fish | C/D |
| Macroinvertebrates | D |
| Instream | C/D |
| Riparian vegetation | C/D |
| **EcoStatus** | C/D |
| Instream IHI | D |
| Riparian IHI | D |
| **EIS** | LOW |

## J3OLIF-EWR9: OLIFANTS RIVER

**EIS: MODERATE**

Three endemic riparian species occur at the site and an effective riparian/wetland migration corridor is provided by dense woody vegetation (mostly *A. karoo* and *S. aphylla*) in an otherwise barren and sparse landscape.

**PES: C**

- Baseflows and moderate flood frequency has decreased due to irrigation.
- Water quality deteriorations especially when flows are low leading to high temperatures and low oxygen rates.
- Overgrazing in the riparian zone leading to bank modification and decreased longitudinal connectivity

**REC: C**

The EIS was MODERATE and the REC was set to maintain the PES.

| Component | PES and REC |
|---|---|
| IHI Hydrology | B |
| Water quality | C |
| Macroinvertebrates | C |
| Riparian vegetation | C |
| **EcoStatus** | C |
| Instream IHI | B/C |
| Riparian IHI | C |
| **EIS** | MODERATE |

| J3KAMM-EWR10: KAMMANASSIE RIVER | |
|---|---|
| **EIS: LOW**<br>The highest scoring metrics were rare and endangered species (*Pseudobarbus asper* – endangered) occurring in the reach; refugia and critical habitat (deep pools) and species/taxon richness. The river is relatively small and it is sensitive to flow changes and is an important corridor in a dry environment.<br><br>**PES: C/D**<br>▪ Decreased base flows with zero flows at times and decreased floods due to irrigation return flows, abstraction and farm dams.<br>▪ Deteriorated water quality due to polluted agricultural return flows.<br>▪ Reduced pool depth and degraded substrate for biota due to elevated sediment input.<br>▪ Alien vegetation in the upper riparian zone and significant *Cyperus textillis* encroachment in the area. Possibly due to nutrient enrichment and more consistent flows or seepage from return flows during dry times.<br>▪ Alien fish species also occur in the reach.<br><br>**REC: C/D**<br>The EIS was LOW and no improvement was required. The REC was set to maintain the PES. | |

| Component | PES and REC |
|---|---|
| IHI Hydrology | C |
| Physico chemical | C |
| Fish | D |
| Macroinvertebrates | C/D |
| Instream | D |
| Riparian vegetation | C/D |
| **EcoStatus** | C/D |
| Instream IHI | D |
| Riparian IHI | D |
| **EIS** | LOW |

The confidence in the EcoClassification process is provided in **Table 13.2** and was based on data and information availability and EcoClassification where:

- Data and information availability: Evaluation based on the adequacy of any available data for interpretation of the EC and alternative ECs.
- EcoClassification: Evaluation based on the confidence in the accuracy of the PES.

The confidence score is based on a scale of 0 – 5 and colour coded where:

0 – 1.9: Low 2 – 3.4: Moderate 3.5 – 5: High

These confidence ratings are applicable to all scoring provided in this section.

**Table 13.2 Confidence in EcoClassification**

| Component | H8DUIW-EWR1 | H9GOUK-EWR2 | J1DORI-EWR7 | J3OLIF-EWR9 | J3KAMM-EWR10 |
|---|---|---|---|---|---|
| **Data and information availability** | | | | | |
| Hydrology | 3.5 | 2.8 | 1.5 | 1.5 | 2.8 |
| Water Quality | 3.5 | 3 | 2 | 2.5 | 2 |
| IHI | 3 | 3 | 3 | 2 | 3 |
| Fish | 3 | 3 | 1.5 | | 1.5 |
| Macroinvertebrates | 3 | 3 | 3 | 2 | 3 |
| Vegetation | 4 | 4 | 3 | 3.5 | 3 |
| **Average** | **3.3** | **3.1** | **2.3** | **2.3** | **2.5** |
| **Median** | **3.4** | **3** | **2.5** | **2.0** | **2.9** |
| **EcoClassification** | | | | | |
| Hydrology | 3 | 3.3 | 1.1 | 1.6 | 1.1 |
| Water Quality | 3.5 | 3.5 | 2 | 2 | 2 |

| Component | H8DUIW-EWR1 | H9GOUK-EWR2 | J1DORI-EWR7 | J3OLIF-EWR9 | J3KAMM-EWR10 |
|---|---|---|---|---|---|
| IHI | 3.2 | 3.2 | 3.2 | 2.7 | 3.2 |
| Fish | 2 | 2 | 2 | | 2 |
| Macroinvertebrates | 2.5 | 2.5 | 1.5 | 1.5 | 2 |
| Vegetation | 4 | 3.6 | 3.7 | 3.1 | 3.6 |
| **Average** | **3** | **3** | **2.3** | **2.2** | **2.3** |
| **Median** | **3.1** | **3.3** | **2** | **2** | **2** |

The confidence in data availability and EcoClassification was mostly Moderate at all the EWR sites. The confidence is higher at H8DUIW-EWR1 and H9GOUK-EWR2 due to the better driver information that was available for these sites.

## 13.2 ECOLOGICAL WATER REQUIREMENTS

The final flow requirements are expressed as a percentage of the nMAR in **Table 13.3**.

**Table 13.3 Summary of results as a percentage of the nMAR**

| | | | | Long-term mean | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **EWR site** | **EcoStatus** | **nMAR (MCM)** | **pMAR (MCM)** | **Low flows (MCM)** | **Low flows (%nMAR)** | **High flows (MCM)** | **High flows (%nMAR)** | **Total flows (MCM)** | **TOTAL (%nMAR)** |
| H8DUIW-EWR1 | PES; REC: D | 83.7 | 79.8 | 14.2 | 17 | 8.2 | 10.2 | 22.7 | 27.1 |
| H9GOUK-EWR2 | PES; REC: C/D | 54.1 | 46 | 7.1 | 13.1 | 4.3 | 13.9 | 11.4 | 21 |
| J1DORI-EWR7 | PES; REC: C/D | 4.52 | 2.01 | 0.386 | 8.5 | 0.644 | 14.3 | 1.03 | 22.8 |
| J3OLIF-EWR9 | PES; REC: C | 13.76 | 11.32 | 0.54 | 3.9 | 3.05 | 22.2 | 3.59 | 26.1 |
| J3KAMM-EWR10 | PES; REC: C/D | 20.6 | 19.6 | 1.8 | 8.9 | 2.8 | 13.5 | 4.6 | 21 |

### 13.2.1 Confidence in low flows

Considering the quality of data, the question the confidence assessment should answer is the following:

*'How confident are you that the recommended EWRs will achieve the EC?'*

**Table 13.4** provides the confidence in the low flow requirements of the biotic components (fish and macroinvertebrates). The final average confidence is representative of these requirements.

**Table 13.4 Low flow confidence ratings for biotic responses**

| EWR site | Fish | Macroinvertebrates | Comment | Overall confidence |
|---|---|---|---|---|
| H8DUIW-EWR1 | 3 | 3.4 | **Fish:** These flows should be adequate to attain the specific EC for fish. No rheophilic species are present and flows in the dry season are suitable for maintenance of water quality and allow for migration of juvenile eels and small catadromous fish (*M. capensis*, *M. cephalus* and *R. dewaali*). Although still limited, the fast habitats in the wet season should be adequate for the small semi-rheophilic *P. burchelli* which spawns in fast flowing riffles (used as the indicator guild) to ensure the maintenance of the instream biota in the PES.<br>**Macroinvertebrates:** The flows requested to maintain macroinvertebrates in a D Category were exceeded as a result of the fish requirements being higher. The flows provide adequate habitat of sufficiently high quality through the dry and wet season to maintain the macroinvertebrate taxa in a PES of a D. | **3.2** |
| H9GOUK-EWR2 | 3 | 2.5 | **Fish:** These flows should be adequate to attain the specific EC for fish. No rheophilic species are present and adequate flows for fish in winter (July) dry season in terms of habitat availability and water quality are present. Adequate fast habitats will be available during the wet season for the small semi-rheophilic *P. burchelli* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES.<br>**Macroinvertebrates:** The flows provided largely meet or exceed those requested to maintain the macroinvertebrates in a D Category. During the wet season, a stress of 6 (discharge 0.25m$^3$/s) at 60% exceedance will maintain the more sensitive elements of the taxa in their present state. However, Heptageniidae may be reduced in abundance or lost at the higher stresses (i.e. 40% of the time and less). The 'no flows' during the drought wet-season months (95% exceedance) mimic the present day flow scenario and it is assumed these are of short enough duration not to affect the macroinvertebrate community substantially, however they may reduce presence and abundances of FDIs scoring >10. During the dry season both maintenance and drought flows (which are higher than summer drought flows) provide adequate habitat to maintain the population in their present state. | **2.8** |
| J1DORI-EWR7 | 2 | 1.5 | **Fish:** These flows should be adequate to attain the specific EC for fish. Note that the specified floods in the Doring River play a very important ecological role in facilitating fish migration and creating suitable fish spawning and larval rearing habitats. The dry season flows (in winter at low water temperatures) are adequate to ensure the survival of all fish species in pools. During the wet season there will be adequate fast habitats and depths in riffles to allow migration and ensure limited spawning habitat for the small semi-rheophilic *P. asper* (used as the indicator guild). The flows should thus ensure the maintenance of the instream biota in the PES.<br>**Macroinvertebrates:** The base flows provided are particularly low, especially for the wet season months. This paucity of flow is not entirely made up for by floods. The community is, however, a resilient one with few FDIs, and may survive these conditions for short periods of time. Confidence is, however, low in these flows. | **1.8** |
| J3KAMM-EWR10 | 2.5 | 2.5 | **Fish:** These flows should be adequate to attain the specific EC for fish. The dry season flows in winter with low water temperatures are adequate to ensure the survival of hardy *S. capensis* as well as the small semi-rheophilic redfin *P. asper*. The wet season (summer) flows will provide adequate fast habitats to ensure the riffle-spawning, small semi-rheophilic *P. asper* (used as the indicator guild) can migrate to suitable riffle areas and breed. The flows should also maintain good water quality and thus ensure the maintenance of the instream biota in the PES. | **2.5** |

| EWR site | Fish | Macroinvertebrates | Comment | Overall confidence |
|---|---|---|---|---|
| | | | **Macroinvertebrates:** The flows provided will maintain the present day, resilient invertebrate community during the wet season. Dry season drought stress is 10 and may result in a loss of FDIs (e.g. Simuliidae, Elmidae, Aeshnidae), however, there are no highly sensitive FDIs and the community should be maintained in the PES of C/D, as long as the no-flow condition does not persist for > 2 weeks (continuous). | |

### 13.2.2 Confidence in high flows

The question the confidence assessment should answer is the following:
*'How confident are you that the high flow (with the associated low flows) recommended will achieve the EC?'*

To determine the confidence, one should consider:

- the quality of available data; and
- whether the vegetation requirement was increased to cater for a larger requirement recommended for geomorphology. Then the riparian vegetation confidence could be high as more water is provided.

The high flow confidence (**Table 13.5**) represents an average of the riparian vegetation and it determines the flood requirements.

**Table 13.5 Confidence in recommended high flows**

| EWR site | Fish | Macroinvertebrates | Riparian vegetation | Comment | Overall confidence |
|---|---|---|---|---|---|
| H8DUIW-EWR1 | 3 | 3 | 3 | **Fish:** These flows should be adequate to attain the specific EC for fish. No rheophilic species are present, but the high flows will ensure channel continuity, (allow fish migrations) for all fish species. In addition, the fast habitats created in the wet summer season should be adequate for spawning of the semi-rheophilic *P. burchelli* (used as the indicator species) to ensure the maintenance of the instream biota in the PES. | **3** |
| | | | | **Macroinvertebrates:** The smaller high flows (3 $m^3/s$) during winter and summer should cleanse habitat (particularly MV and coarse substrates) and assist in providing breeding and developmental cues for macroinvertebrates. The 16 $m^3/s$ flood (set for winter) will reset the cobble habitat and scour fines, without disturbing hatching and development which usually occurs in spring and summer. The large floods are essential for maintenance of the morphology and riparian vegetation of the system, and will ensure drift (of upstream species) from upstream tributaries which may be less disturbed. | |

| EWR site | Fish | Macroinvertebrates | Riparian vegetation | Comment | Overall confidence |
|---|---|---|---|---|---|
| | | | | **Riparian vegetation:** The high level of disturbance within the site as a result of previous flood disturbance and the alien plant cover reduced the overall confidence when assessing this site. The estimations were thus reliant on the few remaining riparian species and using hydraulic lookup tables, coupled to the gauge data. The estimated requirement therefore covers a range of floods that considers the channel morphology and the associated vegetation distribution within the riparian subzones. Confidence that the flooding regime will maintain the PES of the riparian vegetation is moderate and assumes that base flows are sufficient and that non-flow related impacts remain unchanged. | |
| H9GOUK-EWR2 | 2 | 3 | 3 | **Fish:** These flows should be adequate to attain the specific EC for fish. No rheophilic species is present. The high flows should ensure channel continuity, (allow fish migrations) for all fish species. In addition, the fast habitats created in the wet summer season should be adequate for spawning of the semi-rheophilic *P. burchelli* (used as the indicator species) to ensure the maintenance of the instream biota in the PES. | 2.7 |
| | | | | **Macroinvertebrates:** The small, intermediate and large floods provided will perform the function of habitat maintenance and (if occurring during summer) should assist in augmenting baseflows during the wet-season periods when these are particularly low (40% of the time). | |
| | | | | **Riparian vegetation:** This site was dominated by species in an early successional stage of development, particularly in the lower and upper zones due to clearing of alien vegetation. This reduced the overall confidence when assessing this site as it is not known what climax plant communities would occur. The estimations were thus reliant on the few remaining riparian species and using hydraulic lookup tables, coupled to the gauge data. The estimated requirement therefore covers a range of floods that considers the channel morphology and the associated vegetation distribution within the riparian subzones. Confidence that the flooding regime will maintain the PES of the riparian vegetation is moderate and assumes that base flows are sufficient and that non-flow related impacts remain unchanged. | |
| J1DORI-EWR7 | 2 | 1.5 | 1.5 | **Fish:** These flows should be adequate to attain the specific EC for fish. The specified high flows should ensure channel continuity (allow fish migrations) for all fish species and flush out pools and riffle habitats and improve water quality. In addition, the fast habitats created in the wet summer season should be adequate for spawning of the semi-rheophilic *P. asper* (used as the indicator species) to ensure the maintenance of the instream biota in the PES. | 1.7 |
| | | | | **Macroinvertebrates:** Although the present day community is a resilient one, the low baseflows provided should be bolstered by floods to ensure that normal seasonal breeding and hatching cues are forthcoming, and that there is adequate depth (and thus cover) for juveniles to develop. There is low confidence that the floods provided will be sufficiently frequent to provide for the shortfalls in baseflow, particularly during wet season months. | |

| EWR site | Fish | Macroinvertebrates | Riparian vegetation | Comment | Overall confidence |
|---|---|---|---|---|---|
| | | | | **Riparian vegetation:** The confidence of this assessment with regard to floods was the lowest of all three sites due to the lack of available flow data. Setting flood requirements was thus based on the position and requirements of the six obligate / facultative riparian species and the hydraulic lookup tables. An additional factor that lowered the confidence in this assessment was linked to the channel morphology, as it seemed if incision had occurred. Bank incision limits the development of horizontal and vertical riparian zone gradients. These gradients then allow the development of clear distinctions between the various riparian zones, which are then used in assessing the flooding requirements. The estimated requirement does however cover a range of floods that considers the existing channel morphology and the associated vegetation distribution within the riparian subzones. Confidence that the flooding regime will maintain the PES of the riparian vegetation is low and assumes that the predicted flows are accurate. | |
| J3OLIF-EWR9 | N/A | N/A | 4 | **Riparian vegetation:** A rated hydraulic cross-section existed for the site and there were sufficient riparian vegetation indicators that were surveyed in order to determine flood requirements. Riparian vegetation zonation was clear along the upper zone and enabled higher accuracy for determining flood levels, as well as along the valley floor for smaller floods. | **4** |
| J3KAMM-EWR10 | 3 | 2.5 | 2.5 | **Fish:** These flows should be adequate to attain the specific EC for fish. The specified high flows should ensure channel continuity (allow fish migrations) for all fish species, flush out pools and riffle habitats and improve water quality. In addition, the fast habitats created in the wet summer season should be adequate for spawning of the semi-rheophilic *P. asper* (used as the indicator species) to ensure the maintenance of the instream biota in the PES.<br>**Macroinvertebrates:** The small and mid high flows (0.7 and 3 $m^3/s$ respectively) will provide breeding, hatching and development cues if they occur in spring, and will cleanse coarse substrate habitats. The main function of the larger floods in this system, for the maintenance of the macroinvertebrate habitat diversity, will be to ensure no further encroachment of vegetation occurs (*Cyperus* spp particularly). The 1:2 floods of 7.5 $m^3/s$ may scour sediments sufficiently to ensure this.<br>**Riparian vegetation:** The confidence when assessing the required floods for this site was lower when compared to H8DUIW-EWR1 and H9GOUK-EWR2 due to the lack of gauge data. Estimates were thus based on the hydraulic look-up tables and the present distribution of indigenous species along the gradients found within the riparian subzones. Confidence that the flooding regime will maintain the PES of the riparian vegetation is thus reduced and assumes that base flows are sufficient and any impacts remain unchanged. A final factor that lowered the confidence in this assessment was the dense *Cyperus* cover in the marginal zone. It is not known how this species will respond to floods, but it was assumed that the larger floods would be needed to reduce complete encroachment of the channel areas, downstream of the bridge. Encroachment would be halted if and when sufficient juvenile species and/or available habitat (reduce available sediments for available colonisation) are removed. | **2.7** |

### 13.2.3 Confidence in hydrology

Note: If natural hydrology was used to guide requirements, then that confidence will carry a higher weight than normal. Hydrology confidence is provided from the perspective of its usefulness to the EWR assessment. This will be different to the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and therefore high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EWR assessment. The hydrology confidence is summarised in **Table 13.6**.

**Table 13.6 Confidence in hydrology**

| EWR site | Natural hydrology | Present hydrology | Comment | Confidence: Median | Confidence: Average |
|---|---|---|---|---|---|
| Duiwenhoks_EWR1 | 4 | 3 | H8H001 (upstream of this site) with 47 years (Jun 1967 to Jan 2014) of data. | 3.5 | 3.5 |
| Goukou_EWR2 | 3 | 2.5 | H9H005 (upstream of this site) with 47 years (May 1969 to Jan 2014) of data. | 2.75 | 2.75 |
| Doring_EWR7 | 2 | 1 | The lack of a gauge results in a lower confidence. | 1.5 | 1.5 |
| J3OLIF-EWR9 | 1.5 | 1.5 | No reliable gauge in the area. | 1.5 | 1.5 |
| Kammanassie_EWR10 | 3 | 2.5 | The lack of a gauge results in a lower confidence. | 2.75 | 2.75 |

### 13.2.4 Overall confidence in EWR results

The overall confidence in the results are linked to the confidence in the hydrology and hydraulics as the hydrology provides the check and balance of the results and the hydraulics convert the requirements in terms of hydraulic parameters to flow. Therefore, the following rationale was applied when determining the overall confidence:

- If the hydraulics confidence was lower than the biological responses column, the hydraulics confidence determined the overall confidence. Hydrology confidence was also considered, especially if used to guide the requirements.
- If the biological confidence was lower than the hydraulics confidence, the biological confidence determined the overall confidence. Hydrology confidence was also considered. If hydrology was used to guide requirements, then that confidence would be overriding in determining the overall confidence.

The overall confidence in the EWR results is provided in **Table 13.7**.

**Table 13.7 Overall confidence in EWR results**

| Site | Hydrology | Biological responses Low flows | Hydraulic: Low Flows | OVERALL: LOW FLOWS | Comment | Biophysical responses: High flows | Hydraulics: High Flows | OVERALL: HIGH FLOWS | Comment |
|---|---|---|---|---|---|---|---|---|---|
| Duiwenhoks_EWR1 | 3.5 | 3.2 | 3 | 3 | Wet season within measured flow range; dry season below measured flow range. Short riffle immediately downstream of lowlevel bridge - non-uniform conditions. | 3 | 2.5 | 2.5 | High flows above measured flow range. Cross-section immediately downstream of low-level bridge. |
| Goukou_EWR2 | 2.8 | 2.8 | 2.5 | 2.5 | Wet and dry seasons below measured flow range. | 2.7 | 4 | 2.7 | High flows above measured flow range, strand lines and upstream. Gauge H9H005 used to extend observed flow range. |
| Doring_EWR7 | 1.5 | 1.8 | 2.5 | 1.8 | Wet and dry seasons below measured flow range. | 1.7 | 3 | 1.7 | High flows above measured flow range. |
| J3OLIF-EWR9 | 1.5 | N/A | N/A | **1.5** | No reliable gauge in the area. | 4 | 3 | **3** | High flows above measured flow range. |
| Kammanassie_EWR10 | 2.8 | 2.5 | 3 | 2.5 | Wet season largely within measured flow range; dry season largely below measured flow range. | 2.7 | 3 | 2.7 | High flows above measured flow range. |

### 13.3 RECOMMENDATIONS

The confidence in the EcoClassification is generally Moderate which is acceptable for a Rapid to Intermediate assessment. Furthermore, no further work on the EcoClassification is required as it will not influence the EWR determination. However, monitoring is essential to ensure that the ecological objectives in terms of the REC are achieved.

The confidence for all the parameters (**Table 13.8**) is generally Moderate for most sites except J1DORI-EWR7. Low confidence dominates most parameters for J1DORI-EWR7 due to the lack of gauge data which influenced the confidence in setting EWRs. A low confidence for hydrology was achieved at J1DORI-EWR7 and J3OLIF-EWR9. At J1DORI-EWR7 the low confidence in hydrology is linked to the available hydrological model for the Doring River which is out of date. The low confidence for hydrology at J3OLIF-EWR9 is linked to the absence of a reliable gauge in the area and in turn influenced the overall confidence in low flows.

Confidence in the hydraulic modelling results overrides the confidence in the biophysical responses and EWR determination. The confidence is generally Moderate for all the EWR sites with High confidence in the high flow determination for H9GOUK-EWR2. The lowest confidence for low flow determination was achieved at H9GOUK-EWR2 and J1DORI-EWR7. This is because all measured flow data used for calibrating the hydraulic model was higher than the low flow EWR determination. Further work to improve the hydraulics would require additional measured calibration at very low flows.

The most effective way of improving confidence is linked to monitoring the ecological status of the river and, if required, improving the hydraulics for low flows at selected sites as part of the monitoring programme. No specific studies to improve any confidences other than monitoring are therefore recommended.

**Table 13.8 Confidence summary**

| EWR site | H8DUIW-EWR1 | H9GOUK-EWR2 | J1DORI-EWR7 | J3OLIF-EWR9 | J3KAMM-EWR10 |
|---|---|---|---|---|---|
| Data availability | 3.3 | 3.1 | 2.3 | 2.3 | 2.5 |
| EcoClassification | 3.3 | 3.1 | 3.0 | 2.2 | 3.1 |
| Low flow EWR (biotic responses) | 3.2 | 2.8 | 1.8 | N/A | 2.5 |
| High flow EWR (biophysical responses) | 3.0 | 2.7 | 1.7 | 4.0 | 2.7 |
| Hydrology | 3.5 | 2.8 | 1.5 | 1.5 | 2.8 |
| Hydraulics (low) | 3 | 2.5 | 2.5 | N/A | 3 |
| Hydraulics (high) | 2.5 | 4 | 3 | 3.0 | 3 |
| Overall low flow EWR confidence | 3.0 | 2.5 | 1.8 | 1.5 | 2.5 |
| Overall high flow EWR confidence | 2.5 | 2.7 | 1.7 | 3.5 | 2.7 |

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# APPENDIX A: WATER QUALITY PRESENT STATE ASSESSMENT

## A.1 INTRODUCTION

This assessment was conducted as part of the EcoClassification step for the five EWR sites in the Gouritz WMA, i.e. Duiwenhoks (H8DUIW-EWR1; secondary catchment H8), Goukou (H9GOUK-EWR2; secondary catchment H9), Doring (J1DORI-EWR7; secondary catchment J1), Olifants (J3OLIF-EWR9; secondarday cathment J3), and Kammanassie rivers (J3KAMM-EWR10; secondary catchment J3). The site details are provided in **Table 1.1** in the main report.

## A.2 METHODS AND APPROACH

The methods and approach are not detailed in this document, but followed that outlined in DWAF (2008). Note that the following parameters were evaluated, with the associated summary statistic used for the assessment:

- pH: 5$^{th}$ and 95$^{th}$ percentiles.
- Electrical Conductivity, ions, metals, toxics: 95$^{th}$ percentiles.
- Nutrients, i.e. Total Inorganic Nitrogen (TIN) and ortho-phosphate: 50$^{th}$ percentile.
- Chlorophyll-a (phytoplankton): average or mean of values.
- Diatoms: average or mean of values.
- Turbidity, dissolved oxygen (DO), temperature: narrative descriptions when no data are available; alternatively 5$^{th}$ percentile for DO.

Water quality data were utilised in the following way: Nutrients, pH, chlorophyll-a, turbidity, DO, temperature and Electrical Conductivity data were compared to values in DWAF (2008), while all ionic data (i.e. macro-ions and salt ions) were compared to benchmark tables in DWAF (2008), and/or the Target Water Quality Range (TWQR) and Chronic Effects Value (CEV) guidelines of the South African aquatic ecosystem guidelines (DWAF, 1996a), where required. Salt ion data were compared to guidelines only, while parameters found in DWAF (2008) could be compared to Reference Condition (RC) values. Available guidelines were used for comparative purposes, e.g. Irrigation guidelines (DWAF, 1996b). Diatom data were utilised as provided by the diatomologist for the study (n = 2; samples taken January and June 2014; **Appendix B**). On-site water quality data, measured on site in January and June 2014 (**Table A.1**), were used where relevant.

**Table A.1 Water quality variables measured on site (January and June 2014)**

| River | EWR Site | pH | | Electrical Conductivity (mS/m) | | Temperature (ºC) | | Dissolved Oxygen (mg/L) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Jan 14 | Jun 14 | Jan 14 | Jun 14 | Jan 14 | Jun 14 | Jan 14 | Jun 14 |
| Duiwenhoks | H8DUIW-EWR1 | 7.28 | 6.41 | 40.7 | 51.4 | 25.7 | 14.1 | 8.57 | 12.61 |
| Goukou | H9GOUK-EWR2 | 6.38 | 6.34 | 57.1 | 102.5 | 21.7 | 14.8 | 9.08 | 9.22 |
| Doring | J1DORI-EWR7 | 7.44 | Ns[1] | 63.1 | ns | 23 | ns | 8.5 | ns |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Olifants | J3OLIF-EWR9 | 7.94 | 7.74 | 4.49 | 3.95 | 30.3 | 15.4 | 7.33 | 7.85 |
| Kammanassie | J3KAMM-EWR10 | 6.94 | 6.47 | 68.7 | 54.1 | 27.4 | 11.5 | 6.85 | 7.74 |

1 Not sampled

**Setting the Reference Condition**

The most critical part of a water quality assessment is setting RC, or the natural state, as the change or deviation from RC defines the PES or present state. Where early water quality data were not available, benchmark tables for an A Category or natural / least impacted state were used as a proxy for RC.

## A.3 WATER QUALITY OVERVIEW: WMA16

The 2011 Planning Level Review of Water Quality in South Africa (DWA, 2011) identified the major water quality issues in the country, as well as which WMAs in which they are prevalent. The following issues were identified for WMA16:

- Microbial contamination.
- Salinisation and poor quality stormwater run-off.
- Dry weather flow from dense settlements, i.e. conditions associated with urban rivers.

Issues such as eutrophication, metal and toxicant contamination were not considered problematic in WMA16, although high phosphate levels were recorded for large parts of the WMA due to agricultural return flows and discharges from wastewater treatment works. **Table A.2** from DWA (2011) summarises the water quality issues across WMA16. Elevated salinities in the Gouritz River and its major tributaries occur naturally over the inland catchments of the Great and Little Karoo due to geology and high natural evaporation rates (DWA, 2011). A summary of primary land-use activities of the management areas of WMA16, which impact on or determine water quality state, are shown below (RHP, 2007):

- Goukou/Duiwenhoks: Irrigated agriculture (lucerne and pasture).
- Gouritz: Irrigated agriculture (lucerne and pasture), livestock (ostriches and sheep).
- Garden Route: Irrigated agriculture, afforestation (pine), urban.

**Table A.2 Water quality issues across WMA16 (from DWA, 2011)**

| Water quality issue | Driver | Effect |
|---|---|---|
| Salinisation | Natural geology.<br>High evaporation. | Water unsuitable for irrigation agriculture.<br>Corrosion of appliances and equipment.<br>Alteration of the taste of domestic water. |
| Urban impacts on water quality | Densely populated urban areas on coast, urban runoff, treated wastewater not meeting DWS standards and runoff from informal settlements. | Poor bacterial quality. Impacts on downstream users. Human health risks. Low dissolved oxygen and ecosystem impacts. |
| Microbial and organics contamination | Vandalism of sewage reticulation system and pumping infrastructure. Sewage spills into receiving streams e.g. Oudtshoorn. | Poor bacterial quality. Impacts on downstream users. Human health risks. Low dissolved oxygen and ecosystem impacts. |

| Water quality issue | Driver | Effect |
|---|---|---|
| Wood processing waste | Disposal of wood processing waste in the coastal catchment.<br>Some saw mill operators are without permits. | Leachate with high organic acids and COD[1]. Low dissolved oxygen and ecosystem impacts. |

1 Chemical Oxygen Demand.

## A.4 RESULTS

### A.4.1 H8DUIW-EWR1

In primary catchment H elevated salinities are not found to the same extent as in the K and coastal (H8 and H9) catchments and elsewhere in the WMA (DWA, 2011). The main land use and main towns in the area (taken from RHP, 2007) are summarised below summarised below for both the relevant sites in the H primary catchment, i.e. Duiwenhoks in H80 and Goukou in H90.. State of Wastewater Treatment Works (WWTW) is taken from DWA (2012), i.e. the Green Drop (GD) Report for the Western Cape.

| Management area | Duiwenhoks | Goukou |
|---|---|---|
| Main land use | Dryland and irrigated agriculture (vineyards, lucerne, pasture). | Dryland and irrigated agriculture (vineyards, fruit, vegetables, lucerne, pastures), livestock (sheep), commercial forestry (pine). |
| Main town | Heidelberg, Vermaaklikheid. | Riversdale, Stilbaai. |
| Risk rating of WWTW (high – critical only) | Stilbaai WWTW (Duiwenhoks catchment): High risk rating (no monitoring).<br>Barrydale WWTW: High risk rating – secondary catchment H7 but near the Doring River (flow exceeds capacity, poor effluent quality).<br>Riversdale WWTW (Goukou catchment): High risk rating (flow exceeds capacity). | |

The **Duiwenhoks catchment** has a lower rainfall spread evenly throughout the year (Ogden, 2013). The Fynbos Biome has all-year rainfall with slightly less rain in summer and highest rainfall in winter, mainly between March and August. The mean annual rainfall is low with 389 mm in the East Coast Renosterveld, and a higher 615 mm in the Eastern Fynbos Renosterveld (Mucina and Rutherford (2006); cited in Ogden, 2013). The primary impact on water quality is cultivated land (i.e. privately owned farms), with both crop (primarily citrus in the upper and wheat in the lower catchment) and livestock (dairy) farming. High salinity levels have been recorded due to agricultural return flows and discharges from wastewater treatment works (DWA, 2011). Heidelberg is located in the centre of the catchment, with an associated WWTW. Water quality was described as Poor in this area according to the River Health Programme (RHP) (RHP, 2007). However, a large portion of the catchment area is natural fynbos and non-irrigated grains, with no known anthropogenic pollution sources (Ogden, 2013). Water quality around Doringkloof (upstream Heidelberg) and Vermaaklikheid (downstream Heidelberg) is considered Good (RHP, 2007).

Data for the assessment was sourced from DWS gauging weir H8H001Q01 on the Duiwenhoks River. The data records span from 1967 to 2013:

- RC: DWS gauging weir H8H001Q01 (1967 – 1979; n (number) = 66 - 71, Electrical Conductivity: n = 110).

- PES: DWS gauging weir H8H001Q01 (2007 – 2013; n = 69, F (fluoride) = 48).

**Table A.3** presents the water quality assessment for the Duiwenhoks at H8DUIW-EWR1.

**Notes**
- Small-scale abstraction (for irrigation) upstream gauge.
- Small-scale gravel excavation just upstream of the EWR site (January 2014).
- January 2014: Little embeddedness or algal growth on substrate (cobble and gravel).
- June 2014: Information from a passing farmer states *"summer low flows are very low and the system is then very poor due to run off from irrigation and dairy farming directly into the river"*.

**Table A.3 Water quality present state assessment for H8DUIW-EWR1**

| Water Quality Constituents | PES Value | Category/Comment |
|---|---|---|
| **Inorganic salt ions (mg/l)** | | |
| Sulphate as $SO_4$ | - | - |
| Sodium as Na | 382.2 | Exceeds the ≤ 70 mg/L (TWQR) for Agricultural Use: Irrigation. |
| Magnesium as Mg | 67.4 | No guideline. |
| Calcium as Ca | 55.0 | No guideline. |
| Chloride as Cl | 805.4 | Exceeds the ≤ 100 mg/L (TWQR) for Agricultural Use: Irrigation. |
| Potassium as K | 9.25 | No guideline. |
| **Electrical conductivity (mS/m)** | | |
| | 272 | E/F: RC = 80 mS/m. |
| **Nutrients (mg/l)** | | |
| SRP | 0.014 | A |
| TIN | 0.118 | A |
| **Physical variables** | | |
| pH ($5^{th}$ + $95^{th}$ %ile) | 6.6 and 8.1 | B |
| Temperature (ºC) | - | A/B. Impacts expected at low flows. |
| Dissolved oxygen (mg/L) | - | B. Impacts expected at low flows. |
| Turbidity (NTU) | - | B. Changes in turbidity appear to be largely related to natural with minor man-made modifications, e.g. gravel mining upstream |
| **Response variables** | | |
| Chl-*a*: phytoplankton (ug/L) | - | - |
| Macroinvertebrate score (MIRAI)<br>SASS score<br>ASPT score | 50.7%<br>78<br>56 | D |
| Diatoms | 11.1 | C/D (n = 1, Jan 2014) |
| Fish score (FRAI) | 51.6% | D (all estuarine spp. that moved into the freshwater zone and aliens). |
| **Toxics** | | |
| Ammonia (as N) | 0.003 | A |
| Fluoride (as F) | 0.33 | A |
| **OVERALL SITE CLASSIFICATION** | | **C (73.2%)** |

| Water Quality Constituents | PES Value | Category/Comment |
|---|---|---|
| (PAI model) | | |

- no data

In conclusion, the very high Electrical Conductivity levels at low flows (i.e. from a RC of 80 mS/m to a PES value of 272 mS/m), are the major parameter of concern at this site. However, note that this site is at the boundary of the estuary zone. The geology of the region also results in high background salinity levels in the water. Although nutrient data shows low levels in the water column, some nutrients and toxics are expected from fertilizer and pesticide use for irrigation purposes. Stones at the site were also covered in benthic algae, indicating elevated nutrients. Diatom data indicates Moderate water quality with nutrient levels, organic pollution and salinity levels being high and problematic. Moderate oxygenation rates and heavy pollution levels prevailed. The diatoms reflect the accumulative effects of farming activities within the reach. Note that Heidelberg is upstream of the EWR site, while Vermaaklikheid is downstream. The water quality category at EWR 1 is therefore expected to be a **C Category** (73.2%).

### A.4.2 H9GOUK-EWR2

In secondary catchment H9 elevated salt and nutrient concentrations have been recorded in the the Goukou River. Organic loading from dairy farming in this area, especially around Riversdale, is also significant (DWA, 2011).

Data for the assessment was sourced from DWS gauging weir H9H005Q01 on the Goukou River. The data records span from 1969 to 2014, but with only three records before 1984:

- RC was represented by the A Category benchmark tables in DWAF (2008), as no other data were available to describe natural state.
- PES: DWS gauging weir H9H005Q01 (2007 – 2014; n = 63 - 71, F = 52).

**Table A.4** presents the water quality assessment for the Goukou at H9GOUK-EWR2.

**Notes from surveys**

- Extensive grazing and agricultural activities.
- The EWR site is upstream of Riversdale.
- January 2014: Little algal growth on substrate (cobble and gravel).

**Table A.4 Water quality present state assessment for H9GOUK-EWR2**

| Water Quality Constituents | PES Value | Category/Comment |
|---|---|---|
| **Inorganic salt ions (mg/l)** | | |
| Sulphate as $SO_4$ | - | - |
| Sodium as Na | 650.4 | Exceeds the ≤ 70 mg/L (TWQR) for Agricultural Use: Irrigation. |
| Magnesium as Mg | 79.0 | No guideline. |
| Calcium as Ca | 57.1 | No guideline. |
| Chloride as Cl | 1081.3 | Exceeds the ≤ 100 mg/L (TWQR) for Agricultural Use: Irrigation. |

| Water Quality Constituents | PES Value | Category/Comment |
|---|---|---|
| Potassium as K | 20.4 | No guideline. |
| **Electrical conductivity (mS/m)** | | |
| | 408.4 | E/F |
| **Nutrients (mg/l)** | | |
| SRP | 0.085 | D |
| TIN | 0.055 | A |
| **Physical variables** | | |
| pH ($5^{th}$ + $95^{th}$ %ile) | 6.6 and 8.35 | B |
| Temperature (ºC) | - | A/B. Impacts expected at low flows. |
| Dissolved oxygen (mg/L) | - | B. Impacts expected at low flows. |
| Turbidity (NTU) | - | A/B. Changes in turbidity appear to be largely related to natural. |
| **Response variables** | | |
| Chl-*a*: phytoplankton (ug/L) | - | - |
| Macroinvertebrate score (MIRAI)<br>SASS score<br>ASPT score | 51.2%<br>113<br>6.6 | D |
| Diatoms | 14.4 and 11.0 | C/D (n = 2; Jan and July 2014) |
| Fish score (FRAI) | 47.4% | D |
| **Toxics** | | |
| Ammonia (as N) | 0.01 | A |
| Fluoride (as F) | 0.59 | A |
| **OVERALL SITE CLASSIFICATION (PAI model)** | | **C/D (60.8%)** |

- no data

In conclusion, the site is dominated by high Electrical Conductivity and phosphate levels. Toxics are also expected due to extensive irrigation in the area. Although the SPI score for diatoms in January 2014 reflected Good water quality, sub-dominant species indicated that salinity, nutrients and organic pollution levels were increasing (*Nitzscia frustulum* and *Nitzschia* species and *Gomphonema* species) – this was evident for the July sampling survey. Indicators of industrial and sewage related impacts occur in low abundance: January survey. There was a greater abundance of species with a preference for high salinity and organic pollution levels present during July 2014 than during January 2014. The same trend was observed for indicators of industrial related impacts. The dominance of *Navicula gregaria* indicated that organic loading (possibly due to sewage sources) is present at the site. Note that there are more zero flows under present state. The water quality category at H9GOUK-EWR2 is therefore expected to be a **C/D Category** (60.8%).

### A.4.3 J1DORI-EWR7

In secondary catchment J1, the inclusion of an EWR site on the Doring River did not follow the normal ecological hotspot identification process as outlined in DWA (2014). This site was included due to the on-going legal investigation regarding over-exploitation of the system, particularly the diversion of water from the Lemoenshoek Stream to Tierkloof Dam (on the Eersterivier) as brought to the attention of DWS and the project team by Mr Richard Butt during the first Stakeholder

Meeting held for the study on 3 October 2013 in Oudtshoorn. The Lemoenshoek Stream is a contributory sub-catchment – its position in relation to J1DORI-EWR7 can be seen in **Figure A.5**. A study done by Withers Environmental Consultants in 2012 (Withers Consultants, 2012) also refer to the possible pollution of the Lemoenshoek Stream by the run-off of pig effluent from Portion 4 of the Farm Lemoenshoek No. 24. Major earthworks also took place within the Doring River itself just upstream of the confluence of the Lemoenshoek Stream (mid 2012).


**Figure A.5 The position of the Lemoenshoek Stream and J1DORI-EWR7 on the Doring River**

The study by Withers Consultants (2012) states that the earthworks have resulted in long-term and highly significant impacts on the biophysical environment of the Doring River, namely:

- The removal of the entire riparian habitat, which appears to have comprised reeds, wetland grasses, sedges and the more climax riparian vegetation, such as shrubs and thorn trees.
- The destruction of riparian habitat would have had a significant impact on the fauna, avifauna and amphibians that would have frequented this section of the river.
- The excavation of a deep channel in the river bed would change the hydraulic dynamic equilibrium of the river.
- The banks of the river would dry out, dramatically changing the moisture regime of the banks and embankments, making it difficult for wetland vegetation to regrow in this dried out habitat.
- Removal of vegetation would have a dramatic effect on the filtering ability of the river to remove sediments and nutrients from the water column.
- Collectively the changes in the moisture regime would lead to increased sedimentation downstream of this destruction, which in turn would lead to other cumulative ecological impacts, such as smothering of vegetation and smothering of benthic biota (filter and detritus feeders).
- The realignment of the channels of the river and the changes to the morphology of the channel itself (steepness of the banks, depth of the water) would result in a disequilibrium of the hydraulics and ecological regimes, which could lead to a myriad of negative ecological impacts.

- The destruction of peat beds and their exposure to oxygen would release iron sulphides which in turn could cause anoxic conditions in the water column, thus leading to the death of all forms of aquatic biota.

Water quality state of the Doring River has been described as Good (RHP, 2007). The table below summarises the main land use and main towns in the area (RHP, 2007), as relevant to the Doring River. State of WWTW is taken from DWA (2012), i.e. the Green Drop (GD) Report for the Western Cape.

| | |
|---|---|
| Management area | Groot. |
| Main land use | Dryland and irrigated agriculture (vineyards, fruit, 8ucerne), livestock (sheep), conservation areas. |
| Main town | Touwsrivier, Laingsburg, Matjiesfontein, Ladismith, Vanwyksdorp, Barrydale. Doring River: Ladismith, Barrydale. |
| Risk rating of WWTW (high – critical only) | Barrydale WWTW: High risk rating – secondary catchment H7 near the Doring River (flow exceeds capacity, poor effluent quality). |

Note that no water quality data exists for the Doring River systems. The water quality assessment is therefore based on available information and best judgement.

**Notes**

- Cultivation and grazing are the dominant land uses in the area.
- The Fact Sheet from the PES/EIS study for this area (DWS, 2014), SQ (J12L-9895) indicates a physico-chemical rating of a 2, i.e. a moderate impact rating, and a PES of a D Category.
- January 2014: Clear and fast-flowing with some algal growth on substrate. Filamentous algae were seen above and below the crossing.
- Diatoms (n = 2, January and April 2014): SPI values of 11.2 (C/D Category) and 7.5 (D/E Category). The biological water quality at this site was Moderate to Poor. Nutrient levels, organic pollution and salinity were high and problematic for both sampling efforts. The diatoms indicated that salinity levels decreased during April. Nutrient levels increased between January and April while organic pollution levels were stable. Moderate oxygenation rates and high pollution levels prevailed during January and April 2014.
- FRAI: C/D Category (58.3%).
- MIRAI: D Category (54.7%).
- Abstraction and excavation activities in the Doring River and Lemoenshoek/Huis tributaries would suggest elevated turbidities and impacts on temperature and oxygen levels.

In conclusion, it is expected that the site shows elevated salts and nutrients, and that some impact is seen on turbidity, oxygen and temperatures at low flows. The water quality assessment is of low confidence and is expected to be a **C category** (75.6%).

### A.4.4 J3OLIF-EWR9

The EWR site is situated in the upper Olifants River catchment, i.e. upstream Stompdrift Dam. Although a number of water quality monitoring points are located on the Olifants, only one was suitable for this assessment, i.e. J3H021Q01, downstream of the site and upstream of Stompdrift Dam (see **Figure A.6**). Note that data were only collected until 1993.

Data for the assessment was sourced from DWS gauging weir J3H021Q01 on the Olifants River (see **Figure A.6**). The data records spans from 1982 to 1993, data were only used for the present state assessment:

- RC was represented by the specialist assessment as A Category benchmark tables in DWAF (2008) were considered unsuitable and no RC data was available.
- PES: DWS gauging weir J3H021Q01 (2000 – 2014; n = 128).


**Figure A.6 J3OLIF-EWR9 on the Upper Olifants River in relation to monitoring point J3H021Q01**

**Notes from the February 2014 survey**

- The upper Olifants mostly runs underground and pops up in places. J3OLIF-EWR9 is an area of some flow.
- Farmers in the area are reliant on boreholes or water running off the mountains (Johan van Jaarsveld, Rondekop Farm; *pers. comm.*). The latter may also provide some soil moisture.
- Water present on the surface is not from the deep aquifer, but from the vadose zone.
- Exensive algae were present at the site.
- *Cochilla* spread out across the area. This indicates relatively constant “wetness”. The area is dependent on groundwater depth elevation, but the shallow groundwater (Mackenzie, *pers. comm.*).

A low confidence water quality assessment is shown in **Table A.5** below.

### Table A.5 Water quality present state assessment for J3OLIF-EWR9

| Water Quality Constituents | PES Value | Category/Comment |
|---|---|---|
| **Inorganic salt ions (mg/l)** | | |
| Sulphate as $SO_4$ | 1 353.4 | No guideline but concentrations are high. |
| Sodium as Na | 1 774.5 | Exceeds the ≤ 70 mg/L (TWQR) for Agricultural Use: Irrigation. |
| Magnesium as Mg | 336.0 | No guideline |
| Calcium as Ca | 284.4 | No guideline |
| Chloride as Cl | 3 113 | Exceeds the ≤ 100 mg/L (TWQR) for Agricultural Use: Irrigation. |
| Potassium as K | 30.16 | No guideline. |
| **Electrical conductivity (mS/m)** | | |
| | 1 078.7 | Natural salinity expected to be high due to the geology of the area |
| **Nutrients (mg/l)** | | |
| SRP | 0.019 | B/C |
| TIN (only $NO_3$-N) | 0.11 | A |
| **Physical Variables** | | |
| pH ($5^{th}$ + $95^{th}$ %ile) | 7.3 and 9.0 | B/C but assumed to be linked to the groundwater signature. |
| Temperature (ºC) | - | C. Impact expected when little surface flow. |
| Dissolved oxygen (mg/L) | - | |
| Turbidity (NTU) | - | B/C. Impact expected due to extensive livestock farming and erosion in the area. |
| **Response variables** | | |
| Chl-*a*: phytoplankton (ug/L) | - | - |
| Macroinvertebrate score (MIRAI) | 69.0% | C |
| Diatoms | 6.0 (average) | D/E |
| Fish score (FRAI) | n/a | |
| **Toxics** | | |
| Ammonia (as N) | 0.038 | B |
| Fluoride (as F) | 0.678 | A |
| **OVERALL SITE CLASSIFICATION (PAI model)** | | **C (75.9%)** |

- no data

Diatom data (n = 2) indicate Poor biological water quality with elevated nutrient levels, organic pollution and high salinities. The diatom community is representative of a stressed environment where low flows dominate. During these conditions nutrient and organic pollution increases are expected. Although valve deformities occurred at low abundance their presence was continual and would have long term effects on aquatic biota. It is assumed that the low category assigned to diatoms may be linked to stress due to low flows, rather than poor water quality.

Salt levels are elevated, which is also linked to the high natural levels expected due to the geology of the region. Of concern is the high sulphate levels recorded. Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes, with temperature and oxygen impacts expected when little flow is present. Note that irrigation activities are limited in this area, with livestock farming being the predominant land-use activity.

The water quality category at OLIFANTS_EWR9 is therefore expected to be a **C Category** (75.9%). Note that this is set at Low confidence.

### A.4.5 J3KAMM-EWR10

In secondary catchment J3 the Kammanassie River is described as having Fair water quality (RHP, 2007).

The table below summarises the main land use and main towns in the area (RHP, 2007), as relevant to the Kammanassie. State of WWTW is taken from DWA (2012), i.e. the Green Drop (GD) Report for the Western Cape.

| | |
|---|---|
| Management area | Olifants. |
| Main land use | Dryland and irrigated agriculture (lucerne, pastures), livestock (ostriches, sheep), conservation areas. |
| Main town | Oudtshoorn, Uniondale, De Rust, Dysselsdorp, Klaarstroom. |
| Risk rating of WWTW (high – critical only) | Uniondale WWTW: Critical risk rating (no monitoring; potential impact on the Holdrif River just upstream of its confluence with the Kammanassie River). |

Note that no water quality data exist for the Kammanassie River systems. The water quality assessment is therefore based on available information and best judgement.

**Notes**

- Irrigated farming along river margins and livestock farming are the dominant land uses in the area.
- The Fact Sheet from the PES/EIS study for this area (DWS, 2014), SQ (J34C-8869) indicates a physico-chemical rating of a 2, i.e. a moderate impact rating, and a PES of a C Category.
- February 2014: Farmer Kerneels Nortjie of the farm Scheeperskraal reported that the river normally stops flowing in December/January and is often dry in February.
- Diatoms (n = 2, February and July 2014): SPI values of 10.1 (C/D Category) and 13.3 (C Category); overall a C/D Category. The biological water quality at this site was Moderate. Nutrient levels, organic pollution and salinity were elevated with salinity and organic pollution levels becoming problematic. The improvement in diatom-based water quality could mainly be ascribed to higher flows during July 2014 which allowed for the flushing of pollutants as diatom species associated with elevated flows were abundant.
- Although water was clear at the site, there was instream silt when disturbed. Impacted on cover in upstream pools for fish. Predation by bass also important.
- FRAI: D Category (44.8%).
- MIRAI: C/D Category (61.7%).

In conclusion, it is expected that the site shows elevated salts and nutrients, and that some impact is seen on oxygen and temperatures at low flows. The water quality assessment is of low confidence and is expected to be a **C Category** (70.8%).

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# APPENDIX B: DIATOM RESULTS

## B.1 INTRODUCTION

Benthic diatoms were used in this study as indicators of biological water quality. Diatoms typically reflect water quality conditions over the past three days and are ecologically important because of their role as primary producers, which form the base of the aquatic food web, and because they usually account for the highest number of species among the primary producers in aquatic systems (Leira and Sabater, 2005). Diatoms are photosynthetic unicellular organisms and are found in almost all aquatic and semi-aquatic habitats. They have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution (Tilman *et al*., 1982, Dixit *et al*., 1992, Cattaneo *et al*., 2004), as well as for general water quality (AFNOR, 2000).

## B.2 TERMINOLOGY

Terminology used in this specialist appendix is outlined in Taylor *et al.* (2007a) and summarised below.

| | |
|---|---|
| **Trophy** | |
| Dystrophic | Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content. |
| Oligotrophic | Low levels or primary productivity, containing low levels of mineral nutrients required by plants. |
| Mesotrophic | Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants. |
| Eutrophic | High primary productivity, rich in mineral nutrients required by plants. |
| Hypereutrophic | Very high primary productivity, constantly elevated supply of mineral nutrients required by plants. |
| **Mineral content** | |
| Very electrolyte poor | < 50 µS/cm |
| Electrolyte-poor (low electrolyte content) | 50 - 100 µS/cm |
| Moderate electrolyte content | 100 - 500 µS/cm |
| Electrolyte-rich (high electrolyte content) | > 500 µS/cm |
| Brackish (very high electrolyte content) | > 1000 µS/cm |
| Saline | 6000 µS/cm |
| **Pollution (Saprobity)** | |
| Unpolluted to slightly polluted | BOD <2, $O_2$ deficit <15% (oligosaprobic) |
| Moderately polluted | BOD <4, $O_2$ deficit <30% (β-mesosaprobic) |
| Critical level of pollution | BOD <7 (10), $O_2$ deficit <50% (β-ά-mesosaprobic) |
| Strongly polluted | BOD <13, $O_2$ deficit <75% (ά-mesosaprobic) |
| Very heavily polluted | BOD <22, $O_2$ deficit <90% (ά-meso-polysaprobic) |
| Extremely polluted | BOD >22, $O_2$ deficit >90% (polysaprobic) |

## B.3 METHODS

### B.3.1 Sampling

Sampling methods were followed as outlined in Taylor *et al*. (2007a) which were designed and refined as part of the Diatom Assessment Protocol, a Water Research Commission initiative. Five Rapid EWR sites were sampled during June and August 2013, respectively.

### B.3.2 Slide preparation and diatom enumeration

Preparation of diatom slide followed the Hot HCl and $KMnO_4$ method as outlined in Taylor *et al*. (2007a). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. A count of 400 valves per sample or more was enumerated for all the sites based on the findings of Schoeman (1973) and Battarbee (1986) in order to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al*., 2007a). Nomenclature followed Krammer and Lange-Bertalot (1986-91) and diatom index values were calculated with the database programme OMNIDIA (Lecointe *et al*., 1993).

### B.3.3 Diatom-based water quality indices

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. Most indices are based on a weighted average equation (Zelinka and Marvan, 1961). In general, each diatom species used in the calculation of the index is assigned two values; the first value (s value) reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value (v value) indicates how strong (or weak) the relationship is (Taylor, 2004). These values are then weighted by the abundance of the particular diatom species in the sample (Lavoie *et al*., 2006; Taylor, 2004; Besse, 2007). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta and Soininen, 2002).

These indices form the foundation for developing computer software to estimate biological water quality. OMNIDIA (Lecointe *et al*., 1993) is one such software package; it has been approved by the European Union and is used with increasing frequency in Europe and has been used for this study. The program is a taxonomic and ecological database of 7500 diatom species, and it contains indicator values and degrees of sensitivity for given species. It permits the user to perform rapid calculations of indices of general pollution, saprobity and trophic state, indices of species diversity, as well as of ecological systems (Szczepocka, 2007).

## B.4 DATA ANALYSIS

### B.4.1. Diatom-based water quality score

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey *et al*. (2004) concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI. The interpretation of the SPI scores was adjusted during 2011 and the new adjusted class limits are provided in **Table B.1**.

**Table B.1 Adjusted class limit boundaries for the SPI index applied in this study**

| Interpretation of index scores | | |
|---|---|---|
| **Ecological Category (EC)** | **Class** | **Index Score (SPI Score)** |
| A | High quality | 18 - 20 |
| A/B | | 17 - 18 |
| B | Good quality | 15 - 17 |
| B/C | | 14 - 15 |
| C | Moderate quality | 12 - 14 |
| C/D | | 10 - 12 |
| D | Poor quality | 8 - 10 |
| D/E | | 6 - 8 |
| E | Bad quality | 5 - 6 |
| E/F | | 4 - 5 |
| F | | <4 |

### B.4.2 Diatom-based Ecological Classification

Ecological characterisation of the samples was based on Van Dam *et al.* (1994). This work includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state as provided by OMNIDIA (Le Cointe *et al*., 1993). The results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) were also taken into account as this index provides the percentage Pollution Tolerant diatom Valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.

## B.5 UNCERTAINTIES

There are some diatom species that could not be identified to species level. The samples where species identification was problematic are listed below:

- EWR1: Need to confirm a *Navicula* species which was sub-dominant, and *Geissleria* species.
- EWR2: Need to confirm small *Navicula* species.
- EWR7: Need to confirm *Navicula* species.
- EWR10: Need to confirm *Navicula* species (February).

Due to time constraints, species identification could not be confirmed by Dr Taylor from North-West University before the workshop, during July 2014. These species were however included at genus level during the analysis of data and it is not expected that the current results would change to such an extent that the overall ECs for the reaches would change.

## B.6 RESULTS

A summary of the diatom results for the EWR sites located in the Duiwenhoks, Goukou, Doring and Kammanassie rivers are provided in **Table B.2** and include the presence of PTVs and percentage valve deformities based on a total count of 400 diatom valves. The diatom based ecological classification based on Van Dam *et al*. (1994) for diatom-based water quality is given in **Table B.3**. Species lists are provided electronically.

**Table B.2 Diatom analysis results**

| Site | Date | No of species | SPI score | Class | Category | PTV (%) | Deformities (%) |
|---|---|---|---|---|---|---|---|
| H8DUIW-EWR1 | 19-Jan-14 | 33 | 11.1 | Moderate quality | C/D | 67.3 | 0.25 |
| H9GOUK-EWR2 | 20-Jan-14 | 22 | 14.4 | Good quality | B/C | 13 | 4 |
| | 24-Jun-14 | 39 | 11 | Moderate quality | C/D | 25 | 2.5 |
| J1DORI-EWR7 | 22-Jan-14 | 33 | 11.2 | Moderate quality | C/D | 35.5 | 0.5 |
| | 09-Apr-14 | 31 | 7.5 | Poor quality | D/E | 78 | 1.5 |
| J3OLIF-EWR9 | Feb 14 | 25 | 4.9 | Bad quality | E/F | 78.5 | 0.25 |
| | Jun 14 | 21 | 7 | Poor quality | D/E | 84.8 | 0.25 |
| J3KAMM-EWR10 | 12-Feb-14 | 43 | 10.1 | Moderate quality | C/D | 38.5 | 0.5 |
| | 24-Jun-14 | 27 | 13.3 | Moderate quality | C | 20.8 | 0 |

**Table B.3 Generic diatom based ecological classification (Van Dam *et al*., 1994)**

| Site | Date | pH | Salinity | Organic nitrogen (N) | Oxygen levels | Pollution levels | Trophic status |
|---|---|---|---|---|---|---|---|
| H8DUIW-EWR1 | Jan 14 | Alkaline | Brackish fresh | Continuously elevated concentrations of organically bound N | Moderate (>50% saturation) | Very heavily polluted | Eutrophic |
| H9GOUK-EWR2 | Jan 14 | Alkaline | Fresh brackish | Very small concentrations of organically bound N | Continuously high (~100% saturation) | Unpolluted to slightly polluted | Oligotrophic |
| | Jun 14 | Neutral | Fresh brackish | Elevated concentrations of organically bound N | Continuously high (~100% saturation) | Unpolluted to slightly polluted | Oligotrophic |
| J1DORI-EWR7 | Jan 14 | Alkaline | Brackish fresh | Continuously elevated concentrations of organically bound N | Moderate (>50% saturation) | Very heavily polluted | Eutrophic |
| | Apr 14 | Alkaline | Brackish fresh | Continuously elevated concentrations of organically bound N | Moderate (>50% saturation) | Very heavily polluted | Eutrophic |
| J3OLIF-EWR9 | Feb 14 | Alkaline | Brackish fresh | Continuously elevated concentrations of organically bound N | Moderate (>50% saturation) | Very heavily polluted | Eutrophic |
| | Jun 14 | Alkaline | Brackish fresh | Continuously elevated concentrations of organically bound N | Moderate (>50% saturation) | Very heavily polluted | Eutrophic |
| J3KAMM-EWR10 | Feb 14 | Alkaline | Fresh brackish | Elevated concentrations of organically bound N | Moderate (>50% saturation) | Moderately polluted | Eutrophic |
| | Jun 14 | Neutral | Fresh brackish | Elevated concentrations of organically bound N | Continuously high (~100% saturation) | Moderately polluted | Oligotrophic |

## B.7 DISCUSSION

The results of the diatom analyses are provided below. Note: Species contributing 5% or more to the total count were classified as dominant species. A species list is provided electronically.

### B.7.1 H8DUIW-EWR1

According to DWA (2014), the Duiwenhoks River improves slightly in the lower reaches (SQ H80D-9286 and SQ H80D-9314) to a Category D, but is still impacted notably by flow modification (Duiwenhoks Dam and abstraction for irrigation) as well as non-flow related activities (farming).

The diatom results are based on one sample collected on 19 January 2014 at the EWR site. No historic or other present data could be sourced for the Duiwenhoks River.

The biological water quality at this site was moderate with a SPI score of 11.1 (C/D EC) (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and heavy pollution levels prevailed.

Salinity levels are naturally high due to geology and river estuary interface at causeway. This would influence the salinity results for diatoms, however, there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels. Problematic nutrient and organic pollution levels could be originating from the dairy farm in the vicinity of the EWR site. There are more than 1000 head of cattle on the farm, and during the site visit a farmer informed Dr Bok that runoff from the farm enters the river directly with no filtration or any treatment of the water.

Dominant diatom species included:

- *Achnanthidium* species which are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b).
- *Nitzschia hantzschiana*: Acidic electrolyte poor, cool and clean waters (Taylor *et al*., 2007b) and its dominance can be associated with the elevated flows at the time of sampling and the possible influx of cleaner water.
- *Geissleria acceptata*, which according to Potapova (2009) prefers fresh waters with moderate to high electrolyte content.
- *Nitzschia frustulum* was dominant and indicated problematic nutrient and salinity levels. According to Cholnoky (1968), *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that *N. frustulum* is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced.
- *Nitzschia* species, which is associated with water bodies that have readily available nutrients.

The diatoms reflect the accumulative effects of farming activities within the reach. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macroinvertebrates and fish. The total abundance of valve deformities was 0.25%, which is not regarded as problematic as the general threshold for valve deformities is usually considered potentially hazardous if the valve deformities make up between 1 – 2% of the total count. Diatom community generally have a preference for moderate water quality.

The diatom-based water quality was estimated to be in a C/D EC, due to the high salinity and problematic nutrient and organic pollution levels.

### B.7.2 H9GOUK-EWR2

Within MRU A, the impact of tributaries (one which is in an E (Vet River)) has an incremental impact culminating with the water quality impacts at Riversdale. Considering estuary requirements and system operation, an EWR site towards the downstream end of the system would be preferable. However, the downstream section is influenced by Riversdale impacts (WWTW and run-off) as well as the impacts of the Vet River. Access and suitable sites are also problematic in the downstream reach. Therefore, the hotspot section in SQ H90C-09229 which lies immediately upstream of this area and includes a gauging weir was targeted for EWR site selection (DWA, 2014).

The results were based on two samples collected on 20 January 2014 and 24 June 2014 at the EWR site. No historic or other present data could be sourced for the Goukou River.

**January 2014**

The biological water quality at this site was good with a SPI score of 14.4 (B/C EC) (**Table B.2**). Nutrient levels, organic pollution and salinity were low and not problematic. High oxygenation rates and low pollution levels prevailed.

Dominant species included:

- *Achnanthes oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows.
- *Geissleria acceptata*: See **Section B.7.1**.
- *Navicula* small species: Need to confirm what these are, but usually this species prefer impacted waters.

Although the SPI score reflected good water quality, sub-dominant species indicated that salinity, nutrients and organic pollution levels were increasing (*N. frustulum* and *Nitzschia* species). Indicators of industrial and sewage related impacts occurred in low abundance, but their presence indicates that anthropogenic activities in the upper reaches of the RU do impact the site. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macroinvertebrates and fish.

**Of concern was the occurrence of diatom valve deformities which relate to the presence of metal toxicity.** According to Luís *et al*. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The total abundance of valve deformities was 4%, which is regarded as potentially hazardous as the general threshold for valve deformities is usually considered between 1 - 2%. The presence of valve deformities indicated that metal toxicity was present at the time of sampling and could have had an adverse effect on the biological functioning of aquatic biota.

**July 2014**

The biological water quality at this site was moderate with a SPI score of 11 (C/D EC) (**Table B.2**). There was a general deterioration in diatom based water quality between January and July 2014, which could mainly be attributed to increased nutrient, organic pollution and salinity levels. From the data it was evident that salinity and organic pollution were the main determining factors of deteriorated water quality. High oxygenation rates and low pollution levels prevailed during July 2014.

Dominant species included:

- *Achnanthes oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows.
- *Navicula gregaria*: Common in eutrophic and hyper-eutrophic waters. Moderate to high electrolyte content extending into brackish biotopes. Tolerant of strong pollution and a good indicator of these conditions (Taylor *et al*., 2007b).
- *Nitzschia* species: See **Section B.7.1**.
- *Fragilaria capucina* var. *vaucheriae*: Species associated with elevated flows but have a wide ecological amplitude.

The diatom data indicated that although flows were elevated, there was an influx of deteriorated water quality. There was a greater abundance of species with a preference for high salinity and organic pollution levels present during July 2014 than during January 2014. The same trend was observed for indicators of industrial related impacts. The dominance of *N. gregaria* indicated that sewage related activities (septic tanks and soak aways) may be impacting on the site. The presence of *Bacillaria paradoxa*, which is a marine species also suggested that high salinity was present upstream of the site and that salinity levels would increase. Of importance was the sub-dominance of *Fragilaria fasciculata* during July 2014 and has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats, especially $MgS0_4$ and is characterised as most indicative of habitats with high specific conductance and euryhaline conditions (Blinn, 1993). This could be an indication of higher herbicide and pesticide use within the reach and the use of Epsom salts ($MgS0_4$) in citrus orchards in the vicinity of the river.

Sedimentation was higher during July 2014 than January 2014 and could have influenced turbidity levels at the site. Valve deformities made up 2.5% of the total count, which was lower than observed during January 2014. However these levels still exceeded thresholds and indicated that metal toxicity was present at the site for prolonged periods of time. Sub-aerial species were still present and indicated that water level fluctuation for long periods would impact life-cycle stages of aquatic biota.

The overall diatom EC was set at a C/D as the confidence in the assessment was higher for the July sample in terms of species identification and the presence of valve deformities during both sampling efforts. The sub-dominant species also indicated that the water quality would deteriorate.

### B.7.3 J1DORI-EWR7

An EWR site in this river was only included in direct reaction to a current/future development in the Lemoenshoek Stream (not part of the 1:500 000 DWA river coverage), a tributary of the Doring River. The EWR site was therefore selected in the Doring River as close as possible to and downstream of the confluence of the Lemoenshoek confluence with the Doring River (DWA, 2014).

The results are based on two samples collected on 22 January 2014 and 9 April 2014.

**January and April 2014**

The biological water quality at this site was moderate to poor with a SPI score of 11.2 (C/D EC) during January 2014 and 7.5 during April 2014 (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic for both sampling efforts. The diatoms indicated that salinity levels decreased during April. Nutrient levels increased between January and April while organic pollution levels were stable. Moderate oxygenation rates and high pollution levels prevailed during January and April 2014.

Dominant species included:

- *G. acceptata*: See **Section B.7.1**.
- *Navicula* species: Need to confirm species type.
- *Epithemia adnata*: Tolerant to moderate to high electrolyte content, but extends into brackish biotopes. Indicator of elevated water temperatures (Taylor *et al*., 2007b).
- *Nitzschia* species: See **Section B.7.1**.
- *Planothidium engelbrechtii*: Found in saline inland waters with very high electrolyte content tolerating critical to very heavy pollution (Taylor *et al*., 2007b).
- *Planothidium frequentissima*: Prefers moderate to high electrolyte content and tolerates critical pollution levels (Taylor *et al*., 2007b).

The dominance of *N. frustulum* and *Nitzschia* species indicated that salinity and nutrient levels were high and problematic. The abundance of these species were higher during April than January 2014 and suggested that nutrient and salinity levels were higher in April than in January 2014. *Planothidium* species are indicators for organic pollution. These species were dominant during January 2014 and sub-dominant during April 2014 and suggested that organic pollution was generally elevated throughout the river system. Of importance was the sub-dominance of *F. fasciculata* during January 2014 and has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats, especially $MgS0_4$ and is characterised as most indicative of habitats with high specific conductance and euryhaline conditions (Blinn, 1993). This could be an indication of higher herbicide and pesticide use within the reach and the use of Epsom salts ($MgS0_4$) in citrus orchards in the vicinity of the river.

Valve deformities made up 0.5% of the total count during January 2014 and 1.5% during April 2014. This suggested that toxicity was present for prolonged periods of time in the system which would impact the aquatic biota. *E. adnata* was dominant during January 2014 and sub-dominant during April 2014 and indicated that water temperatures fluctuated notably and were elevated at times which was most probably caused by abstraction. Indicators of industrial activity and sewage (to a lesser extent) were sub-dominant during January and April 2014, which suggested that this was the cause of deteriorated water quality within the system. Sewage related impacts could be originating from septic tanks and soak aways. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macroinvertebrates and fish.

The overall diatom EC was set at a D due to the presence of valve deformities during both sampling efforts. The sub-dominant species also indicated that the water quality would deteriorate.

### B.7.4 J3OLIF-EWR9

According to DWA (2014), the main landuse in MRU Olifants A where J3OLIF-EWR9 is situated consists of mostly grazing and small localised areas of irrigation (groundwater dependant).

The diatom results are based on two samples collected during February and June 2014 respectively at the EWR site. No historic or other present data could be sourced for the Olifants River.

**February 2014**

The biological water quality at this site was bad with a SPI score of 4.9 (E/F Ecological Category) (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum*: See **Section B.7.1**.
- *Nitzschia* species: See **Section B.7.1**.

The diatom-based water quality was unacceptable. *N. frustulum* and *Nitzschia* species were dominant and suggested that very high salinity levels prevailed along with high nutrient levels. All species present had a preference for deteriorated water quality with high salinity, nutrient and organic pollution levels. From the photographic records available of the EWR site flows were very low and deteriorated water quality conditions were expected. Indicators of anthropogenic activities were prolific and were associated with sewage, as well as herbicide and pesticide use and included *Navicula veneta*, *Nitzschia aurariae* and *Navicula erifuga*. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macroinvertebrates and fish. Valve deformities occurred at an abundance of 0.25% and were not deemed problematic at the time of sampling, although due to the presence of indicators of anthropogenic activities metal toxicity could most probably become problematic at times.

**June 2014**

During June there was an improvement in diatom-based water quality. The SPI score was 7 (D Ecological Category) (**Table B.2**) and the improvement could mainly be attributed to slightly improved salinity levels while nutrient and organic pollution levels increased. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum*: See **Section B.7.1**.

*N. frustulum* was observed in higher numbers than during February 2014 and accounted for the higher nutrient levels. The diatom data indicated that salinity levels were increasing as *Fragilaria fasciculata* was sub-dominant and indicated that sulphates could be elevated. PTVs made up 84.8% of the total count compared to 78.5% observed during February 2014. These levels were unacceptably high. As observed during February 2014 most species had a preference for deteriorated water quality with high nutrient levels as well as salinity. Indicators of anthropogenic activities were observed at similar levels as observed during February 2014, suggesting that surrounding agriculture was impacting the site to a certain extent. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macroinvertebrates and fish. Valve deformities occurred at an abundance of 0.25%, similar to February 2014 and indicated that although levels were not deemed problematic, the site was exposed to continual impact which would have a long term impact on aquatic biota.

The hydrological data indicated that flows at J3OLIF-EWR9 are limited to a trickle most of the time which is mostly groundwater fed. The diatom community was representative of a stressed environment where low flows dominate. During these conditions nutrient and organic pollution increases are expected especially in the presence of goats which were observed at the time of sampling.

**Conclusions**
MRU Olifant A was characterised by generally high salinity levels as well as high nutrient and organic pollution levels which were problematic most of the time. Salt deposits were observed along with a characteristic odour relating to high salinity. The upper vegetation zone also comprised of species associated with high levels of salinity. The hydrological data indicated that flows at J3OLIF-EWR9 are limited to a trickle most of the time which is mostly groundwater fed. The diatom community was representative of a stressed environment where low flows dominate. During these conditions nutrient and organic pollution increases are expected. Although valve deformities occurred at low abundance their presence was continual and would have long term effects on aquatic biota.

The overall Ecological Category for the reach was set at a D EC.

### B.7.5 J3KAMM-EWR10

Upstream of Kammanassie Dam the impacts are related to urban impacts, agricultural fields in the riparian zone and alien vegetation. The areas which are in the best condition are due to inaccessibility being in a deep river valley. Two SQs fall in a B/C state (SQ J34D-08868 and 08899). Most of the rest of the SQs fall in a C and C/D state (DWA, 2014).

The results were based on two samples collected on 10 February 2014 and 24 June 2014.

**February 2014**

The biological water quality at this site was moderate with a SPI score of 10.1 (C/D EC) (**Table B.2**). Nutrient levels, organic pollution and salinity were elevated with salinity and organic pollution levels becoming problematic. Moderate oxygenation rates and moderate pollution levels prevailed.

Dominant species included:

- *Achnanthidium* species: See H8DUIW-EWR1.
- *N. dissipata*: Indicating hard water (calcium based salinity), and favouring alkaline conditions (Taylor, *pers comm.*).
- *N. gregaria*: Common in eutrophic and hyper-eutrophic waters. Moderate to high electrolyte content extending into brackish biotopes. Tolerant of strong pollution and a good indicator of these conditions (Taylor *et al*., 2007b).
- *N. frustulum*: See H8DUIW-EWR1.
- *Nitzschia irremissa:* Tolerant to elevated levels of pollution (Taylor *et al*., 2007b).
- *N. schroeteri* var. *symmetrica*: Cosmopolitan in eutrophic electrolyte rich waters, tolerant of strong pollution (Taylor *et al*., 2007b).
- *Nitzschia* species: See H8DUIW-EWR1.

The dominance of *Achnanthidium* species suggested that flows were recently elevated. Dominant species have a preference for elevated salinity and organic pollution levels. *N. gregaria* and *N. schroeteri* var. *symmetrica* are species usually associated with sewage and industry related activities. Although it is acknowledged that cattle is contributing to higher organic and nutrient loads in the system, *N. gregaria* and *N. schroeteri* var. *symmetrica* are indicator species of sewage related activities and their presence could be due to septic tanks and soak aways located in the vicinity. If cattle were the main contributing factor to increased organic pollution loads it would be expected that there would be a greater abundance or dominance of *Planothidium* species. Higher organic loads could also be due to the use of pesticides and herbicides in the area.

The high abundance of *N. frustulum* suggested that nutrient levels were increasing along with salinity. The presence of *B. paradoxa*, which is a marine species also suggested that high salinity was present upstream of the site and that salinity levels would increase. Sub-dominant species have an affinity for high salinity and organic pollution levels and it was assumed that these variables were deteriorating, which would lead to a further deterioration in water quality. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macroinvertebrates and fish. The total abundance of valve deformities was 0.5%, which is not regarded as problematic as the general threshold for valve deformities is usually considered potentially hazardous if the valve deformities make up between 1 - 2% of the total count. The diatom community generally had a preference for moderate water quality.

**June 2014**

The biological water quality at this site was moderate with a SPI score of 13.3 (C EC) (**Table B.2**). Nutrient levels, organic pollution and salinity improved from February 2014. Oxygenation rates were higher during July 2014 while moderate pollution levels still prevailed.

Dominant species included:

- *N. gregaria*: Common in eutrophic and hyper-eutrophic waters. Moderate to high electrolyte content extending into brackish biotopes. Tolerant of strong pollution and a good indicator of these conditions (Taylor *et al*., 2007b).
- *Achnanthidium* species which are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates.
- *Fragilaria capucina* var. *vaucheriae*: Species associated with elevated flows, but has a wide ecological amplitude (Taylor *et al*., 2007b).
- *Fragilaria capucina* var. *rumpens*: Species associated with elevated flows preference for oligo- to mesotrophic waters (Taylor *et al*., 2007b)
- *Gomphonema parvulum*: Cosmopolitan species tolerant of extreme pollution (Taylor *et al*., 2007b).

The improvement in diatom-based water quality could mainly be ascribed to higher flows during July 2014, which allowed for the flushing of pollutants as diatom species associated with elevated flows were abundant. The abundance of Gomphonema species were generally higher during July than February 2014 and indicated that organic pollution levels would increase. The impacts of sewage discharge were still evident as *N. gregaria* was still dominant while sewage indicator species i.e. *Craticula halophila* and *N. schroeteri* var. *symmetrica* were sub-dominant. Generally there was a variety of indicator species of industry related activities present which suggested that the site was impacted by these upstream activities. Sub-aerial species were still present and indicated that water level fluctuation for long periods would impact life-cycle stages of aquatic biota. No valve deformities were noted.

The overall diatom EC was set at a C/D. The diatom community reflects anthropogenically impacted waters with elevated nutrient and salinity levels while organic pollution levels were problematic.

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# APPENDIX C: ECO-HYDRAULICS

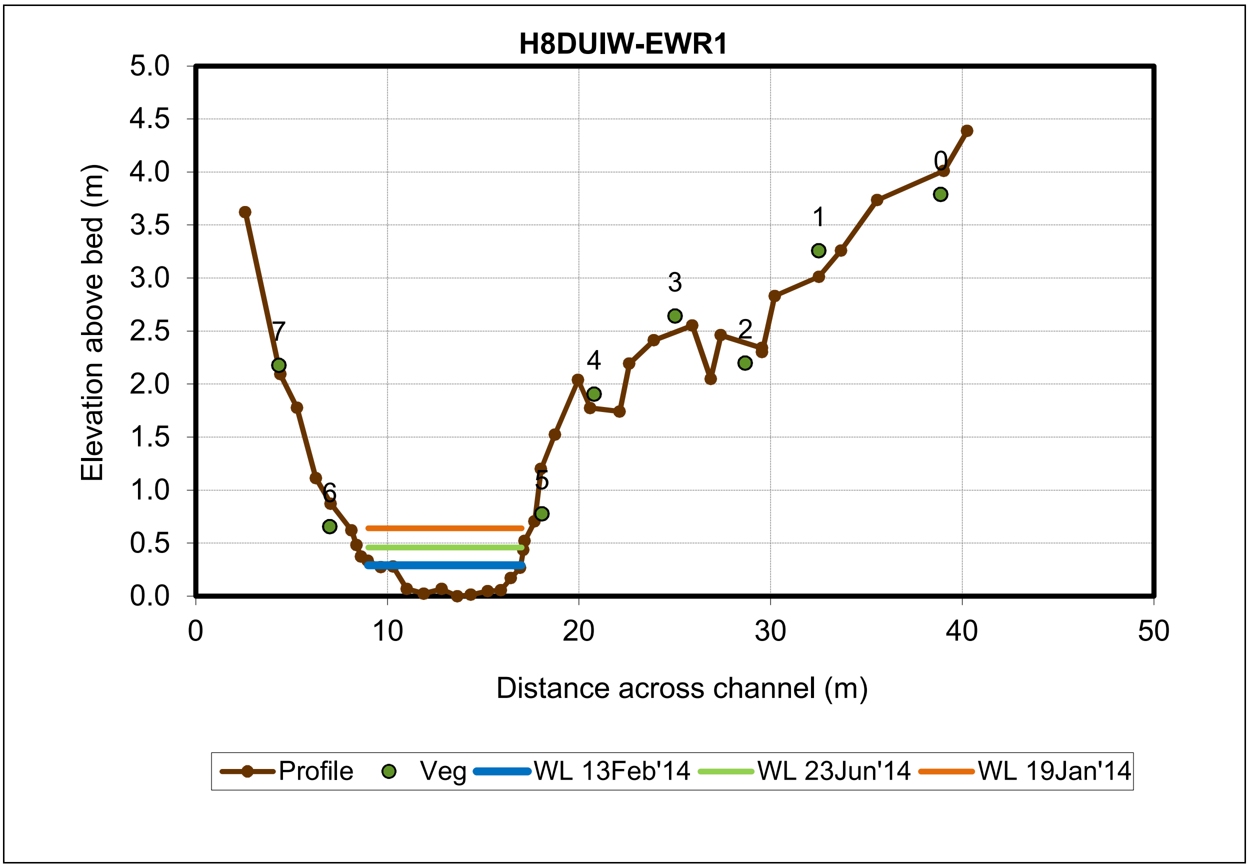
## C.1 METHODOLOGY

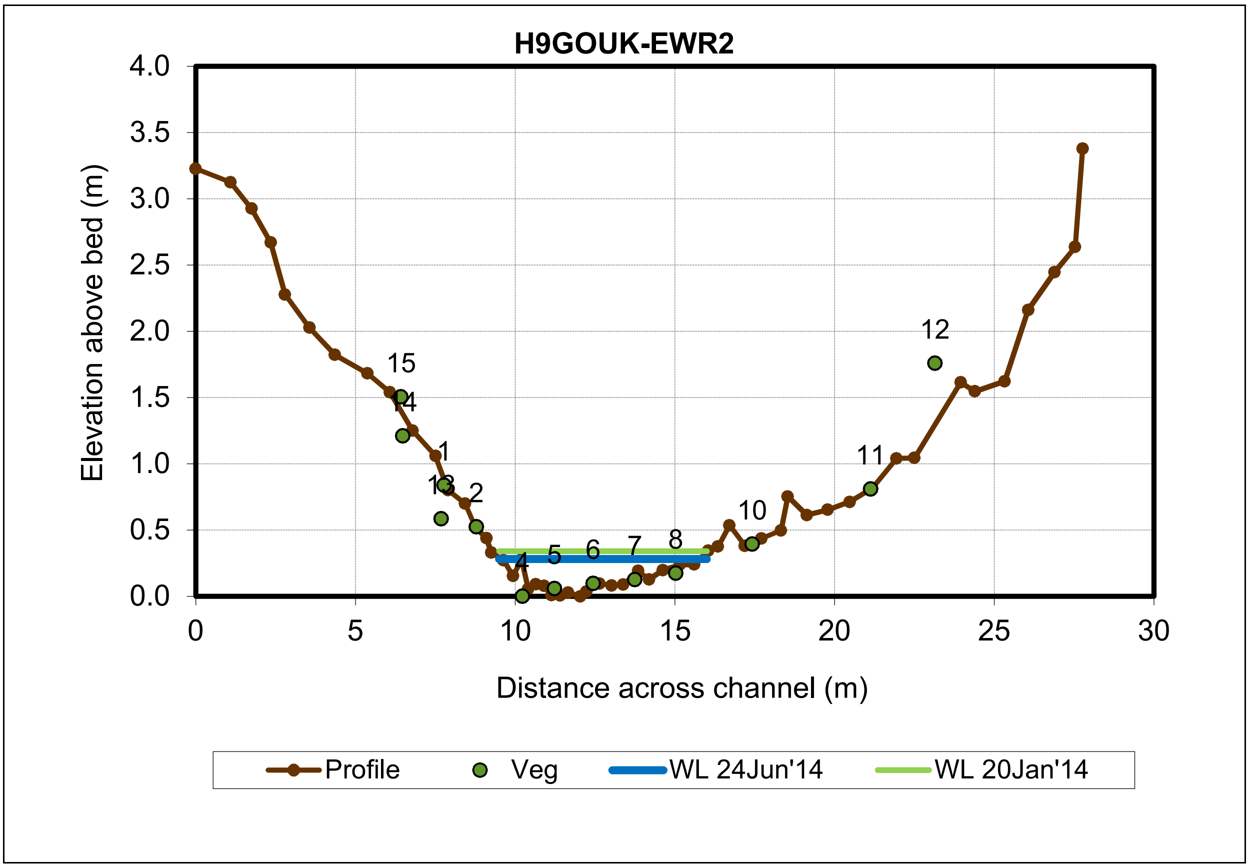
The application of holistic methods for ecological flow determination (refer to Tharme, 1996) requires EWRs to be expressed as discharge rates (including their temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and modelling at sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants, which have been found over the course of numerous flow assessments, to be the most useful: depth (maximum and average), velocity (average), wetted perimeter, and width of the water surface. The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesised data (refer to Rowlston *et al*. (2000), Birkhead (1999), Jordanova *et al*. (2004), Hirschowitz *et al*. (2007) and Birkhead (2010) for descriptions of procedures for deriving hydraulic information for use in EWRs in South Africa). Once the rating relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters (listed above) may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables (**Table C.2**).

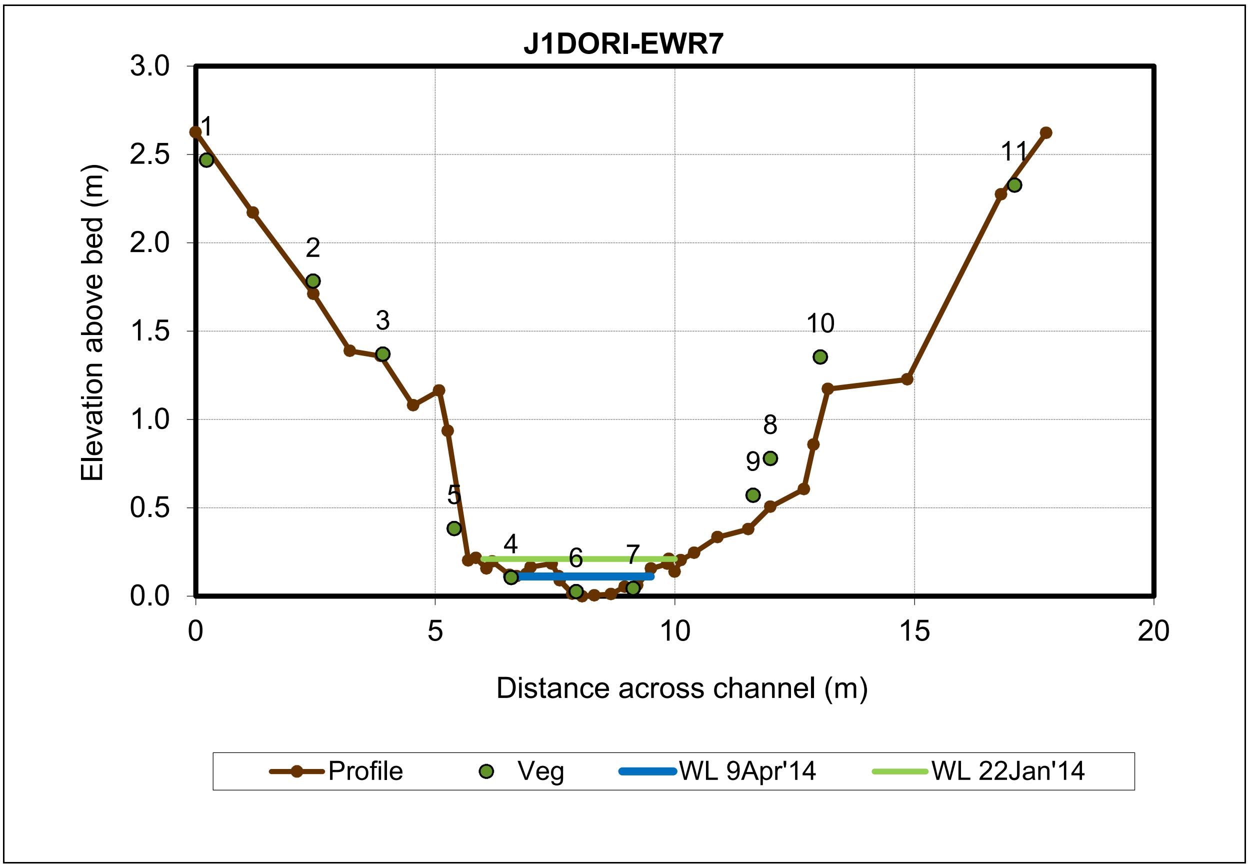
The cross-sectional profile plots and look-up tables comprise the ‘standard hydraulic data’ used in EWR determinations in South Africa. Ecologists use these standard hydraulic data with the aid of site assessments and photographs to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based biological habitats using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat, *e.g.* hydraulic, substrate and cover attributes for fish). Procedures have therefore been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (refer to Hirschowitz *et al*. (2007) and Birkhead (2010) for an explanation of the method). The method allows the assessment of abundance of different flow classes to be applied more consistently in EWRs, and has been used in this study.

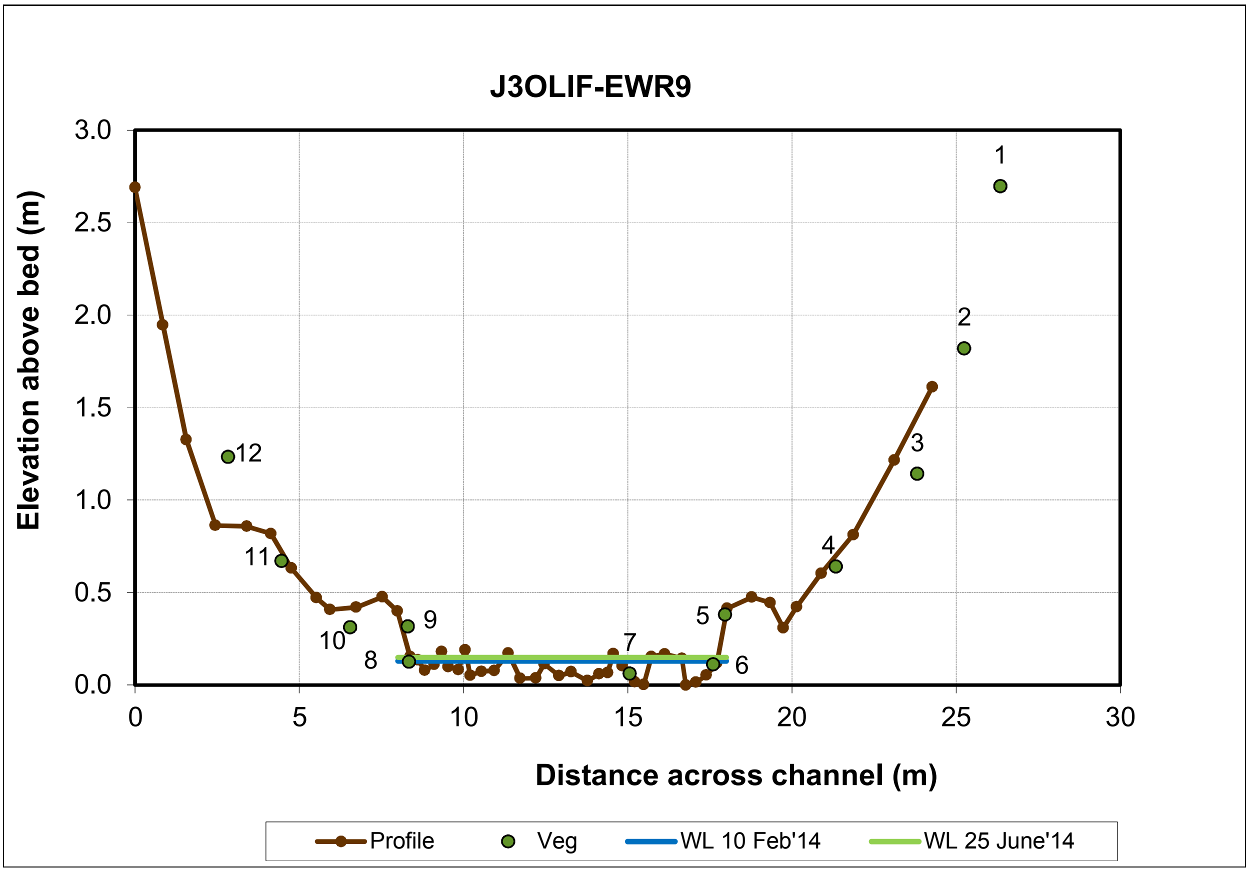
## C.2 DATA COLLECTION

The initial field trip to the study area took place during January and June 2014 when cross-sections, vegetation markers and water levels were surveyed, and discharge was measured (refer to **Figure C.1** and **Table C.1**).


H8DUIW-EWR1
Elevation above bed (m)
Distance across channel (m)
Profile
Veg
WL 13Feb'14
WL 23Jun'14
WL 19Jan'14


H9GOUK-EWR2
Elevation above bed (m)
Distance across channel (m)
Profile
Veg
WL 24Jun'14
WL 20Jan'14


J1DORI-EWR7
Elevation above bed (m)
Distance across channel (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
Profile
Veg
WL 9Apr'14
WL 22Jan'14


J3OLIF-EWR9
Elevation above bed (m)
Distance across channel (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10
11
12
Profile
Veg
WL 10 Feb'14
WL 25 June'14

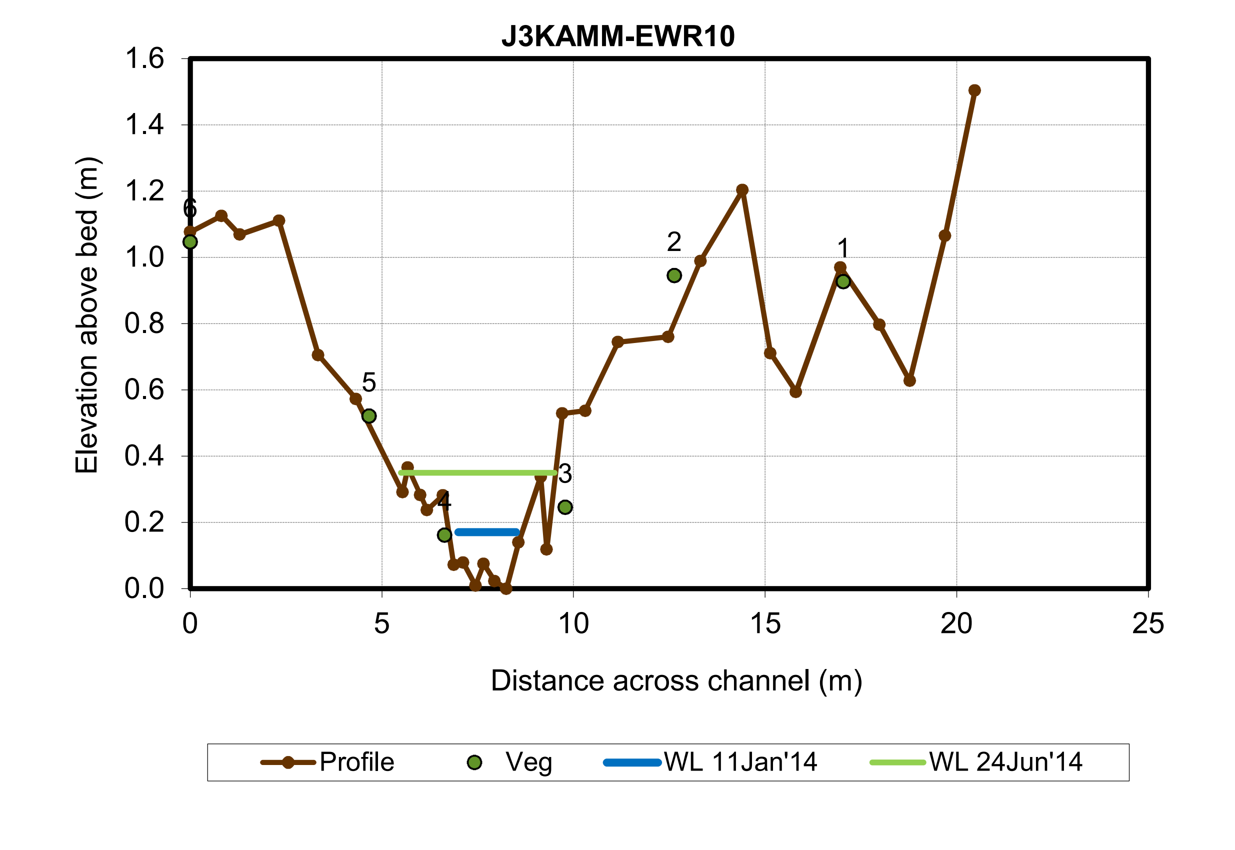



**Figure C.1 Cross-sectional profiles surveyed at the Rapid EWR sites in the study area**

**Table C.1 Hydraulic data collected at the Rapid EWR sites in the study area**

| Site | Date | Discharge ($m^3/s$) |
|---|---|---|
| H8DUIW-EWR1 | 19/01/2014 | 2.5 |
| | 13/02/2014 | 0.27 |
| | 23/06/2014 | 127 |
| H9GOUK-EWR2 | 20/01/2014 | 0.98 |
| | 24/06/2014 | 0.87 |
| J1DORI-EWR7 | 22/01/2014 | 0.22 |
| | 09/04/2014 | 0.024 |
| J3OLIF-EWR9 | 11/02/14 | 0.049 |
| J3KAMM-EWR10 | 11/01/2014 | 0.013 |
| | 24/06/2014 | 0.51 |

## C.3 RESULTS

The lookup table is provided in **Table C.2** and shaded rows denote field trip data.

## Table C.2 Lookup table providing relevant hydraulic parameters and flow classes used for ecological interpretation at the Rapid EWR sites in the study area

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| **Duiwenhoks River: H8DUIW-EWR1** | | | | | | | | | | | | | | | | | | |
| 0.02 | 0.01 | 0.000 | 1.2 | 1.2 | 0.02 | 0.07 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 70 | 0 | 0 | 30 | 0 |
| 0.04 | 0.02 | 0.001 | 2.6 | 2.6 | 0.03 | 0.10 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 70 | 0 | 0 | 30 | 0 |
| 0.06 | 0.03 | 0.004 | 4.4 | 4.4 | 0.03 | 0.12 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 70 | 0 | 0 | 30 | 0 |
| 0.08 | 0.04 | 0.011 | 5.1 | 5.1 | 0.05 | 0.17 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 70 | 0 | 0 | 30 | 0 |
| 0.10 | 0.06 | 0.020 | 5.2 | 5.2 | 0.06 | 0.23 | 98 | 1 | 0 | 0 | 0 | 0 | 0 | 70 | 0 | 0 | 30 | 0 |
| 0.12 | 0.08 | 0.033 | 5.4 | 5.4 | 0.08 | 0.27 | 76 | 22 | 0 | 1 | 0 | 0 | 0 | 69 | 1 | 0 | 30 | 0 |
| 0.14 | 0.10 | 0.048 | 5.5 | 5.6 | 0.09 | 0.32 | 52 | 44 | 0 | 2 | 2 | 0 | 0 | 67 | 3 | 0 | 29 | 1 |
| 0.16 | 0.11 | 0.067 | 5.7 | 5.7 | 0.10 | 0.36 | 23 | 71 | 0 | 1 | 4 | 0 | 0 | 66 | 4 | 0 | 28 | 2 |
| 0.18 | 0.13 | 0.089 | 5.9 | 5.9 | 0.12 | 0.41 | 12 | 80 | 0 | 1 | 7 | 0 | 0 | 64 | 6 | 0 | 28 | 2 |
| 0.20 | 0.15 | 0.11 | 6.0 | 6.1 | 0.13 | 0.45 | 12 | 77 | 0 | 1 | 9 | 0 | 0 | 63 | 7 | 0 | 27 | 3 |
| 0.22 | 0.16 | 0.14 | 6.2 | 6.2 | 0.14 | 0.49 | 10 | 78 | 0 | 1 | 8 | 2 | 0 | 62 | 8 | 0 | 27 | 3 |
| 0.24 | 0.18 | 0.18 | 6.4 | 6.4 | 0.16 | 0.53 | 12 | 75 | 0 | 2 | 6 | 5 | 0 | 60 | 9 | 1 | 26 | 4 |
| 0.26 | 0.19 | 0.22 | 6.5 | 6.6 | 0.17 | 0.57 | 10 | 75 | 0 | 2 | 4 | 10 | 0 | 59 | 9 | 1 | 25 | 5 |
| 0.28 | 0.19 | 0.24 | 7.4 | 7.4 | 0.17 | 0.59 | 17 | 67 | 0 | 3 | 2 | 11 | 0 | 59 | 10 | 2 | 25 | 5 |
| 0.30 | 0.20 | 0.29 | 7.6 | 7.7 | 0.19 | 0.63 | 15 | 65 | 0 | 4 | 2 | 13 | 0 | 56 | 11 | 2 | 24 | 6 |
| 0.32 | 0.22 | 0.35 | 7.8 | 7.9 | 0.21 | 0.68 | 15 | 61 | 0 | 5 | 2 | 12 | 4 | 54 | 13 | 3 | 23 | 7 |
| 0.34 | 0.23 | 0.42 | 8.0 | 8.1 | 0.23 | 0.73 | 14 | 58 | 0 | 5 | 3 | 11 | 9 | 51 | 16 | 3 | 22 | 8 |
| 0.36 | 0.24 | 0.50 | 8.3 | 8.4 | 0.25 | 0.79 | 14 | 53 | 0 | 7 | 3 | 6 | 17 | 47 | 19 | 4 | 20 | 10 |
| 0.38 | 0.26 | 0.59 | 8.4 | 8.5 | 0.27 | 0.85 | 9 | 53 | 0 | 6 | 6 | 4 | 23 | 43 | 22 | 5 | 18 | 12 |
| 0.40 | 0.28 | 0.71 | 8.5 | 8.6 | 0.30 | 0.93 | 6 | 49 | 0 | 5 | 8 | 4 | 28 | 39 | 25 | 6 | 17 | 13 |
| 0.42 | 0.29 | 0.85 | 8.6 | 8.7 | 0.34 | 1.00 | 4 | 46 | 0 | 4 | 10 | 5 | 32 | 35 | 27 | 8 | 15 | 15 |
| 0.44 | 0.31 | 1.0 | 8.6 | 8.8 | 0.38 | 1.08 | 3 | 40 | 0 | 4 | 11 | 5 | 37 | 30 | 28 | 12 | 13 | 17 |
| 0.46 | 0.33 | 1.2 | 8.7 | 8.9 | 0.43 | 1.19 | 2 | 34 | 0 | 3 | 11 | 7 | 42 | 25 | 28 | 17 | 11 | 19 |
| 0.48 | 0.35 | 1.4 | 8.7 | 8.9 | 0.45 | 1.20 | 1 | 33 | 0 | 2 | 8 | 10 | 45 | 24 | 28 | 18 | 10 | 20 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.50 | 0.37 | 1.5 | 8.8 | 9.0 | 0.46 | 1.24 | 1 | 30 | 1 | 3 | 7 | 12 | 46 | 23 | 27 | 20 | 10 | 20 |
| 0.52 | 0.38 | 1.6 | 8.9 | 9.1 | 0.48 | 1.25 | 1 | 26 | 5 | 2 | 5 | 13 | 48 | 22 | 27 | 21 | 9 | 21 |
| 0.54 | 0.40 | 1.8 | 9.0 | 9.2 | 0.49 | 1.27 | 1 | 20 | 9 | 2 | 4 | 13 | 50 | 21 | 26 | 23 | 9 | 21 |
| 0.56 | 0.42 | 1.9 | 9.0 | 9.3 | 0.51 | 1.30 | 1 | 14 | 13 | 3 | 3 | 13 | 52 | 20 | 25 | 25 | 9 | 21 |
| 0.58 | 0.43 | 2.0 | 9.1 | 9.4 | 0.52 | 1.33 | 1 | 11 | 15 | 3 | 3 | 12 | 55 | 19 | 24 | 26 | 8 | 22 |
| 0.60 | 0.45 | 2.2 | 9.2 | 9.5 | 0.53 | 1.34 | 1 | 11 | 15 | 3 | 3 | 8 | 60 | 19 | 24 | 27 | 8 | 22 |
| 0.62 | 0.46 | 2.4 | 9.3 | 9.6 | 0.55 | 1.36 | 1 | 10 | 15 | 4 | 3 | 5 | 62 | 18 | 23 | 29 | 8 | 22 |
| 0.64 | 0.47 | 2.5 | 9.5 | 9.7 | 0.56 | 1.38 | 1 | 9 | 15 | 4 | 2 | 5 | 63 | 18 | 23 | 30 | 8 | 22 |
| 0.66 | 0.49 | 2.7 | 9.6 | 9.9 | 0.57 | 1.39 | 1 | 9 | 15 | 3 | 3 | 4 | 65 | 17 | 22 | 30 | 7 | 23 |
| 0.68 | 0.50 | 2.9 | 9.8 | 10.0 | 0.58 | 1.40 | 1 | 8 | 14 | 4 | 3 | 3 | 66 | 17 | 22 | 32 | 7 | 23 |
| 0.70 | 0.51 | 3.0 | 9.9 | 10.2 | 0.60 | 1.43 | 1 | 7 | 14 | 5 | 4 | 2 | 66 | 16 | 21 | 33 | 7 | 23 |
| 0.72 | 0.53 | 3.2 | 10.0 | 10.3 | 0.61 | 1.45 | 2 | 7 | 14 | 6 | 4 | 2 | 66 | 16 | 21 | 34 | 7 | 23 |
| 0.74 | 0.54 | 3.4 | 10.1 | 10.4 | 0.62 | 1.47 | 1 | 7 | 14 | 5 | 4 | 3 | 67 | 15 | 20 | 35 | 6 | 24 |
| 0.76 | 0.56 | 3.6 | 10.2 | 10.5 | 0.64 | 1.48 | 1 | 6 | 14 | 4 | 5 | 3 | 68 | 15 | 20 | 35 | 6 | 24 |
| 0.78 | 0.57 | 3.8 | 10.3 | 10.6 | 0.65 | 1.51 | 1 | 5 | 14 | 5 | 5 | 3 | 68 | 14 | 19 | 37 | 6 | 24 |
| 0.80 | 0.59 | 4.0 | 10.4 | 10.7 | 0.66 | 1.51 | 1 | 5 | 14 | 3 | 5 | 4 | 68 | 14 | 19 | 37 | 6 | 24 |
| 0.82 | 0.60 | 4.2 | 10.5 | 10.8 | 0.67 | 1.54 | 1 | 4 | 14 | 4 | 5 | 3 | 69 | 13 | 18 | 38 | 6 | 24 |
| 0.84 | 0.61 | 4.5 | 10.6 | 11.0 | 0.69 | 1.58 | 1 | 4 | 14 | 4 | 5 | 4 | 69 | 13 | 18 | 39 | 6 | 24 |
| 0.86 | 0.63 | 4.7 | 10.7 | 11.1 | 0.70 | 1.59 | 1 | 3 | 14 | 4 | 5 | 4 | 69 | 13 | 17 | 40 | 5 | 25 |
| 0.88 | 0.64 | 4.9 | 10.8 | 11.2 | 0.71 | 1.59 | 1 | 3 | 14 | 3 | 5 | 4 | 71 | 12 | 17 | 40 | 5 | 25 |
| 0.90 | 0.66 | 5.2 | 10.9 | 11.3 | 0.73 | 1.62 | 1 | 3 | 13 | 4 | 4 | 5 | 71 | 12 | 17 | 42 | 5 | 25 |
| 0.92 | 0.67 | 5.5 | 10.9 | 11.4 | 0.74 | 1.63 | 1 | 3 | 13 | 3 | 4 | 5 | 71 | 12 | 16 | 42 | 5 | 25 |
| 0.94 | 0.69 | 5.7 | 11.0 | 11.5 | 0.75 | 1.68 | 1 | 3 | 13 | 3 | 4 | 5 | 72 | 11 | 16 | 43 | 5 | 25 |
| 0.96 | 0.70 | 6.0 | 11.1 | 11.5 | 0.77 | 1.68 | 0 | 3 | 12 | 2 | 4 | 4 | 74 | 11 | 16 | 43 | 5 | 25 |
| 0.98 | 0.72 | 6.3 | 11.2 | 11.6 | 0.78 | 1.69 | 0 | 3 | 12 | 2 | 4 | 4 | 75 | 11 | 15 | 44 | 5 | 25 |
| 1.00 | 0.73 | 6.6 | 11.3 | 11.7 | 0.79 | 1.72 | 0 | 3 | 12 | 3 | 4 | 4 | 75 | 10 | 15 | 45 | 4 | 26 |
| 1.02 | 0.75 | 6.9 | 11.3 | 11.8 | 0.81 | 1.72 | 0 | 3 | 12 | 2 | 4 | 4 | 76 | 10 | 15 | 45 | 4 | 26 |
| 1.04 | 0.76 | 7.2 | 11.4 | 11.9 | 0.82 | 1.78 | 0 | 3 | 11 | 2 | 4 | 4 | 76 | 10 | 14 | 46 | 4 | 26 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 1.06 | 0.78 | 7.5 | 11.5 | 12.0 | 0.84 | 1.78 | 0 | 2 | 11 | 2 | 3 | 3 | 78 | 10 | 14 | 46 | 4 | 26 |
| 1.08 | 0.79 | 7.8 | 11.6 | 12.1 | 0.85 | 1.80 | 0 | 2 | 11 | 2 | 3 | 3 | 78 | 9 | 14 | 47 | 4 | 26 |
| 1.10 | 0.81 | 8.1 | 11.7 | 12.2 | 0.86 | 1.82 | 0 | 2 | 10 | 2 | 3 | 3 | 79 | 9 | 13 | 48 | 4 | 26 |
| 1.12 | 0.82 | 8.4 | 11.7 | 12.3 | 0.88 | 1.83 | 0 | 2 | 10 | 2 | 4 | 3 | 79 | 9 | 13 | 48 | 4 | 26 |
| 1.14 | 0.84 | 8.8 | 11.8 | 12.3 | 0.89 | 1.86 | 0 | 2 | 10 | 1 | 3 | 3 | 80 | 9 | 13 | 49 | 4 | 26 |
| 1.16 | 0.86 | 9.2 | 11.8 | 12.4 | 0.91 | 1.91 | 0 | 2 | 10 | 2 | 3 | 3 | 80 | 8 | 12 | 49 | 4 | 26 |
| 1.18 | 0.87 | 9.5 | 11.8 | 12.4 | 0.92 | 1.92 | 0 | 2 | 10 | 1 | 3 | 3 | 82 | 8 | 12 | 50 | 3 | 27 |
| 1.20 | 0.89 | 9.9 | 11.9 | 12.5 | 0.94 | 1.96 | 0 | 2 | 9 | 2 | 3 | 3 | 81 | 8 | 12 | 51 | 3 | 27 |
| 1.22 | 0.90 | 10.3 | 12.0 | 12.6 | 0.95 | 1.96 | 0 | 2 | 9 | 1 | 3 | 3 | 82 | 8 | 12 | 51 | 3 | 27 |
| 1.24 | 0.92 | 10.7 | 12.0 | 12.7 | 0.96 | 2.00 | 0 | 1 | 9 | 2 | 2 | 3 | 82 | 7 | 11 | 51 | 3 | 27 |
| 1.26 | 0.93 | 11.1 | 12.1 | 12.8 | 0.98 | 2.02 | 0 | 1 | 9 | 2 | 2 | 3 | 83 | 7 | 11 | 52 | 3 | 27 |
| 1.28 | 0.95 | 11.5 | 12.2 | 12.8 | 0.99 | 2.07 | 0 | 1 | 8 | 3 | 2 | 3 | 83 | 7 | 11 | 52 | 3 | 27 |
| 1.30 | 0.96 | 11.9 | 12.3 | 12.9 | 1.01 | 2.08 | 0 | 1 | 8 | 2 | 2 | 2 | 84 | 7 | 11 | 53 | 3 | 27 |
| 1.32 | 0.98 | 12.3 | 12.3 | 13.0 | 1.02 | 2.11 | 0 | 1 | 8 | 2 | 2 | 2 | 85 | 7 | 10 | 53 | 3 | 27 |
| 1.34 | 0.99 | 12.7 | 12.4 | 13.1 | 1.04 | 2.15 | 0 | 1 | 8 | 3 | 2 | 2 | 84 | 6 | 10 | 54 | 3 | 27 |
| 1.36 | 1.00 | 13.2 | 12.5 | 13.2 | 1.05 | 2.18 | 0 | 1 | 8 | 3 | 3 | 1 | 84 | 6 | 10 | 54 | 3 | 27 |
| 1.38 | 1.02 | 13.6 | 12.6 | 13.3 | 1.06 | 2.20 | 0 | 1 | 7 | 3 | 3 | 1 | 84 | 6 | 10 | 54 | 3 | 27 |
| 1.40 | 1.03 | 14.1 | 12.6 | 13.4 | 1.08 | 2.22 | 0 | 1 | 7 | 3 | 3 | 2 | 84 | 6 | 9 | 55 | 3 | 27 |
| 1.42 | 1.05 | 14.5 | 12.7 | 13.4 | 1.09 | 2.21 | 0 | 1 | 7 | 2 | 3 | 2 | 85 | 6 | 9 | 55 | 2 | 28 |
| 1.44 | 1.06 | 15.0 | 12.8 | 13.5 | 1.11 | 2.25 | 0 | 1 | 7 | 3 | 3 | 2 | 84 | 6 | 9 | 55 | 2 | 28 |
| 1.46 | 1.07 | 15.5 | 12.9 | 13.6 | 1.12 | 2.26 | 0 | 1 | 7 | 2 | 3 | 2 | 85 | 6 | 9 | 55 | 2 | 28 |
| 1.48 | 1.09 | 16.0 | 12.9 | 13.7 | 1.14 | 2.32 | 0 | 1 | 7 | 3 | 3 | 2 | 85 | 5 | 9 | 56 | 2 | 28 |
| 1.50 | 1.10 | 16.5 | 13.0 | 13.8 | 1.15 | 2.31 | 0 | 1 | 7 | 2 | 3 | 3 | 85 | 5 | 9 | 56 | 2 | 28 |
| 1.52 | 1.12 | 17.0 | 13.1 | 13.9 | 1.17 | 2.35 | 0 | 1 | 6 | 2 | 3 | 3 | 85 | 5 | 8 | 56 | 2 | 28 |
| 1.54 | 1.13 | 17.5 | 13.2 | 13.9 | 1.18 | 2.41 | 0 | 1 | 6 | 3 | 3 | 3 | 85 | 5 | 8 | 57 | 2 | 28 |
| 1.56 | 1.14 | 18.1 | 13.2 | 14.0 | 1.20 | 2.41 | 0 | 1 | 6 | 2 | 3 | 3 | 86 | 5 | 8 | 57 | 2 | 28 |
| 1.58 | 1.16 | 18.6 | 13.3 | 14.1 | 1.21 | 2.45 | 0 | 1 | 6 | 2 | 3 | 3 | 86 | 5 | 8 | 57 | 2 | 28 |
| 1.60 | 1.17 | 19.2 | 13.4 | 14.2 | 1.23 | 2.48 | 0 | 1 | 6 | 2 | 3 | 3 | 86 | 5 | 8 | 58 | 2 | 28 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 1.62 | 1.18 | 19.8 | 13.5 | 14.3 | 1.24 | 2.54 | 0 | 1 | 6 | 3 | 3 | 3 | 86 | 5 | 7 | 58 | 2 | 28 |
| 1.64 | 1.20 | 20.4 | 13.5 | 14.4 | 1.26 | 2.57 | 0 | 1 | 6 | 3 | 3 | 3 | 86 | 4 | 7 | 58 | 2 | 28 |
| 1.66 | 1.21 | 21.0 | 13.6 | 14.5 | 1.28 | 2.58 | 0 | 1 | 5 | 3 | 3 | 3 | 86 | 4 | 7 | 58 | 2 | 28 |
| 1.68 | 1.22 | 21.6 | 13.7 | 14.5 | 1.29 | 2.60 | 0 | 1 | 5 | 2 | 2 | 3 | 87 | 4 | 7 | 59 | 2 | 28 |
| 1.70 | 1.24 | 22.2 | 13.8 | 14.6 | 1.31 | 2.66 | 0 | 1 | 5 | 2 | 2 | 2 | 87 | 4 | 7 | 59 | 2 | 28 |
| 1.72 | 1.25 | 22.9 | 13.8 | 14.7 | 1.32 | 2.68 | 0 | 1 | 5 | 2 | 2 | 2 | 88 | 4 | 7 | 59 | 2 | 28 |
| 1.74 | 1.26 | 23.5 | 13.9 | 14.8 | 1.34 | 2.70 | 0 | 1 | 5 | 2 | 2 | 2 | 88 | 4 | 7 | 59 | 2 | 28 |
| 1.76 | 1.19 | 23.1 | 15.0 | 15.9 | 1.30 | 2.62 | 0 | 1 | 5 | 7 | 3 | 2 | 81 | 4 | 7 | 59 | 2 | 28 |
| 1.78 | 1.16 | 23.3 | 15.7 | 16.6 | 1.28 | 2.58 | 1 | 1 | 5 | 9 | 4 | 2 | 78 | 4 | 7 | 58 | 2 | 28 |
| 1.80 | 1.17 | 23.9 | 15.8 | 16.8 | 1.30 | 2.64 | 1 | 1 | 5 | 11 | 4 | 2 | 77 | 4 | 7 | 59 | 2 | 28 |
| 1.82 | 1.17 | 24.6 | 16.0 | 17.0 | 1.31 | 2.67 | 1 | 1 | 5 | 11 | 4 | 2 | 77 | 4 | 7 | 59 | 2 | 28 |
| 1.84 | 1.18 | 25.3 | 16.2 | 17.2 | 1.32 | 2.67 | 1 | 1 | 5 | 10 | 4 | 2 | 78 | 4 | 7 | 59 | 2 | 28 |
| 1.86 | 1.19 | 25.9 | 16.3 | 17.4 | 1.34 | 2.74 | 1 | 1 | 4 | 11 | 5 | 2 | 76 | 4 | 7 | 59 | 2 | 28 |
| 1.88 | 1.20 | 26.6 | 16.5 | 17.6 | 1.35 | 2.75 | 1 | 1 | 4 | 8 | 7 | 4 | 75 | 4 | 7 | 59 | 2 | 28 |
| 1.90 | 1.20 | 27.4 | 16.7 | 17.7 | 1.36 | 2.73 | 0 | 1 | 4 | 4 | 8 | 6 | 76 | 4 | 7 | 59 | 2 | 28 |
| 1.92 | 1.21 | 28.1 | 16.9 | 17.9 | 1.38 | 2.79 | 0 | 1 | 4 | 5 | 8 | 6 | 76 | 4 | 6 | 60 | 2 | 28 |
| 1.94 | 1.22 | 28.9 | 17.0 | 18.1 | 1.39 | 2.80 | 0 | 1 | 4 | 4 | 8 | 7 | 75 | 4 | 6 | 60 | 2 | 28 |
| 1.96 | 1.23 | 29.6 | 17.2 | 18.3 | 1.40 | 2.87 | 0 | 1 | 4 | 5 | 8 | 7 | 75 | 4 | 6 | 60 | 2 | 28 |
| 1.98 | 1.23 | 30.4 | 17.4 | 18.5 | 1.42 | 2.89 | 0 | 1 | 4 | 5 | 7 | 6 | 76 | 4 | 6 | 60 | 2 | 28 |
| 2.00 | 1.24 | 31.2 | 17.6 | 18.7 | 1.43 | 2.94 | 0 | 1 | 4 | 5 | 8 | 7 | 74 | 4 | 6 | 60 | 2 | 28 |
| 2.02 | 1.25 | 32.1 | 17.7 | 18.9 | 1.45 | 2.95 | 0 | 1 | 4 | 5 | 8 | 8 | 75 | 4 | 6 | 61 | 2 | 28 |
| 2.04 | 1.26 | 32.9 | 17.9 | 19.1 | 1.46 | 2.95 | 0 | 1 | 4 | 3 | 5 | 6 | 81 | 4 | 6 | 61 | 2 | 28 |
| 2.06 | 1.27 | 33.9 | 18.0 | 19.2 | 1.48 | 3.00 | 0 | 1 | 4 | 4 | 4 | 5 | 82 | 3 | 6 | 61 | 1 | 29 |
| 2.08 | 1.28 | 34.8 | 18.2 | 19.4 | 1.50 | 3.03 | 0 | 1 | 4 | 3 | 4 | 5 | 82 | 3 | 6 | 61 | 1 | 29 |
| 2.10 | 1.29 | 35.8 | 18.3 | 19.5 | 1.52 | 3.10 | 0 | 1 | 4 | 5 | 4 | 4 | 82 | 3 | 5 | 61 | 1 | 29 |
| 2.12 | 1.30 | 36.8 | 18.4 | 19.7 | 1.54 | 3.12 | 0 | 1 | 4 | 3 | 4 | 5 | 83 | 3 | 5 | 61 | 1 | 29 |
| 2.14 | 1.31 | 37.9 | 18.5 | 19.8 | 1.56 | 3.18 | 0 | 1 | 3 | 3 | 4 | 5 | 83 | 3 | 5 | 62 | 1 | 29 |
| 2.16 | 1.33 | 39.0 | 18.6 | 19.9 | 1.58 | 3.20 | 0 | 1 | 3 | 3 | 4 | 5 | 84 | 3 | 5 | 62 | 1 | 29 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 2.18 | 1.34 | 40.0 | 18.7 | 20.1 | 1.60 | 3.24 | 0 | 1 | 3 | 3 | 3 | 4 | 85 | 3 | 5 | 62 | 1 | 29 |
| 2.20 | 1.35 | 41.1 | 18.9 | 20.3 | 1.62 | 3.27 | 0 | 1 | 3 | 3 | 3 | 4 | 86 | 3 | 5 | 62 | 1 | 29 |
| 2.22 | 1.35 | 42.1 | 19.1 | 20.5 | 1.63 | 3.32 | 0 | 1 | 3 | 4 | 4 | 4 | 84 | 3 | 5 | 62 | 1 | 29 |
| 2.24 | 1.36 | 43.2 | 19.3 | 20.7 | 1.65 | 3.30 | 0 | 1 | 3 | 3 | 4 | 4 | 85 | 3 | 5 | 62 | 1 | 29 |
| 2.26 | 1.36 | 44.3 | 19.5 | 20.9 | 1.67 | 3.34 | 0 | 1 | 3 | 3 | 3 | 3 | 86 | 3 | 5 | 62 | 1 | 29 |
| 2.28 | 1.37 | 45.4 | 19.7 | 21.2 | 1.68 | 3.42 | 0 | 1 | 3 | 4 | 3 | 3 | 85 | 3 | 5 | 62 | 1 | 29 |
| 2.30 | 1.38 | 46.6 | 19.9 | 21.4 | 1.70 | 3.44 | 0 | 1 | 3 | 4 | 3 | 3 | 85 | 3 | 5 | 62 | 1 | 29 |
| 2.32 | 1.38 | 47.7 | 20.1 | 21.7 | 1.72 | 3.47 | 0 | 1 | 3 | 4 | 3 | 3 | 86 | 3 | 4 | 63 | 1 | 29 |
| 2.34 | 1.38 | 48.8 | 20.4 | 21.9 | 1.73 | 3.54 | 0 | 1 | 3 | 5 | 4 | 3 | 84 | 3 | 4 | 63 | 1 | 29 |
| 2.36 | 1.36 | 49.5 | 21.0 | 22.6 | 1.73 | 3.54 | 0 | 1 | 3 | 6 | 5 | 3 | 82 | 3 | 4 | 63 | 1 | 29 |
| 2.38 | 1.35 | 50.3 | 21.5 | 23.2 | 1.73 | 3.55 | 0 | 1 | 3 | 7 | 6 | 3 | 80 | 3 | 4 | 63 | 1 | 29 |
| 2.40 | 1.33 | 51.1 | 22.1 | 23.8 | 1.73 | 3.49 | 0 | 1 | 3 | 7 | 5 | 3 | 81 | 3 | 4 | 63 | 1 | 29 |
| 2.42 | 1.31 | 51.8 | 22.8 | 24.5 | 1.73 | 3.47 | 0 | 1 | 3 | 8 | 6 | 3 | 79 | 3 | 4 | 63 | 1 | 29 |
| 2.44 | 1.29 | 52.5 | 23.6 | 25.3 | 1.73 | 3.54 | 0 | 1 | 3 | 10 | 8 | 3 | 75 | 3 | 4 | 63 | 1 | 29 |
| 2.46 | 1.27 | 53.3 | 24.3 | 26.1 | 1.73 | 3.52 | 0 | 1 | 3 | 10 | 8 | 3 | 74 | 3 | 4 | 63 | 1 | 29 |
| 2.48 | 1.27 | 54.6 | 24.7 | 26.5 | 1.74 | 3.53 | 0 | 1 | 3 | 10 | 8 | 4 | 74 | 3 | 4 | 63 | 1 | 29 |
| 2.50 | 1.27 | 56.1 | 25.1 | 26.8 | 1.76 | 3.54 | 0 | 1 | 3 | 11 | 8 | 3 | 74 | 3 | 4 | 63 | 1 | 29 |
| 2.52 | 1.27 | 57.0 | 25.4 | 27.2 | 1.76 | 3.54 | 0 | 1 | 3 | 10 | 9 | 5 | 72 | 3 | 4 | 63 | 1 | 29 |
| 2.54 | 1.27 | 57.9 | 25.8 | 27.6 | 1.76 | 3.53 | 0 | 1 | 3 | 10 | 8 | 5 | 73 | 3 | 4 | 63 | 1 | 29 |
| 2.56 | 1.28 | 59.2 | 26.0 | 27.9 | 1.77 | 3.56 | 0 | 1 | 3 | 8 | 8 | 7 | 74 | 3 | 4 | 63 | 1 | 29 |
| 2.58 | 1.30 | 60.6 | 26.1 | 27.9 | 1.79 | 3.61 | 0 | 1 | 3 | 7 | 7 | 7 | 75 | 3 | 4 | 63 | 1 | 29 |
| 2.60 | 1.32 | 62.1 | 26.1 | 28.0 | 1.80 | 3.65 | 0 | 1 | 3 | 6 | 6 | 8 | 77 | 3 | 4 | 63 | 1 | 29 |
| 2.62 | 1.34 | 63.6 | 26.2 | 28.1 | 1.82 | 3.68 | 0 | 1 | 3 | 4 | 5 | 9 | 77 | 3 | 4 | 63 | 1 | 29 |
| 2.64 | 1.35 | 65.1 | 26.2 | 28.1 | 1.83 | 3.69 | 0 | 1 | 3 | 3 | 5 | 9 | 79 | 3 | 4 | 63 | 1 | 29 |
| 2.66 | 1.37 | 66.6 | 26.3 | 28.2 | 1.85 | 3.72 | 0 | 1 | 3 | 2 | 4 | 10 | 80 | 3 | 4 | 63 | 1 | 29 |
| 2.68 | 1.39 | 68.1 | 26.3 | 28.2 | 1.87 | 3.77 | 0 | 1 | 3 | 2 | 3 | 11 | 80 | 3 | 4 | 63 | 1 | 29 |
| 2.70 | 1.40 | 69.6 | 26.4 | 28.3 | 1.88 | 3.77 | 0 | 1 | 3 | 1 | 3 | 10 | 82 | 3 | 4 | 63 | 1 | 29 |
| 2.72 | 1.42 | 71.2 | 26.4 | 28.4 | 1.90 | 3.81 | 0 | 1 | 3 | 1 | 2 | 10 | 83 | 3 | 4 | 63 | 1 | 29 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 2.74 | 1.44 | 72.8 | 26.5 | 28.4 | 1.91 | 3.84 | 0 | 1 | 3 | 0 | 1 | 9 | 85 | 3 | 4 | 63 | 1 | 29 |
| 2.76 | 1.46 | 74.4 | 26.5 | 28.5 | 1.92 | 3.88 | 0 | 1 | 3 | 0 | 1 | 8 | 87 | 3 | 4 | 64 | 1 | 29 |
| 2.78 | 1.47 | 76.0 | 26.6 | 28.6 | 1.94 | 3.91 | 0 | 1 | 3 | 0 | 1 | 8 | 87 | 3 | 4 | 64 | 1 | 29 |
| 2.80 | 1.49 | 77.6 | 26.6 | 28.6 | 1.95 | 3.94 | 0 | 1 | 3 | 0 | 1 | 6 | 89 | 3 | 4 | 64 | 1 | 29 |
| 2.82 | 1.51 | 79.2 | 26.7 | 28.7 | 1.97 | 3.97 | 0 | 1 | 3 | 0 | 0 | 5 | 91 | 3 | 4 | 64 | 1 | 29 |
| 2.84 | 1.52 | 80.6 | 26.8 | 28.9 | 1.98 | 4.05 | 0 | 1 | 3 | 1 | 1 | 5 | 90 | 3 | 4 | 64 | 1 | 29 |
| 2.86 | 1.52 | 81.9 | 27.1 | 29.1 | 1.98 | 4.02 | 0 | 1 | 3 | 1 | 1 | 4 | 91 | 3 | 4 | 64 | 1 | 29 |
| 2.88 | 1.53 | 83.1 | 27.4 | 29.4 | 1.99 | 4.03 | 0 | 1 | 3 | 1 | 1 | 3 | 91 | 3 | 4 | 64 | 1 | 29 |
| 2.90 | 1.53 | 84.415 | 27.66 | 29.72 | 1.99 | 4.06 | 0 | 1 | 3 | 2 | 2 | 2 | 90 | 3 | 4 | 64 | 1 | 29 |
| 2.92 | 1.54 | 85.717 | 27.94 | 30.01 | 2.00 | 4.07 | 0 | 1 | 3 | 2 | 2 | 1 | 90 | 2 | 4 | 64 | 1 | 29 |
| 2.94 | 1.54 | 87.038 | 28.22 | 30.29 | 2.00 | 4.01 | 0 | 1 | 3 | 2 | 2 | 1 | 90 | 3 | 4 | 64 | 1 | 29 |
| 2.96 | 1.55 | 88.379 | 28.50 | 30.58 | 2.01 | 4.03 | 0 | 0 | 3 | 3 | 3 | 1 | 90 | 3 | 4 | 64 | 1 | 29 |
| 2.98 | 1.55 | 89.740 | 28.78 | 30.87 | 2.01 | 4.06 | 0 | 0 | 3 | 3 | 3 | 1 | 89 | 3 | 4 | 64 | 1 | 29 |
| 3.00 | 1.56 | 91.121 | 29.06 | 31.16 | 2.01 | 4.08 | 0 | 0 | 3 | 4 | 4 | 1 | 88 | 3 | 4 | 64 | 1 | 29 |
| **Goukou River : H9GOUK-EWR2** | | | | | | | | | | | | | | | | | | |
| 0.02 | 0.01 | 0.001 | 0.8 | 0.8 | 0.06 | 0.21 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 | 20 | 0 |
| 0.04 | 0.02 | 0.004 | 1.2 | 1.3 | 0.12 | 0.38 | 94 | 0 | 0 | 6 | 0 | 0 | 0 | 76 | 4 | 0 | 19 | 1 |
| 0.06 | 0.04 | 0.010 | 1.5 | 1.5 | 0.17 | 0.54 | 86 | 0 | 0 | 14 | 0 | 0 | 0 | 69 | 10 | 1 | 17 | 3 |
| 0.08 | 0.05 | 0.019 | 1.9 | 1.9 | 0.21 | 0.64 | 77 | 0 | 0 | 23 | 0 | 0 | 0 | 62 | 16 | 3 | 15 | 5 |
| 0.10 | 0.05 | 0.031 | 3.1 | 3.1 | 0.21 | 0.66 | 75 | 0 | 0 | 24 | 0 | 0 | 0 | 60 | 17 | 3 | 15 | 5 |
| 0.12 | 0.06 | 0.06 | 3.2 | 3.2 | 0.28 | 0.84 | 43 | 16 | 0 | 30 | 11 | 0 | 0 | 47 | 28 | 5 | 12 | 8 |
| 0.14 | 0.08 | 0.09 | 3.4 | 3.5 | 0.34 | 0.98 | 30 | 18 | 0 | 33 | 19 | 0 | 0 | 38 | 32 | 9 | 10 | 10 |
| 0.16 | 0.09 | 0.14 | 3.8 | 3.9 | 0.40 | 1.10 | 25 | 16 | 0 | 36 | 23 | 0 | 0 | 32 | 33 | 15 | 8 | 12 |
| 0.18 | 0.10 | 0.19 | 4.2 | 4.4 | 0.45 | 1.22 | 18 | 16 | 0 | 35 | 31 | 0 | 0 | 27 | 32 | 21 | 7 | 13 |
| 0.20 | 0.11 | 0.27 | 4.6 | 4.7 | 0.52 | 1.38 | 10 | 19 | 0 | 25 | 46 | 1 | 0 | 23 | 27 | 30 | 6 | 14 |
| 0.22 | 0.12 | 0.37 | 5.0 | 5.1 | 0.60 | 1.51 | 8 | 15 | 0 | 27 | 37 | 13 | 0 | 19 | 24 | 37 | 5 | 15 |
| 0.24 | 0.12 | 0.47 | 5.8 | 5.9 | 0.66 | 1.57 | 8 | 12 | 0 | 32 | 30 | 17 | 0 | 17 | 21 | 42 | 4 | 16 |
| 0.26 | 0.14 | 0.65 | 6.0 | 6.1 | 0.78 | 1.77 | 6 | 10 | 0 | 30 | 34 | 21 | 0 | 13 | 17 | 50 | 3 | 17 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3$/s) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.28 | 0.15 | 0.88 | 6.2 | 6.4 | 0.92 | 1.99 | 4 | 8 | 0 | 27 | 29 | 31 | 0 | 10 | 14 | 57 | 2 | 18 |
| 0.30 | 0.17 | 0.90 | 6.4 | 6.6 | 0.84 | 1.90 | 4 | 11 | 0 | 22 | 21 | 40 | 2 | 12 | 16 | 52 | 3 | 17 |
| 0.32 | 0.18 | 0.94 | 6.6 | 6.8 | 0.78 | 1.89 | 4 | 13 | 0 | 20 | 23 | 30 | 10 | 14 | 17 | 49 | 4 | 16 |
| 0.34 | 0.20 | 1.0 | 6.8 | 7.0 | 0.73 | 1.88 | 3 | 16 | 0 | 14 | 26 | 27 | 14 | 16 | 18 | 46 | 4 | 16 |
| 0.36 | 0.21 | 1.1 | 7.0 | 7.2 | 0.76 | 1.89 | 3 | 15 | 0 | 13 | 24 | 26 | 18 | 15 | 17 | 48 | 4 | 16 |
| 0.38 | 0.23 | 1.3 | 7.2 | 7.4 | 0.79 | 1.88 | 2 | 15 | 0 | 11 | 23 | 25 | 24 | 14 | 17 | 50 | 3 | 17 |
| 0.40 | 0.24 | 1.4 | 7.5 | 7.8 | 0.80 | 1.88 | 2 | 14 | 0 | 12 | 20 | 20 | 33 | 13 | 16 | 51 | 3 | 17 |
| 0.42 | 0.25 | 1.6 | 7.8 | 8.1 | 0.82 | 1.89 | 2 | 13 | 0 | 13 | 18 | 19 | 35 | 12 | 16 | 52 | 3 | 17 |
| 0.44 | 0.26 | 1.7 | 8.2 | 8.4 | 0.84 | 1.89 | 2 | 12 | 0 | 13 | 15 | 21 | 36 | 12 | 16 | 53 | 3 | 17 |
| 0.46 | 0.26 | 1.9 | 8.5 | 8.8 | 0.85 | 1.90 | 3 | 12 | 0 | 16 | 10 | 21 | 38 | 11 | 15 | 53 | 3 | 17 |
| 0.48 | 0.27 | 2.1 | 8.9 | 9.2 | 0.86 | 1.89 | 3 | 11 | 0 | 16 | 10 | 19 | 41 | 11 | 15 | 54 | 3 | 17 |
| 0.50 | 0.28 | 2.3 | 9.3 | 9.6 | 0.87 | 1.91 | 3 | 10 | 0 | 17 | 10 | 17 | 43 | 11 | 15 | 55 | 3 | 17 |
| 0.52 | 0.29 | 2.5 | 9.5 | 9.8 | 0.90 | 1.91 | 2 | 9 | 1 | 14 | 11 | 14 | 48 | 10 | 14 | 56 | 3 | 17 |
| 0.54 | 0.31 | 2.8 | 9.6 | 10.0 | 0.92 | 1.93 | 2 | 8 | 2 | 13 | 12 | 11 | 51 | 9 | 14 | 57 | 2 | 18 |
| 0.56 | 0.33 | 3.0 | 9.7 | 10.1 | 0.95 | 1.98 | 1 | 8 | 2 | 10 | 15 | 9 | 56 | 9 | 13 | 58 | 2 | 18 |
| 0.58 | 0.35 | 3.3 | 9.7 | 10.1 | 0.98 | 2.05 | 1 | 7 | 2 | 8 | 16 | 10 | 57 | 8 | 12 | 60 | 2 | 18 |
| 0.60 | 0.36 | 3.6 | 9.8 | 10.2 | 1.01 | 2.10 | 1 | 6 | 2 | 5 | 15 | 11 | 59 | 8 | 12 | 61 | 2 | 18 |
| 0.62 | 0.38 | 3.8 | 10.0 | 10.4 | 1.02 | 2.08 | 0 | 6 | 3 | 4 | 16 | 10 | 61 | 7 | 12 | 61 | 2 | 18 |
| 0.64 | 0.38 | 4.1 | 10.5 | 10.9 | 1.02 | 2.10 | 1 | 5 | 3 | 7 | 13 | 11 | 60 | 7 | 12 | 61 | 2 | 18 |
| 0.66 | 0.38 | 4.3 | 10.9 | 11.3 | 1.02 | 2.11 | 1 | 5 | 3 | 10 | 9 | 13 | 58 | 7 | 12 | 61 | 2 | 18 |
| 0.68 | 0.39 | 4.5 | 11.3 | 11.7 | 1.03 | 2.09 | 1 | 4 | 3 | 11 | 7 | 14 | 59 | 7 | 12 | 61 | 2 | 18 |
| 0.70 | 0.40 | 4.8 | 11.6 | 12.1 | 1.04 | 2.13 | 1 | 4 | 3 | 15 | 4 | 14 | 59 | 7 | 11 | 62 | 2 | 18 |
| 0.72 | 0.40 | 5.1 | 12.0 | 12.5 | 1.04 | 2.12 | 1 | 4 | 4 | 15 | 3 | 13 | 60 | 7 | 11 | 62 | 2 | 18 |
| 0.74 | 0.41 | 5.4 | 12.4 | 12.9 | 1.05 | 2.14 | 1 | 3 | 4 | 15 | 6 | 10 | 60 | 7 | 11 | 62 | 2 | 18 |
| 0.76 | 0.42 | 5.7 | 12.7 | 13.2 | 1.06 | 2.15 | 1 | 3 | 4 | 13 | 8 | 8 | 61 | 7 | 11 | 62 | 2 | 18 |
| 0.78 | 0.43 | 6.0 | 12.9 | 13.5 | 1.07 | 2.18 | 1 | 3 | 4 | 11 | 11 | 6 | 64 | 7 | 11 | 63 | 2 | 18 |
| 0.80 | 0.45 | 6.4 | 13.2 | 13.7 | 1.09 | 2.20 | 1 | 3 | 4 | 11 | 12 | 5 | 64 | 6 | 10 | 63 | 2 | 18 |
| 0.82 | 0.46 | 6.8 | 13.3 | 13.9 | 1.10 | 2.22 | 1 | 3 | 4 | 8 | 13 | 6 | 66 | 6 | 10 | 64 | 2 | 18 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.84 | 0.48 | 7.2 | 13.4 | 14.0 | 1.12 | 2.29 | 1 | 3 | 4 | 8 | 13 | 6 | 66 | 6 | 10 | 64 | 1 | 19 |
| 0.86 | 0.49 | 7.6 | 13.5 | 14.1 | 1.14 | 2.33 | 0 | 3 | 4 | 5 | 13 | 8 | 66 | 6 | 10 | 65 | 1 | 19 |
| 0.88 | 0.51 | 8.1 | 13.6 | 14.2 | 1.16 | 2.35 | 0 | 3 | 4 | 4 | 11 | 11 | 67 | 6 | 9 | 65 | 1 | 19 |
| 0.90 | 0.53 | 8.5 | 13.7 | 14.3 | 1.18 | 2.36 | 0 | 3 | 4 | 3 | 10 | 13 | 67 | 6 | 9 | 65 | 1 | 19 |
| 0.92 | 0.54 | 8.9 | 13.8 | 14.4 | 1.19 | 2.43 | 0 | 3 | 4 | 4 | 8 | 14 | 67 | 5 | 9 | 65 | 1 | 19 |
| 0.94 | 0.56 | 9.4 | 13.9 | 14.5 | 1.21 | 2.45 | 0 | 3 | 4 | 3 | 8 | 12 | 71 | 5 | 9 | 66 | 1 | 19 |
| 0.96 | 0.58 | 9.9 | 14.0 | 14.6 | 1.22 | 2.48 | 0 | 2 | 4 | 2 | 6 | 13 | 72 | 5 | 9 | 66 | 1 | 19 |
| 0.98 | 0.59 | 10.3 | 14.1 | 14.7 | 1.24 | 2.53 | 0 | 2 | 4 | 3 | 4 | 11 | 74 | 5 | 8 | 66 | 1 | 19 |
| 1.00 | 0.61 | 10.8 | 14.2 | 14.8 | 1.25 | 2.52 | 0 | 2 | 4 | 2 | 4 | 10 | 77 | 5 | 9 | 66 | 1 | 19 |
| 1.02 | 0.62 | 11.3 | 14.3 | 14.9 | 1.27 | 2.56 | 0 | 2 | 4 | 2 | 3 | 9 | 80 | 5 | 8 | 67 | 1 | 19 |
| 1.04 | 0.64 | 11.8 | 14.4 | 15.0 | 1.28 | 2.62 | 0 | 2 | 4 | 3 | 3 | 7 | 80 | 5 | 8 | 67 | 1 | 19 |
| 1.06 | 0.63 | 12.0 | 15.0 | 15.7 | 1.26 | 2.58 | 0 | 2 | 4 | 6 | 3 | 5 | 79 | 5 | 8 | 67 | 1 | 19 |
| 1.08 | 0.65 | 12.5 | 15.2 | 15.8 | 1.28 | 2.59 | 0 | 2 | 4 | 6 | 3 | 4 | 81 | 5 | 8 | 67 | 1 | 19 |
| 1.10 | 0.66 | 13.0 | 15.3 | 16.0 | 1.29 | 2.61 | 0 | 2 | 4 | 6 | 3 | 4 | 81 | 5 | 8 | 67 | 1 | 19 |
| 1.12 | 0.68 | 13.5 | 15.4 | 16.1 | 1.30 | 2.65 | 0 | 2 | 4 | 5 | 6 | 2 | 82 | 5 | 8 | 67 | 1 | 19 |
| 1.14 | 0.69 | 14.0 | 15.5 | 16.2 | 1.31 | 2.65 | 0 | 2 | 4 | 4 | 6 | 3 | 82 | 5 | 8 | 67 | 1 | 19 |
| 1.16 | 0.70 | 14.5 | 15.7 | 16.3 | 1.32 | 2.67 | 0 | 2 | 4 | 3 | 5 | 3 | 82 | 5 | 8 | 67 | 1 | 19 |
| 1.18 | 0.72 | 15.1 | 15.8 | 16.5 | 1.33 | 2.70 | 0 | 1 | 4 | 5 | 6 | 2 | 81 | 5 | 8 | 68 | 1 | 19 |
| 1.20 | 0.73 | 15.6 | 15.9 | 16.6 | 1.34 | 2.72 | 0 | 1 | 4 | 4 | 6 | 3 | 81 | 5 | 8 | 68 | 1 | 19 |
| 1.22 | 0.75 | 16.1 | 16.1 | 16.7 | 1.35 | 2.71 | 0 | 1 | 4 | 3 | 5 | 5 | 82 | 5 | 8 | 68 | 1 | 19 |
| 1.24 | 0.76 | 16.7 | 16.2 | 16.9 | 1.35 | 2.75 | 0 | 1 | 4 | 3 | 5 | 5 | 81 | 5 | 7 | 68 | 1 | 19 |
| 1.26 | 0.78 | 17.2 | 16.3 | 17.0 | 1.36 | 2.78 | 0 | 1 | 4 | 3 | 5 | 5 | 81 | 5 | 7 | 68 | 1 | 19 |
| 1.28 | 0.79 | 17.8 | 16.4 | 17.1 | 1.37 | 2.80 | 0 | 1 | 4 | 3 | 4 | 6 | 81 | 4 | 7 | 68 | 1 | 19 |
| 1.30 | 0.81 | 18.3 | 16.5 | 17.2 | 1.38 | 2.83 | 0 | 1 | 4 | 3 | 4 | 6 | 81 | 4 | 7 | 68 | 1 | 19 |
| 1.32 | 0.82 | 18.9 | 16.6 | 17.3 | 1.39 | 2.84 | 0 | 1 | 4 | 3 | 3 | 5 | 83 | 4 | 7 | 68 | 1 | 19 |
| 1.34 | 0.84 | 19.5 | 16.7 | 17.4 | 1.40 | 2.86 | 0 | 1 | 4 | 3 | 3 | 5 | 83 | 4 | 7 | 69 | 1 | 19 |
| 1.36 | 0.85 | 20.1 | 16.8 | 17.5 | 1.41 | 2.85 | 0 | 1 | 4 | 2 | 3 | 5 | 84 | 4 | 7 | 69 | 1 | 19 |
| 1.38 | 0.87 | 20.7 | 16.9 | 17.6 | 1.41 | 2.87 | 0 | 1 | 4 | 2 | 3 | 5 | 85 | 4 | 7 | 69 | 1 | 19 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 1.40 | 0.88 | 21.2 | 17.0 | 17.8 | 1.42 | 2.86 | 0 | 1 | 4 | 2 | 3 | 4 | 85 | 4 | 7 | 69 | 1 | 19 |
| 1.42 | 0.90 | 21.8 | 17.1 | 17.9 | 1.43 | 2.87 | 0 | 1 | 4 | 2 | 2 | 5 | 85 | 4 | 7 | 69 | 1 | 19 |
| 1.44 | 0.91 | 22.4 | 17.2 | 18.0 | 1.43 | 2.88 | 0 | 1 | 4 | 2 | 2 | 4 | 87 | 4 | 7 | 69 | 1 | 19 |
| 1.46 | 0.92 | 23.0 | 17.3 | 18.1 | 1.44 | 2.92 | 0 | 1 | 4 | 3 | 2 | 4 | 86 | 4 | 7 | 69 | 1 | 19 |
| 1.48 | 0.94 | 23.6 | 17.4 | 18.2 | 1.45 | 2.94 | 0 | 1 | 4 | 3 | 2 | 4 | 86 | 4 | 7 | 69 | 1 | 19 |
| 1.50 | 0.95 | 24.2 | 17.5 | 18.3 | 1.45 | 2.97 | 0 | 1 | 4 | 3 | 2 | 4 | 86 | 4 | 7 | 69 | 1 | 19 |
| 1.52 | 0.97 | 24.8 | 17.6 | 18.4 | 1.46 | 2.94 | 0 | 1 | 4 | 2 | 2 | 4 | 87 | 4 | 7 | 69 | 1 | 19 |
| 1.54 | 0.98 | 25.4 | 17.7 | 18.5 | 1.46 | 2.98 | 0 | 1 | 4 | 3 | 2 | 4 | 87 | 4 | 7 | 69 | 1 | 19 |
| 1.56 | 0.98 | 25.7 | 18.1 | 18.9 | 1.45 | 2.92 | 0 | 1 | 4 | 3 | 4 | 2 | 86 | 4 | 7 | 69 | 1 | 19 |
| 1.58 | 0.97 | 26.0 | 18.6 | 19.5 | 1.43 | 2.87 | 0 | 1 | 4 | 4 | 4 | 2 | 85 | 4 | 7 | 69 | 1 | 19 |
| 1.60 | 0.97 | 26.2 | 19.2 | 20.0 | 1.42 | 2.83 | 0 | 1 | 4 | 7 | 3 | 2 | 83 | 4 | 7 | 69 | 1 | 19 |
| 1.62 | 0.96 | 26.6 | 19.6 | 20.5 | 1.41 | 2.85 | 1 | 1 | 4 | 10 | 2 | 3 | 79 | 4 | 7 | 69 | 1 | 19 |
| 1.64 | 0.98 | 27.2 | 19.8 | 20.6 | 1.41 | 2.85 | 1 | 1 | 4 | 9 | 3 | 3 | 80 | 4 | 7 | 69 | 1 | 19 |
| 1.66 | 0.99 | 27.8 | 19.9 | 20.8 | 1.42 | 2.85 | 0 | 1 | 4 | 8 | 4 | 2 | 81 | 4 | 7 | 69 | 1 | 19 |
| 1.68 | 1.00 | 28.5 | 20.0 | 20.9 | 1.42 | 2.85 | 0 | 1 | 4 | 6 | 5 | 3 | 81 | 4 | 7 | 69 | 1 | 19 |
| 1.70 | 1.01 | 29.1 | 20.2 | 21.1 | 1.42 | 2.88 | 0 | 1 | 4 | 5 | 6 | 4 | 80 | 4 | 7 | 69 | 1 | 19 |
| 1.72 | 1.03 | 29.7 | 20.4 | 21.3 | 1.42 | 2.87 | 0 | 1 | 4 | 4 | 7 | 4 | 80 | 4 | 7 | 69 | 1 | 19 |
| 1.74 | 1.04 | 30.3 | 20.5 | 21.4 | 1.42 | 2.89 | 0 | 1 | 4 | 3 | 7 | 5 | 79 | 4 | 7 | 69 | 1 | 19 |
| 1.76 | 1.05 | 30.9 | 20.7 | 21.6 | 1.43 | 2.89 | 0 | 1 | 4 | 3 | 8 | 5 | 79 | 4 | 7 | 69 | 1 | 19 |
| 1.78 | 1.06 | 31.5 | 20.9 | 21.8 | 1.43 | 2.86 | 0 | 1 | 4 | 2 | 8 | 5 | 80 | 4 | 7 | 69 | 1 | 19 |
| 1.80 | 1.07 | 32.2 | 21.1 | 22.0 | 1.43 | 2.87 | 0 | 1 | 4 | 3 | 7 | 5 | 80 | 4 | 7 | 69 | 1 | 19 |
| 1.82 | 1.08 | 32.8 | 21.2 | 22.2 | 1.43 | 2.88 | 0 | 1 | 4 | 3 | 6 | 5 | 81 | 4 | 7 | 69 | 1 | 19 |
| 1.84 | 1.10 | 33.5 | 21.3 | 22.3 | 1.43 | 2.88 | 0 | 1 | 4 | 2 | 5 | 6 | 81 | 4 | 7 | 69 | 1 | 19 |
| 1.86 | 1.11 | 34.1 | 21.4 | 22.4 | 1.43 | 2.88 | 0 | 1 | 4 | 2 | 4 | 6 | 83 | 4 | 7 | 69 | 1 | 19 |
| 1.88 | 1.12 | 34.8 | 21.6 | 22.5 | 1.44 | 2.90 | 0 | 1 | 4 | 2 | 3 | 6 | 84 | 4 | 7 | 69 | 1 | 19 |
| 1.90 | 1.14 | 35.5 | 21.7 | 22.6 | 1.44 | 2.90 | 0 | 1 | 4 | 2 | 3 | 5 | 84 | 4 | 7 | 69 | 1 | 19 |
| 1.92 | 1.15 | 36.2 | 21.8 | 22.7 | 1.44 | 2.91 | 0 | 1 | 4 | 1 | 3 | 6 | 85 | 4 | 7 | 69 | 1 | 19 |
| 1.94 | 1.17 | 36.9 | 21.9 | 22.9 | 1.44 | 2.91 | 0 | 1 | 4 | 1 | 3 | 5 | 85 | 4 | 7 | 69 | 1 | 19 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 1.96 | 1.18 | 37.6 | 22.0 | 23.0 | 1.45 | 2.91 | 0 | 1 | 4 | 1 | 3 | 5 | 86 | 4 | 7 | 69 | 1 | 19 |
| 1.98 | 1.20 | 38.3 | 22.1 | 23.1 | 1.45 | 2.92 | 0 | 1 | 4 | 1 | 3 | 4 | 86 | 4 | 7 | 69 | 1 | 19 |
| 2.00 | 1.21 | 39.0 | 22.2 | 23.2 | 1.45 | 2.91 | 0 | 1 | 4 | 1 | 3 | 4 | 87 | 4 | 7 | 69 | 1 | 19 |
| 2.02 | 1.23 | 39.7 | 22.3 | 23.3 | 1.45 | 2.92 | 0 | 1 | 4 | 1 | 2 | 3 | 88 | 4 | 7 | 69 | 1 | 19 |
| 2.04 | 1.24 | 40.4 | 22.4 | 23.4 | 1.45 | 2.95 | 0 | 1 | 4 | 2 | 3 | 3 | 87 | 4 | 7 | 69 | 1 | 19 |
| 2.06 | 1.25 | 41.1 | 22.5 | 23.5 | 1.46 | 2.94 | 0 | 1 | 4 | 1 | 2 | 3 | 88 | 4 | 7 | 69 | 1 | 19 |
| 2.08 | 1.27 | 41.8 | 22.6 | 23.6 | 1.46 | 2.94 | 0 | 1 | 4 | 1 | 2 | 2 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.10 | 1.29 | 42.5 | 22.7 | 23.7 | 1.46 | 2.94 | 0 | 1 | 4 | 1 | 2 | 2 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.12 | 1.30 | 43.2 | 22.7 | 23.8 | 1.46 | 2.97 | 0 | 1 | 4 | 2 | 2 | 2 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.14 | 1.31 | 43.9 | 22.8 | 23.9 | 1.46 | 2.98 | 0 | 1 | 4 | 2 | 2 | 2 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.16 | 1.33 | 44.6 | 22.9 | 24.0 | 1.46 | 2.95 | 0 | 1 | 4 | 1 | 2 | 3 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.18 | 1.34 | 45.2 | 23.0 | 24.1 | 1.46 | 2.98 | 0 | 1 | 4 | 2 | 2 | 2 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.20 | 1.36 | 45.9 | 23.2 | 24.3 | 1.46 | 2.95 | 0 | 1 | 5 | 1 | 2 | 3 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.22 | 1.37 | 46.5 | 23.3 | 24.4 | 1.46 | 2.97 | 0 | 1 | 4 | 2 | 2 | 3 | 88 | 4 | 7 | 69 | 1 | 19 |
| 2.24 | 1.38 | 47.2 | 23.4 | 24.5 | 1.46 | 2.98 | 0 | 1 | 4 | 2 | 2 | 3 | 88 | 4 | 7 | 69 | 1 | 19 |
| 2.26 | 1.39 | 47.8 | 23.5 | 24.6 | 1.46 | 2.94 | 0 | 0 | 5 | 1 | 2 | 3 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.28 | 1.41 | 48.5 | 23.6 | 24.7 | 1.46 | 2.97 | 0 | 0 | 5 | 2 | 2 | 2 | 88 | 4 | 7 | 69 | 1 | 19 |
| 2.30 | 1.42 | 49.2 | 23.7 | 24.8 | 1.46 | 2.95 | 0 | 0 | 5 | 1 | 2 | 2 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.32 | 1.44 | 49.9 | 23.8 | 24.9 | 1.46 | 2.94 | 0 | 0 | 5 | 1 | 1 | 2 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.34 | 1.45 | 50.5 | 23.9 | 25.0 | 1.46 | 2.94 | 0 | 0 | 5 | 1 | 1 | 2 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.36 | 1.47 | 51.2 | 23.9 | 25.1 | 1.46 | 2.95 | 0 | 0 | 5 | 1 | 2 | 2 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.38 | 1.48 | 51.9 | 24.0 | 25.2 | 1.46 | 2.98 | 0 | 0 | 5 | 2 | 2 | 2 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.40 | 1.50 | 52.6 | 24.1 | 25.3 | 1.46 | 2.97 | 0 | 0 | 5 | 2 | 2 | 2 | 89 | 4 | 7 | 69 | 1 | 19 |
| 2.42 | 1.51 | 53.2 | 24.2 | 25.4 | 1.45 | 2.96 | 0 | 0 | 5 | 1 | 2 | 2 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.44 | 1.53 | 53.9 | 24.3 | 25.5 | 1.45 | 2.95 | 0 | 0 | 5 | 1 | 2 | 2 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.46 | 1.54 | 54.9 | 24.4 | 25.6 | 1.46 | 2.98 | 0 | 0 | 5 | 2 | 2 | 2 | 90 | 4 | 7 | 69 | 1 | 19 |
| 2.48 | 1.56 | 56.0 | 24.4 | 25.7 | 1.47 | 2.96 | 0 | 0 | 5 | 1 | 1 | 2 | 91 | 4 | 7 | 69 | 1 | 19 |
| 2.50 | 1.57 | 57.1 | 24.5 | 25.8 | 1.48 | 3.02 | 0 | 0 | 5 | 2 | 2 | 2 | 89 | 4 | 6 | 70 | 1 | 19 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| **Doring River: J1DORI-EWR7** | | | | | | | | | | | | | | | | | | |
| 0.02 | 0.01 | 0.000 | 0.9 | 0.9 | 0.03 | 0.10 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 75 | 0 | 0 | 25 | 0 |
| 0.04 | 0.03 | 0.002 | 1.1 | 1.1 | 0.05 | 0.19 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 75 | 0 | 0 | 25 | 0 |
| 0.06 | 0.04 | 0.004 | 1.5 | 1.5 | 0.07 | 0.25 | 99 | 0 | 0 | 1 | 0 | 0 | 0 | 74 | 1 | 0 | 25 | 0 |
| 0.08 | 0.05 | 0.009 | 1.6 | 1.7 | 0.10 | 0.35 | 95 | 0 | 0 | 5 | 0 | 0 | 0 | 71 | 4 | 0 | 24 | 1 |
| 0.10 | 0.07 | 0.018 | 1.8 | 1.8 | 0.15 | 0.48 | 87 | 3 | 0 | 10 | 0 | 0 | 0 | 67 | 7 | 0 | 22 | 3 |
| 0.12 | 0.08 | 0.028 | 2.1 | 2.1 | 0.18 | 0.58 | 48 | 36 | 0 | 9 | 7 | 0 | 0 | 63 | 10 | 2 | 21 | 4 |
| 0.14 | 0.08 | 0.044 | 2.4 | 2.5 | 0.21 | 0.69 | 42 | 34 | 0 | 14 | 11 | 0 | 0 | 56 | 15 | 3 | 19 | 6 |
| 0.16 | 0.09 | 0.067 | 2.8 | 2.9 | 0.26 | 0.81 | 31 | 33 | 0 | 17 | 19 | 0 | 0 | 48 | 22 | 5 | 16 | 9 |
| 0.18 | 0.09 | 0.10 | 3.7 | 3.8 | 0.30 | 0.90 | 31 | 24 | 0 | 25 | 20 | 0 | 0 | 42 | 27 | 6 | 14 | 11 |
| 0.20 | 0.10 | 0.16 | 4.2 | 4.3 | 0.41 | 1.14 | 22 | 16 | 0 | 36 | 24 | 2 | 0 | 29 | 30 | 16 | 10 | 15 |
| 0.22 | 0.11 | 0.25 | 4.6 | 4.7 | 0.51 | 1.29 | 16 | 13 | 0 | 40 | 18 | 14 | 0 | 21 | 27 | 27 | 7 | 18 |
| 0.24 | 0.12 | 0.33 | 4.7 | 4.9 | 0.56 | 1.31 | 12 | 12 | 0 | 37 | 22 | 17 | 0 | 18 | 25 | 32 | 6 | 19 |
| 0.26 | 0.14 | 0.41 | 4.8 | 5.0 | 0.61 | 1.35 | 8 | 12 | 0 | 32 | 24 | 23 | 0 | 16 | 23 | 37 | 5 | 20 |
| 0.28 | 0.16 | 0.51 | 5.0 | 5.1 | 0.66 | 1.38 | 4 | 14 | 0 | 20 | 35 | 27 | 0 | 14 | 21 | 40 | 5 | 20 |
| 0.30 | 0.17 | 0.61 | 5.1 | 5.3 | 0.70 | 1.44 | 3 | 13 | 0 | 14 | 41 | 27 | 2 | 12 | 20 | 44 | 4 | 21 |
| 0.32 | 0.19 | 0.72 | 5.2 | 5.4 | 0.74 | 1.49 | 2 | 12 | 0 | 11 | 41 | 19 | 15 | 11 | 18 | 46 | 4 | 21 |
| 0.34 | 0.20 | 0.84 | 5.4 | 5.6 | 0.77 | 1.58 | 2 | 11 | 0 | 11 | 37 | 23 | 17 | 9 | 17 | 49 | 3 | 22 |
| 0.36 | 0.21 | 0.95 | 5.7 | 5.9 | 0.80 | 1.60 | 2 | 10 | 0 | 13 | 30 | 23 | 22 | 9 | 17 | 49 | 3 | 22 |
| 0.38 | 0.22 | 1.1 | 6.0 | 6.2 | 0.82 | 1.65 | 2 | 9 | 0 | 15 | 19 | 30 | 25 | 8 | 16 | 51 | 3 | 22 |
| 0.40 | 0.24 | 1.2 | 6.0 | 6.3 | 0.86 | 1.73 | 2 | 9 | 0 | 14 | 13 | 37 | 26 | 8 | 15 | 52 | 3 | 22 |
| 0.42 | 0.25 | 1.4 | 6.1 | 6.4 | 0.90 | 1.81 | 1 | 9 | 0 | 13 | 9 | 37 | 30 | 7 | 14 | 54 | 2 | 23 |
| 0.44 | 0.27 | 1.6 | 6.2 | 6.5 | 0.93 | 1.89 | 1 | 8 | 0 | 10 | 11 | 34 | 35 | 7 | 13 | 55 | 2 | 23 |
| 0.46 | 0.29 | 1.7 | 6.3 | 6.6 | 0.97 | 1.97 | 1 | 8 | 0 | 9 | 12 | 27 | 43 | 7 | 12 | 56 | 2 | 23 |
| 0.48 | 0.30 | 1.9 | 6.4 | 6.7 | 1.00 | 2.04 | 1 | 8 | 0 | 6 | 14 | 19 | 53 | 6 | 11 | 57 | 2 | 23 |
| 0.50 | 0.32 | 2.1 | 6.5 | 6.8 | 1.04 | 2.10 | 0 | 8 | 0 | 5 | 14 | 12 | 60 | 6 | 10 | 58 | 2 | 23 |
| 0.52 | 0.33 | 2.3 | 6.6 | 6.9 | 1.06 | 2.16 | 1 | 7 | 1 | 6 | 13 | 10 | 63 | 6 | 10 | 59 | 2 | 23 |
| 0.54 | 0.34 | 2.5 | 6.7 | 7.1 | 1.09 | 2.19 | 1 | 6 | 1 | 6 | 11 | 10 | 65 | 6 | 10 | 59 | 2 | 23 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.56 | 0.36 | 2.7 | 6.9 | 7.3 | 1.11 | 2.24 | 1 | 5 | 2 | 7 | 9 | 12 | 65 | 6 | 10 | 60 | 2 | 23 |
| 0.58 | 0.37 | 2.9 | 7.0 | 7.4 | 1.14 | 2.30 | 1 | 5 | 2 | 8 | 6 | 13 | 65 | 6 | 9 | 60 | 2 | 23 |
| 0.60 | 0.38 | 3.2 | 7.2 | 7.6 | 1.16 | 2.36 | 1 | 5 | 2 | 9 | 6 | 12 | 66 | 5 | 9 | 61 | 2 | 23 |
| 0.62 | 0.40 | 3.4 | 7.3 | 7.7 | 1.19 | 2.42 | 1 | 4 | 2 | 8 | 6 | 12 | 67 | 5 | 9 | 61 | 2 | 23 |
| 0.64 | 0.42 | 3.7 | 7.3 | 7.7 | 1.22 | 2.50 | 0 | 4 | 2 | 6 | 7 | 11 | 69 | 5 | 8 | 62 | 2 | 23 |
| 0.66 | 0.43 | 4.0 | 7.3 | 7.8 | 1.26 | 2.54 | 0 | 3 | 3 | 4 | 8 | 9 | 73 | 5 | 8 | 62 | 2 | 23 |
| 0.68 | 0.45 | 4.3 | 7.3 | 7.8 | 1.29 | 2.60 | 0 | 3 | 3 | 3 | 9 | 7 | 75 | 5 | 8 | 63 | 2 | 23 |
| 0.70 | 0.47 | 4.6 | 7.4 | 7.9 | 1.32 | 2.66 | 0 | 2 | 3 | 2 | 9 | 6 | 77 | 4 | 7 | 63 | 1 | 24 |
| 0.72 | 0.49 | 4.9 | 7.4 | 7.9 | 1.35 | 2.73 | 0 | 2 | 3 | 1 | 8 | 7 | 79 | 4 | 7 | 64 | 1 | 24 |
| 0.74 | 0.51 | 5.2 | 7.4 | 8.0 | 1.38 | 2.79 | 0 | 2 | 4 | 1 | 7 | 8 | 79 | 4 | 7 | 64 | 1 | 24 |
| 0.76 | 0.52 | 5.5 | 7.5 | 8.0 | 1.41 | 2.84 | 0 | 2 | 3 | 1 | 5 | 8 | 81 | 4 | 7 | 64 | 1 | 24 |
| 0.78 | 0.54 | 5.8 | 7.5 | 8.1 | 1.44 | 2.91 | 0 | 2 | 3 | 1 | 4 | 9 | 81 | 4 | 6 | 65 | 1 | 24 |
| 0.80 | 0.56 | 6.2 | 7.5 | 8.1 | 1.47 | 2.98 | 0 | 2 | 3 | 1 | 3 | 8 | 83 | 4 | 6 | 65 | 1 | 24 |
| 0.82 | 0.58 | 6.5 | 7.5 | 8.2 | 1.50 | 3.06 | 0 | 1 | 3 | 2 | 2 | 9 | 83 | 4 | 6 | 65 | 1 | 24 |
| 0.84 | 0.60 | 6.9 | 7.6 | 8.2 | 1.52 | 3.10 | 0 | 1 | 3 | 2 | 2 | 7 | 85 | 4 | 6 | 66 | 1 | 24 |
| 0.86 | 0.61 | 7.2 | 7.6 | 8.3 | 1.55 | 3.18 | 0 | 1 | 3 | 2 | 2 | 5 | 87 | 3 | 6 | 66 | 1 | 24 |
| 0.88 | 0.63 | 7.6 | 7.6 | 8.3 | 1.57 | 3.20 | 0 | 1 | 4 | 1 | 2 | 4 | 89 | 3 | 5 | 66 | 1 | 24 |
| 0.90 | 0.65 | 7.9 | 7.7 | 8.4 | 1.60 | 3.27 | 0 | 1 | 3 | 2 | 2 | 3 | 89 | 3 | 5 | 66 | 1 | 24 |
| 0.92 | 0.67 | 8.3 | 7.7 | 8.4 | 1.63 | 3.31 | 0 | 1 | 4 | 2 | 2 | 2 | 90 | 3 | 5 | 67 | 1 | 24 |
| 0.94 | 0.68 | 8.7 | 7.7 | 8.5 | 1.65 | 3.33 | 0 | 1 | 4 | 1 | 2 | 1 | 91 | 3 | 5 | 67 | 1 | 24 |
| 0.96 | 0.70 | 9.1 | 7.8 | 8.5 | 1.67 | 3.40 | 0 | 1 | 4 | 2 | 2 | 1 | 90 | 3 | 5 | 67 | 1 | 24 |
| 0.98 | 0.72 | 9.5 | 7.8 | 8.6 | 1.70 | 3.45 | 0 | 1 | 3 | 2 | 2 | 1 | 90 | 3 | 5 | 67 | 1 | 24 |
| 1.00 | 0.73 | 9.9 | 7.8 | 8.6 | 1.72 | 3.44 | 0 | 1 | 4 | 1 | 2 | 2 | 91 | 3 | 5 | 67 | 1 | 24 |
| 1.02 | 0.75 | 10.3 | 7.9 | 8.7 | 1.74 | 3.50 | 0 | 1 | 4 | 1 | 2 | 2 | 91 | 3 | 5 | 67 | 1 | 24 |
| 1.04 | 0.77 | 10.7 | 7.9 | 8.7 | 1.76 | 3.59 | 0 | 0 | 4 | 2 | 2 | 2 | 90 | 3 | 5 | 67 | 1 | 24 |
| 1.06 | 0.78 | 11.1 | 7.9 | 8.8 | 1.79 | 3.64 | 0 | 0 | 3 | 2 | 2 | 2 | 90 | 3 | 5 | 67 | 1 | 24 |
| 1.08 | 0.80 | 11.5 | 8.0 | 8.9 | 1.81 | 3.65 | 0 | 0 | 4 | 1 | 3 | 2 | 91 | 3 | 4 | 68 | 1 | 24 |
| 1.10 | 0.80 | 11.8 | 8.2 | 9.1 | 1.80 | 3.63 | 0 | 0 | 4 | 3 | 3 | 2 | 89 | 3 | 5 | 68 | 1 | 24 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 1.12 | 0.80 | 12.1 | 8.4 | 9.3 | 1.80 | 3.62 | 0 | 0 | 3 | 5 | 2 | 2 | 87 | 3 | 5 | 67 | 1 | 24 |
| 1.14 | 0.80 | 12.4 | 8.6 | 9.6 | 1.80 | 3.63 | 0 | 0 | 3 | 7 | 2 | 2 | 85 | 3 | 5 | 67 | 1 | 24 |
| 1.16 | 0.80 | 12.7 | 8.8 | 9.8 | 1.80 | 3.62 | 0 | 0 | 3 | 8 | 3 | 2 | 84 | 3 | 5 | 67 | 1 | 24 |
| 1.18 | 0.79 | 12.9 | 9.2 | 10.1 | 1.79 | 3.62 | 0 | 0 | 3 | 10 | 3 | 2 | 81 | 3 | 5 | 67 | 1 | 24 |
| 1.20 | 0.76 | 12.9 | 9.8 | 10.8 | 1.74 | 3.51 | 1 | 0 | 3 | 14 | 5 | 1 | 76 | 3 | 5 | 67 | 1 | 24 |
| 1.22 | 0.73 | 13.0 | 10.5 | 11.5 | 1.70 | 3.46 | 1 | 0 | 3 | 19 | 5 | 1 | 71 | 3 | 5 | 67 | 1 | 24 |
| 1.24 | 0.73 | 13.3 | 10.7 | 11.7 | 1.70 | 3.46 | 1 | 1 | 3 | 18 | 7 | 2 | 69 | 3 | 5 | 67 | 1 | 24 |
| 1.26 | 0.74 | 13.9 | 10.8 | 11.8 | 1.73 | 3.54 | 1 | 1 | 3 | 18 | 7 | 2 | 68 | 3 | 5 | 67 | 1 | 24 |
| 1.28 | 0.76 | 14.4 | 10.9 | 11.9 | 1.75 | 3.54 | 0 | 1 | 3 | 12 | 11 | 4 | 69 | 3 | 5 | 67 | 1 | 24 |
| 1.30 | 0.77 | 15.0 | 11.0 | 12.0 | 1.77 | 3.58 | 0 | 1 | 3 | 8 | 15 | 4 | 69 | 3 | 5 | 67 | 1 | 24 |
| 1.32 | 0.79 | 15.5 | 11.1 | 12.1 | 1.78 | 3.60 | 0 | 1 | 3 | 4 | 18 | 5 | 69 | 3 | 5 | 67 | 1 | 24 |
| 1.34 | 0.80 | 16.1 | 11.2 | 12.2 | 1.80 | 3.64 | 0 | 1 | 3 | 4 | 17 | 7 | 69 | 3 | 4 | 68 | 1 | 24 |
| 1.36 | 0.81 | 16.7 | 11.3 | 12.3 | 1.82 | 3.67 | 0 | 1 | 3 | 4 | 16 | 8 | 68 | 3 | 4 | 68 | 1 | 24 |
| 1.38 | 0.80 | 16.9 | 11.7 | 12.8 | 1.80 | 3.64 | 0 | 1 | 3 | 7 | 12 | 11 | 66 | 3 | 4 | 68 | 1 | 24 |
| 1.40 | 0.80 | 17.4 | 12.0 | 13.1 | 1.81 | 3.67 | 0 | 1 | 3 | 8 | 8 | 13 | 67 | 3 | 4 | 68 | 1 | 24 |
| 1.42 | 0.82 | 18.0 | 12.1 | 13.2 | 1.83 | 3.65 | 0 | 1 | 3 | 7 | 4 | 17 | 67 | 3 | 4 | 68 | 1 | 24 |
| 1.44 | 0.83 | 18.6 | 12.2 | 13.2 | 1.85 | 3.72 | 0 | 1 | 3 | 7 | 4 | 17 | 68 | 3 | 4 | 68 | 1 | 24 |
| 1.46 | 0.84 | 19.3 | 12.2 | 13.3 | 1.87 | 3.77 | 0 | 1 | 2 | 7 | 4 | 15 | 70 | 3 | 4 | 68 | 1 | 24 |
| 1.48 | 0.86 | 20.0 | 12.3 | 13.4 | 1.88 | 3.85 | 0 | 1 | 2 | 5 | 7 | 13 | 71 | 3 | 4 | 68 | 1 | 24 |
| 1.50 | 0.87 | 20.6 | 12.4 | 13.5 | 1.90 | 3.88 | 0 | 1 | 2 | 3 | 9 | 10 | 75 | 3 | 4 | 68 | 1 | 24 |
| 1.52 | 0.89 | 21.3 | 12.5 | 13.6 | 1.92 | 3.89 | 0 | 1 | 2 | 3 | 8 | 6 | 79 | 3 | 4 | 68 | 1 | 24 |
| 1.54 | 0.90 | 22.0 | 12.6 | 13.7 | 1.94 | 3.88 | 0 | 1 | 2 | 2 | 8 | 3 | 83 | 3 | 4 | 68 | 1 | 24 |
| 1.56 | 0.91 | 22.7 | 12.7 | 13.8 | 1.96 | 3.94 | 0 | 1 | 2 | 2 | 8 | 3 | 83 | 3 | 4 | 68 | 1 | 24 |
| 1.58 | 0.93 | 23.4 | 12.8 | 13.9 | 1.98 | 3.99 | 0 | 1 | 2 | 2 | 7 | 4 | 83 | 3 | 4 | 68 | 1 | 24 |
| 1.60 | 0.94 | 24.1 | 12.8 | 14.0 | 1.99 | 4.07 | 0 | 1 | 2 | 3 | 4 | 6 | 83 | 3 | 4 | 68 | 1 | 24 |
| 1.62 | 0.96 | 24.8 | 12.9 | 14.1 | 2.01 | 4.11 | 0 | 1 | 2 | 4 | 4 | 6 | 84 | 3 | 4 | 69 | 1 | 24 |
| 1.64 | 0.97 | 25.6 | 13.0 | 14.2 | 2.03 | 4.16 | 0 | 1 | 2 | 3 | 3 | 6 | 84 | 3 | 4 | 69 | 1 | 24 |
| 1.66 | 0.98 | 26.3 | 13.1 | 14.3 | 2.04 | 4.13 | 0 | 1 | 3 | 3 | 3 | 5 | 85 | 3 | 4 | 69 | 1 | 24 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 1.68 | 1.00 | 27.1 | 13.2 | 14.4 | 2.06 | 4.12 | 0 | 1 | 3 | 3 | 3 | 5 | 85 | 3 | 4 | 69 | 1 | 24 |
| 1.70 | 1.01 | 27.8 | 13.3 | 14.5 | 2.08 | 4.18 | 0 | 1 | 3 | 3 | 3 | 5 | 85 | 3 | 4 | 69 | 1 | 24 |
| 1.72 | 1.02 | 28.6 | 13.4 | 14.6 | 2.09 | 4.25 | 0 | 1 | 3 | 3 | 3 | 4 | 86 | 3 | 4 | 69 | 1 | 24 |
| 1.74 | 1.04 | 29.4 | 13.4 | 14.7 | 2.11 | 4.26 | 0 | 1 | 3 | 2 | 3 | 3 | 88 | 3 | 4 | 69 | 1 | 24 |
| 1.76 | 1.05 | 30.2 | 13.5 | 14.8 | 2.12 | 4.34 | 0 | 1 | 3 | 3 | 3 | 3 | 87 | 3 | 3 | 69 | 1 | 24 |
| 1.78 | 1.06 | 31.0 | 13.6 | 14.9 | 2.14 | 4.33 | 0 | 1 | 3 | 2 | 3 | 3 | 88 | 3 | 3 | 69 | 1 | 24 |
| 1.80 | 1.08 | 31.8 | 13.7 | 15.0 | 2.15 | 4.40 | 0 | 1 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 69 | 1 | 24 |
| 1.82 | 1.09 | 32.6 | 13.8 | 15.1 | 2.17 | 4.39 | 0 | 1 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 69 | 1 | 24 |
| 1.84 | 1.10 | 33.4 | 13.9 | 15.2 | 2.18 | 4.45 | 0 | 1 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 69 | 1 | 24 |
| 1.86 | 1.11 | 34.2 | 14.0 | 15.3 | 2.20 | 4.40 | 0 | 1 | 3 | 2 | 3 | 3 | 88 | 2 | 3 | 69 | 1 | 24 |
| 1.88 | 1.13 | 35.1 | 14.1 | 15.4 | 2.21 | 4.48 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 69 | 1 | 24 |
| 1.90 | 1.14 | 35.9 | 14.2 | 15.5 | 2.23 | 4.48 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 69 | 1 | 24 |
| 1.92 | 1.15 | 36.8 | 14.3 | 15.6 | 2.24 | 4.56 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 69 | 1 | 24 |
| 1.94 | 1.16 | 37.7 | 14.4 | 15.7 | 2.25 | 4.57 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 69 | 1 | 24 |
| 1.96 | 1.18 | 38.6 | 14.5 | 15.8 | 2.27 | 4.64 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 1.98 | 1.19 | 39.5 | 14.6 | 15.9 | 2.28 | 4.63 | 0 | 0 | 3 | 2 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.00 | 1.20 | 40.4 | 14.6 | 16.0 | 2.29 | 4.70 | 0 | 0 | 3 | 3 | 3 | 3 | 87 | 2 | 3 | 70 | 1 | 24 |
| 2.02 | 1.21 | 41.3 | 14.7 | 16.1 | 2.31 | 4.67 | 0 | 0 | 3 | 2 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.04 | 1.23 | 42.2 | 14.8 | 16.2 | 2.32 | 4.74 | 0 | 0 | 3 | 3 | 3 | 3 | 87 | 2 | 3 | 70 | 1 | 24 |
| 2.06 | 1.24 | 43.1 | 14.9 | 16.3 | 2.33 | 4.71 | 0 | 0 | 3 | 2 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.08 | 1.25 | 44.1 | 15.0 | 16.4 | 2.35 | 4.75 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.10 | 1.26 | 45.0 | 15.1 | 16.5 | 2.36 | 4.73 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.12 | 1.28 | 46.0 | 15.2 | 16.6 | 2.37 | 4.81 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.14 | 1.29 | 46.9 | 15.3 | 16.7 | 2.38 | 4.82 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.16 | 1.30 | 47.9 | 15.4 | 16.8 | 2.40 | 4.90 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.18 | 1.31 | 48.9 | 15.5 | 16.9 | 2.41 | 4.94 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.20 | 1.32 | 49.9 | 15.6 | 17.0 | 2.42 | 4.96 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |
| 2.22 | 1.34 | 50.9 | 15.7 | 17.1 | 2.43 | 5.00 | 0 | 0 | 3 | 3 | 3 | 3 | 88 | 2 | 3 | 70 | 1 | 24 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 2.24 | 1.35 | 51.9 | 15.7 | 17.2 | 2.45 | 4.96 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.26 | 1.36 | 53.0 | 15.8 | 17.3 | 2.46 | 4.98 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.28 | 1.37 | 54.0 | 15.9 | 17.4 | 2.47 | 5.00 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.30 | 1.38 | 55.0 | 16.0 | 17.5 | 2.48 | 5.00 | 0 | 0 | 3 | 2 | 2 | 3 | 90 | 2 | 3 | 70 | 1 | 24 |
| 2.32 | 1.39 | 56.0 | 16.1 | 17.6 | 2.49 | 5.00 | 0 | 0 | 3 | 3 | 3 | 3 | 90 | 2 | 3 | 70 | 1 | 24 |
| 2.34 | 1.41 | 57.1 | 16.2 | 17.7 | 2.50 | 5.00 | 0 | 0 | 3 | 2 | 2 | 2 | 90 | 2 | 3 | 70 | 1 | 24 |
| 2.36 | 1.42 | 58.1 | 16.4 | 17.8 | 2.51 | 5.04 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.38 | 1.43 | 59.2 | 16.5 | 18.0 | 2.52 | 5.07 | 0 | 0 | 3 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.40 | 1.44 | 60.3 | 16.6 | 18.1 | 2.53 | 5.10 | 0 | 0 | 2 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.42 | 1.45 | 61.3 | 16.7 | 18.2 | 2.54 | 5.13 | 0 | 0 | 2 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.44 | 1.46 | 62.4 | 16.8 | 18.3 | 2.55 | 5.16 | 0 | 0 | 2 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.46 | 1.47 | 63.5 | 16.9 | 18.4 | 2.56 | 5.19 | 0 | 0 | 2 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.48 | 1.48 | 64.6 | 17.0 | 18.5 | 2.57 | 5.21 | 0 | 0 | 2 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| 2.50 | 1.49 | 65.7 | 17.1 | 18.6 | 2.58 | 5.23 | 0 | 0 | 2 | 2 | 3 | 3 | 89 | 2 | 3 | 70 | 1 | 24 |
| **Olifants River: J3OLIF-EWR9** | | | | | | | | | | | | | | | | | | |
| 0.02 | 0.01 | 0.000 | 0.7 | 0.7 | 0.02 | 0.08 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 80 | 0 |
| 0.04 | 0.02 | 0.001 | 1.8 | 1.8 | 0.03 | 0.11 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 80 | 0 |
| 0.06 | 0.02 | 0.003 | 3.0 | 3.0 | 0.05 | 0.16 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 80 | 0 |
| 0.08 | 0.03 | 0.009 | 4.7 | 4.8 | 0.06 | 0.20 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 80 | 0 |
| 0.10 | 0.04 | 0.019 | 5.9 | 6.1 | 0.08 | 0.25 | 98 | 1 | 0 | 1 | 0 | 0 | 0 | 20 | 0 | 0 | 79 | 1 |
| 0.12 | 0.06 | 0.037 | 6.8 | 7.0 | 0.10 | 0.33 | 86 | 10 | 0 | 3 | 0 | 0 | 0 | 19 | 1 | 0 | 77 | 3 |
| 0.14 | 0.07 | 0.061 | 7.4 | 7.7 | 0.12 | 0.40 | 74 | 18 | 0 | 6 | 1 | 0 | 0 | 19 | 1 | 0 | 74 | 6 |
| 0.16 | 0.08 | 0.087 | 8.6 | 8.9 | 0.13 | 0.43 | 61 | 31 | 0 | 6 | 3 | 0 | 0 | 18 | 2 | 0 | 73 | 7 |
| 0.18 | 0.09 | 0.12 | 9.4 | 9.8 | 0.14 | 0.48 | 46 | 43 | 0 | 5 | 5 | 0 | 0 | 18 | 2 | 0 | 72 | 8 |
| 0.20 | 0.11 | 0.17 | 9.5 | 9.9 | 0.16 | 0.53 | 33 | 54 | 0 | 5 | 8 | 0 | 0 | 17 | 2 | 0 | 70 | 10 |
| 0.22 | 0.13 | 0.22 | 9.6 | 10.0 | 0.18 | 0.58 | 23 | 61 | 0 | 4 | 10 | 1 | 0 | 17 | 3 | 0 | 67 | 13 |
| 0.24 | 0.15 | 0.28 | 9.6 | 10.0 | 0.20 | 0.63 | 18 | 61 | 0 | 5 | 13 | 3 | 0 | 16 | 3 | 1 | 63 | 17 |
| 0.26 | 0.17 | 0.35 | 9.7 | 10.1 | 0.21 | 0.67 | 9 | 67 | 0 | 3 | 14 | 8 | 0 | 15 | 4 | 1 | 61 | 19 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.28 | 0.19 | 0.42 | 9.7 | 10.2 | 0.23 | 0.71 | 2 | 69 | 0 | 1 | 14 | 14 | 0 | 14 | 5 | 1 | 57 | 23 |
| 0.30 | 0.21 | 0.50 | 9.8 | 10.2 | 0.25 | 0.75 | 1 | 66 | 0 | 1 | 12 | 20 | 0 | 13 | 6 | 1 | 54 | 26 |
| 0.32 | 0.22 | 0.58 | 9.9 | 10.4 | 0.26 | 0.79 | 2 | 61 | 0 | 1 | 11 | 22 | 3 | 13 | 6 | 1 | 50 | 30 |
| 0.34 | 0.24 | 0.67 | 10.1 | 10.6 | 0.28 | 0.82 | 3 | 57 | 0 | 2 | 9 | 22 | 7 | 12 | 7 | 1 | 48 | 32 |
| 0.36 | 0.26 | 0.76 | 10.2 | 10.8 | 0.29 | 0.84 | 3 | 54 | 0 | 2 | 3 | 24 | 13 | 11 | 7 | 1 | 46 | 34 |
| 0.38 | 0.27 | 0.86 | 10.4 | 11.0 | 0.30 | 0.87 | 3 | 52 | 0 | 3 | 1 | 21 | 20 | 11 | 8 | 1 | 44 | 36 |
| 0.40 | 0.29 | 1.0 | 10.6 | 11.2 | 0.32 | 0.90 | 4 | 49 | 0 | 3 | 1 | 17 | 26 | 10 | 8 | 2 | 42 | 38 |
| 0.42 | 0.28 | 1.0 | 11.8 | 12.3 | 0.31 | 0.89 | 8 | 45 | 0 | 7 | 1 | 12 | 27 | 11 | 8 | 2 | 42 | 38 |
| 0.44 | 0.28 | 1.1 | 12.7 | 13.3 | 0.31 | 0.90 | 11 | 41 | 0 | 10 | 2 | 8 | 29 | 10 | 8 | 2 | 42 | 38 |
| 0.46 | 0.27 | 1.2 | 13.9 | 14.4 | 0.31 | 0.91 | 13 | 39 | 0 | 12 | 2 | 5 | 29 | 10 | 8 | 2 | 42 | 38 |
| 0.48 | 0.27 | 1.3 | 14.9 | 15.5 | 0.32 | 0.90 | 15 | 37 | 0 | 14 | 2 | 2 | 30 | 10 | 8 | 2 | 41 | 39 |
| 0.50 | 0.29 | 1.4 | 15.1 | 15.7 | 0.33 | 0.93 | 14 | 35 | 1 | 15 | 3 | 1 | 32 | 10 | 8 | 2 | 39 | 41 |
| 0.52 | 0.31 | 1.6 | 15.3 | 15.9 | 0.35 | 0.96 | 11 | 33 | 2 | 12 | 7 | 1 | 34 | 9 | 8 | 2 | 37 | 43 |
| 0.54 | 0.32 | 1.8 | 15.4 | 16.0 | 0.36 | 0.99 | 7 | 33 | 5 | 8 | 11 | 1 | 35 | 9 | 8 | 3 | 35 | 45 |
| 0.56 | 0.34 | 2.0 | 15.6 | 16.2 | 0.38 | 1.03 | 5 | 27 | 9 | 8 | 12 | 2 | 36 | 8 | 8 | 3 | 33 | 47 |
| 0.58 | 0.35 | 2.2 | 15.8 | 16.4 | 0.39 | 1.04 | 3 | 25 | 12 | 4 | 15 | 3 | 37 | 8 | 8 | 4 | 32 | 48 |
| 0.60 | 0.37 | 2.4 | 16.0 | 16.6 | 0.41 | 1.07 | 2 | 22 | 14 | 3 | 17 | 3 | 39 | 8 | 8 | 4 | 30 | 50 |
| 0.62 | 0.39 | 2.6 | 16.1 | 16.8 | 0.42 | 1.10 | 2 | 18 | 15 | 4 | 15 | 7 | 39 | 7 | 8 | 5 | 29 | 51 |
| 0.64 | 0.40 | 2.8 | 16.3 | 17.0 | 0.43 | 1.13 | 2 | 16 | 16 | 4 | 10 | 12 | 40 | 7 | 8 | 5 | 27 | 53 |
| 0.66 | 0.42 | 3.1 | 16.5 | 17.1 | 0.45 | 1.14 | 2 | 14 | 17 | 4 | 7 | 14 | 42 | 7 | 8 | 5 | 26 | 54 |
| 0.68 | 0.43 | 3.4 | 16.7 | 17.3 | 0.46 | 1.17 | 2 | 12 | 18 | 4 | 5 | 18 | 43 | 6 | 8 | 6 | 25 | 55 |
| 0.70 | 0.45 | 3.6 | 16.8 | 17.5 | 0.48 | 1.19 | 1 | 12 | 17 | 3 | 4 | 17 | 46 | 6 | 8 | 6 | 24 | 56 |
| 0.72 | 0.46 | 3.9 | 17.0 | 17.6 | 0.49 | 1.20 | 1 | 11 | 16 | 3 | 4 | 13 | 51 | 6 | 8 | 7 | 23 | 57 |
| 0.74 | 0.48 | 4.2 | 17.1 | 17.8 | 0.51 | 1.23 | 1 | 11 | 16 | 2 | 4 | 11 | 55 | 6 | 7 | 7 | 22 | 58 |
| 0.76 | 0.50 | 4.5 | 17.3 | 18.0 | 0.53 | 1.26 | 1 | 11 | 15 | 2 | 4 | 9 | 58 | 5 | 7 | 8 | 21 | 59 |
| 0.78 | 0.51 | 4.8 | 17.5 | 18.1 | 0.54 | 1.28 | 1 | 10 | 14 | 4 | 4 | 6 | 61 | 5 | 7 | 8 | 20 | 60 |
| 0.80 | 0.53 | 5.2 | 17.6 | 18.3 | 0.56 | 1.30 | 1 | 10 | 13 | 4 | 4 | 4 | 65 | 5 | 7 | 8 | 20 | 60 |
| 0.82 | 0.54 | 5.5 | 17.8 | 18.5 | 0.57 | 1.32 | 1 | 10 | 13 | 3 | 4 | 4 | 66 | 5 | 7 | 9 | 19 | 61 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.84 | 0.55 | 5.8 | 18.2 | 18.9 | 0.58 | 1.34 | 1 | 9 | 13 | 4 | 4 | 3 | 65 | 5 | 6 | 9 | 18 | 62 |
| 0.86 | 0.55 | 6.1 | 18.9 | 19.5 | 0.59 | 1.35 | 2 | 8 | 12 | 7 | 3 | 4 | 64 | 5 | 6 | 9 | 18 | 62 |
| 0.88 | 0.55 | 6.4 | 19.7 | 20.4 | 0.59 | 1.34 | 2 | 8 | 12 | 8 | 3 | 4 | 63 | 5 | 6 | 9 | 18 | 62 |
| 0.90 | 0.56 | 6.8 | 19.8 | 20.5 | 0.61 | 1.38 | 2 | 7 | 12 | 8 | 3 | 3 | 64 | 4 | 6 | 10 | 17 | 63 |
| 0.92 | 0.58 | 7.3 | 19.9 | 20.6 | 0.63 | 1.40 | 2 | 6 | 13 | 7 | 4 | 3 | 65 | 4 | 6 | 10 | 17 | 63 |
| 0.94 | 0.60 | 7.7 | 20.0 | 20.7 | 0.65 | 1.42 | 1 | 6 | 13 | 5 | 6 | 3 | 66 | 4 | 6 | 10 | 16 | 64 |
| 0.96 | 0.61 | 8.2 | 20.1 | 20.8 | 0.67 | 1.47 | 1 | 5 | 13 | 4 | 7 | 3 | 67 | 4 | 5 | 11 | 15 | 65 |
| 0.98 | 0.63 | 8.7 | 20.2 | 20.9 | 0.69 | 1.50 | 1 | 5 | 13 | 4 | 7 | 3 | 68 | 4 | 5 | 11 | 14 | 66 |
| 1.00 | 0.65 | 9.3 | 20.3 | 21.0 | 0.70 | 1.51 | 0 | 4 | 13 | 2 | 8 | 4 | 69 | 3 | 5 | 11 | 14 | 66 |
| 1.02 | 0.67 | 9.8 | 20.4 | 21.1 | 0.72 | 1.57 | 0 | 4 | 12 | 2 | 8 | 4 | 70 | 3 | 5 | 12 | 13 | 67 |
| 1.04 | 0.68 | 10.4 | 20.5 | 21.2 | 0.74 | 1.61 | 0 | 3 | 12 | 2 | 7 | 4 | 71 | 3 | 5 | 12 | 13 | 67 |
| 1.06 | 0.70 | 11.0 | 20.6 | 21.3 | 0.76 | 1.64 | 0 | 3 | 11 | 2 | 6 | 5 | 72 | 3 | 4 | 13 | 12 | 68 |
| 1.08 | 0.71 | 11.6 | 20.7 | 21.4 | 0.79 | 1.66 | 0 | 3 | 11 | 2 | 3 | 8 | 72 | 3 | 4 | 13 | 11 | 69 |
| 1.10 | 0.73 | 12.3 | 20.8 | 21.6 | 0.81 | 1.71 | 0 | 3 | 10 | 2 | 2 | 8 | 73 | 3 | 4 | 13 | 11 | 69 |
| 1.12 | 0.75 | 12.9 | 20.9 | 21.7 | 0.83 | 1.73 | 0 | 3 | 10 | 1 | 2 | 8 | 75 | 3 | 4 | 13 | 10 | 70 |
| 1.14 | 0.76 | 13.6 | 21.0 | 21.8 | 0.85 | 1.77 | 0 | 2 | 10 | 2 | 2 | 7 | 76 | 2 | 4 | 14 | 10 | 70 |
| 1.16 | 0.78 | 14.4 | 21.1 | 21.9 | 0.87 | 1.82 | 0 | 2 | 9 | 2 | 2 | 6 | 78 | 2 | 4 | 14 | 9 | 71 |
| 1.18 | 0.80 | 15.1 | 21.2 | 22.0 | 0.90 | 1.87 | 0 | 2 | 9 | 2 | 2 | 2 | 82 | 2 | 4 | 14 | 9 | 71 |
| 1.20 | 0.81 | 15.9 | 21.3 | 22.1 | 0.92 | 1.92 | 0 | 2 | 8 | 2 | 2 | 2 | 83 | 2 | 3 | 14 | 9 | 71 |
| 1.22 | 0.83 | 16.8 | 21.4 | 22.2 | 0.95 | 1.94 | 0 | 2 | 8 | 2 | 2 | 2 | 84 | 2 | 3 | 15 | 8 | 72 |
| 1.24 | 0.85 | 17.6 | 21.5 | 22.3 | 0.97 | 2.00 | 0 | 2 | 8 | 2 | 2 | 2 | 84 | 2 | 3 | 15 | 8 | 72 |
| 1.26 | 0.86 | 18.5 | 21.6 | 22.4 | 1.00 | 2.05 | 0 | 2 | 7 | 2 | 2 | 2 | 84 | 2 | 3 | 15 | 7 | 73 |
| 1.28 | 0.88 | 19.5 | 21.7 | 22.5 | 1.02 | 2.08 | 0 | 1 | 7 | 1 | 2 | 2 | 86 | 2 | 3 | 15 | 7 | 73 |
| 1.30 | 0.89 | 20.5 | 21.8 | 22.6 | 1.05 | 2.11 | 0 | 1 | 7 | 1 | 2 | 2 | 86 | 2 | 3 | 16 | 7 | 73 |
| 1.32 | 0.91 | 21.5 | 21.9 | 22.7 | 1.08 | 2.17 | 0 | 1 | 7 | 1 | 2 | 2 | 87 | 2 | 3 | 16 | 6 | 74 |
| 1.34 | 0.93 | 22.6 | 21.9 | 22.8 | 1.11 | 2.24 | 0 | 1 | 7 | 1 | 2 | 2 | 87 | 2 | 3 | 16 | 6 | 74 |
| 1.36 | 0.94 | 23.7 | 22.0 | 22.9 | 1.14 | 2.29 | 0 | 1 | 6 | 1 | 2 | 2 | 87 | 1 | 2 | 16 | 6 | 74 |
| 1.38 | 0.96 | 24.9 | 22.1 | 23.0 | 1.18 | 2.39 | 0 | 1 | 6 | 2 | 2 | 2 | 87 | 1 | 2 | 16 | 6 | 74 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 1.40 | 0.98 | 26.2 | 22.2 | 23.1 | 1.21 | 2.44 | 0 | 1 | 6 | 2 | 2 | 2 | 87 | 1 | 2 | 16 | 5 | 75 |
| 1.42 | 0.99 | 27.5 | 22.3 | 23.2 | 1.25 | 2.50 | 0 | 1 | 6 | 1 | 2 | 2 | 89 | 1 | 2 | 17 | 5 | 75 |
| 1.44 | 1.01 | 28.9 | 22.3 | 23.3 | 1.28 | 2.58 | 0 | 1 | 6 | 1 | 2 | 2 | 89 | 1 | 2 | 17 | 5 | 75 |
| 1.46 | 1.02 | 30.4 | 22.4 | 23.4 | 1.32 | 2.67 | 0 | 0 | 5 | 1 | 2 | 2 | 88 | 1 | 2 | 17 | 5 | 75 |
| 1.48 | 1.04 | 31.9 | 22.5 | 23.5 | 1.36 | 2.77 | 0 | 0 | 5 | 2 | 2 | 2 | 89 | 1 | 2 | 17 | 5 | 75 |
| 1.50 | 1.06 | 33.5 | 22.6 | 23.6 | 1.40 | 2.85 | 0 | 0 | 5 | 2 | 2 | 1 | 90 | 1 | 2 | 17 | 4 | 76 |
| 1.52 | 1.07 | 35.3 | 22.7 | 23.7 | 1.45 | 2.92 | 0 | 0 | 5 | 1 | 2 | 1 | 91 | 1 | 2 | 17 | 4 | 76 |
| 1.54 | 1.09 | 37.1 | 22.8 | 23.7 | 1.50 | 3.01 | 0 | 0 | 5 | 1 | 2 | 1 | 91 | 1 | 2 | 17 | 4 | 76 |
| 1.56 | 1.11 | 39.1 | 22.8 | 23.8 | 1.55 | 3.15 | 0 | 0 | 4 | 2 | 2 | 2 | 90 | 1 | 2 | 18 | 4 | 76 |
| 1.58 | 1.12 | 41.1 | 22.9 | 23.9 | 1.60 | 3.25 | 0 | 0 | 4 | 2 | 2 | 2 | 90 | 1 | 1 | 18 | 4 | 76 |
| 1.60 | 1.14 | 43.3 | 23.0 | 24.0 | 1.66 | 3.34 | 0 | 0 | 4 | 1 | 2 | 2 | 91 | 1 | 1 | 18 | 3 | 77 |
| **Kammanassie River: J3KAMM-EWR10** | | | | | | | | | | | | | | | | | | |
| 0.01 | 0.00 | 0.000 | 0.2 | 0.2 | 0.00 | 0.01 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.02 | 0.01 | 0.000 | 0.4 | 0.4 | 0.01 | 0.02 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.03 | 0.02 | 0.000 | 0.6 | 0.6 | 0.01 | 0.03 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.04 | 0.02 | 0.000 | 0.8 | 0.8 | 0.01 | 0.04 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.05 | 0.03 | 0.000 | 0.9 | 0.9 | 0.01 | 0.05 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.06 | 0.03 | 0.001 | 1.1 | 1.1 | 0.02 | 0.06 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.07 | 0.04 | 0.001 | 1.2 | 1.3 | 0.02 | 0.07 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.08 | 0.04 | 0.001 | 1.6 | 1.6 | 0.02 | 0.07 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.09 | 0.05 | 0.002 | 1.6 | 1.7 | 0.02 | 0.08 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.10 | 0.06 | 0.002 | 1.6 | 1.7 | 0.03 | 0.10 | 99 | 1 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.11 | 0.06 | 0.003 | 1.7 | 1.7 | 0.03 | 0.11 | 90 | 10 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.12 | 0.07 | 0.004 | 1.7 | 1.8 | 0.04 | 0.13 | 76 | 24 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.13 | 0.07 | 0.005 | 2.1 | 2.2 | 0.04 | 0.12 | 70 | 30 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.14 | 0.07 | 0.006 | 2.5 | 2.6 | 0.04 | 0.13 | 68 | 32 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.15 | 0.08 | 0.008 | 2.5 | 2.7 | 0.04 | 0.15 | 61 | 39 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.16 | 0.09 | 0.010 | 2.5 | 2.7 | 0.05 | 0.17 | 55 | 45 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.17 | 0.10 | 0.013 | 2.5 | 2.7 | 0.05 | 0.19 | 47 | 53 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.18 | 0.11 | 0.016 | 2.5 | 2.7 | 0.06 | 0.21 | 38 | 62 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.19 | 0.12 | 0.019 | 2.5 | 2.8 | 0.07 | 0.24 | 34 | 66 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.20 | 0.13 | 0.023 | 2.6 | 2.8 | 0.07 | 0.26 | 32 | 67 | 0 | 0 | 1 | 0 | 0 | 50 | 0 | 0 | 50 | 0 |
| 0.21 | 0.13 | 0.028 | 2.6 | 2.8 | 0.08 | 0.29 | 32 | 65 | 0 | 1 | 1 | 0 | 0 | 49 | 1 | 0 | 49 | 1 |
| 0.22 | 0.14 | 0.033 | 2.6 | 2.9 | 0.09 | 0.32 | 27 | 69 | 0 | 1 | 2 | 1 | 0 | 48 | 2 | 0 | 48 | 2 |
| 0.23 | 0.15 | 0.040 | 2.6 | 2.9 | 0.10 | 0.36 | 19 | 76 | 0 | 1 | 3 | 1 | 0 | 47 | 3 | 0 | 47 | 3 |
| 0.24 | 0.16 | 0.047 | 2.6 | 2.9 | 0.11 | 0.40 | 9 | 83 | 0 | 1 | 5 | 2 | 0 | 46 | 4 | 0 | 46 | 4 |
| 0.25 | 0.16 | 0.054 | 2.7 | 3.1 | 0.12 | 0.42 | 9 | 82 | 0 | 1 | 5 | 3 | 0 | 46 | 4 | 0 | 46 | 4 |
| 0.26 | 0.17 | 0.062 | 2.9 | 3.3 | 0.13 | 0.46 | 14 | 75 | 0 | 2 | 5 | 4 | 0 | 45 | 5 | 0 | 45 | 5 |
| 0.27 | 0.17 | 0.073 | 3.0 | 3.5 | 0.14 | 0.50 | 17 | 71 | 0 | 2 | 5 | 5 | 0 | 44 | 6 | 0 | 44 | 6 |
| 0.28 | 0.17 | 0.086 | 3.2 | 3.6 | 0.16 | 0.55 | 19 | 66 | 0 | 3 | 5 | 7 | 0 | 43 | 6 | 1 | 43 | 7 |
| 0.29 | 0.18 | 0.11 | 3.2 | 3.7 | 0.18 | 0.63 | 20 | 61 | 0 | 5 | 5 | 10 | 0 | 40 | 8 | 2 | 40 | 10 |
| 0.30 | 0.18 | 0.13 | 3.3 | 3.8 | 0.21 | 0.71 | 19 | 55 | 0 | 7 | 6 | 12 | 0 | 37 | 10 | 2 | 37 | 13 |
| 0.31 | 0.19 | 0.16 | 3.4 | 3.9 | 0.25 | 0.82 | 18 | 47 | 0 | 10 | 8 | 14 | 3 | 33 | 14 | 3 | 33 | 17 |
| 0.32 | 0.19 | 0.20 | 3.5 | 4.0 | 0.30 | 0.94 | 16 | 40 | 0 | 12 | 9 | 17 | 5 | 28 | 17 | 5 | 28 | 22 |
| 0.33 | 0.20 | 0.26 | 3.6 | 4.1 | 0.37 | 1.13 | 13 | 31 | 0 | 17 | 9 | 21 | 9 | 22 | 20 | 8 | 22 | 28 |
| 0.34 | 0.20 | 0.35 | 3.7 | 4.3 | 0.47 | 1.34 | 10 | 22 | 0 | 21 | 7 | 26 | 14 | 16 | 18 | 16 | 16 | 34 |
| 0.35 | 0.21 | 0.51 | 3.8 | 4.4 | 0.66 | 1.54 | 6 | 14 | 0 | 22 | 7 | 30 | 20 | 10 | 13 | 27 | 10 | 40 |
| 0.36 | 0.21 | 0.55 | 3.9 | 4.5 | 0.67 | 1.55 | 5 | 14 | 0 | 22 | 9 | 27 | 22 | 10 | 13 | 27 | 10 | 40 |
| 0.37 | 0.21 | 0.58 | 4.1 | 4.7 | 0.68 | 1.58 | 5 | 14 | 0 | 22 | 11 | 22 | 26 | 9 | 13 | 28 | 9 | 41 |
| 0.38 | 0.22 | 0.62 | 4.1 | 4.7 | 0.69 | 1.60 | 4 | 14 | 0 | 20 | 13 | 20 | 28 | 9 | 12 | 28 | 9 | 41 |
| 0.39 | 0.22 | 0.66 | 4.2 | 4.8 | 0.70 | 1.59 | 4 | 14 | 0 | 19 | 15 | 18 | 31 | 9 | 12 | 29 | 9 | 41 |
| 0.40 | 0.23 | 0.70 | 4.3 | 4.9 | 0.72 | 1.61 | 4 | 13 | 0 | 19 | 17 | 16 | 32 | 9 | 12 | 30 | 9 | 41 |
| 0.41 | 0.24 | 0.75 | 4.3 | 5.0 | 0.73 | 1.62 | 4 | 13 | 0 | 18 | 18 | 14 | 34 | 8 | 12 | 30 | 8 | 42 |
| 0.42 | 0.24 | 0.79 | 4.4 | 5.0 | 0.74 | 1.61 | 3 | 13 | 0 | 18 | 19 | 11 | 37 | 8 | 12 | 30 | 8 | 42 |
| 0.43 | 0.25 | 0.84 | 4.5 | 5.1 | 0.76 | 1.63 | 3 | 12 | 0 | 17 | 20 | 8 | 40 | 8 | 11 | 31 | 8 | 42 |
| 0.44 | 0.25 | 0.89 | 4.6 | 5.2 | 0.77 | 1.65 | 3 | 12 | 0 | 16 | 20 | 6 | 43 | 7 | 11 | 32 | 7 | 43 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.45 | 0.26 | 0.94 | 4.6 | 5.3 | 0.78 | 1.68 | 3 | 12 | 0 | 16 | 21 | 5 | 44 | 7 | 11 | 32 | 7 | 43 |
| 0.46 | 0.27 | 1.0 | 4.7 | 5.3 | 0.79 | 1.69 | 2 | 12 | 0 | 14 | 21 | 7 | 45 | 7 | 11 | 32 | 7 | 43 |
| 0.47 | 0.27 | 1.0 | 4.8 | 5.4 | 0.81 | 1.72 | 2 | 11 | 0 | 13 | 20 | 10 | 43 | 7 | 10 | 33 | 7 | 43 |
| 0.48 | 0.28 | 1.1 | 4.9 | 5.5 | 0.82 | 1.73 | 2 | 11 | 0 | 13 | 19 | 12 | 43 | 6 | 10 | 33 | 6 | 44 |
| 0.49 | 0.28 | 1.2 | 4.9 | 5.6 | 0.83 | 1.75 | 2 | 11 | 0 | 13 | 19 | 13 | 43 | 6 | 10 | 34 | 6 | 44 |
| 0.50 | 0.29 | 1.2 | 5.0 | 5.6 | 0.84 | 1.74 | 2 | 10 | 0 | 12 | 17 | 14 | 44 | 6 | 10 | 34 | 6 | 44 |
| 0.51 | 0.29 | 1.3 | 5.1 | 5.7 | 0.86 | 1.80 | 2 | 10 | 1 | 13 | 17 | 16 | 43 | 6 | 9 | 35 | 6 | 44 |
| 0.52 | 0.30 | 1.3 | 5.1 | 5.8 | 0.87 | 1.79 | 2 | 9 | 1 | 12 | 16 | 17 | 43 | 6 | 9 | 35 | 6 | 44 |
| 0.53 | 0.31 | 1.4 | 5.2 | 5.9 | 0.88 | 1.79 | 1 | 8 | 1 | 12 | 15 | 18 | 44 | 6 | 9 | 35 | 6 | 44 |
| 0.54 | 0.28 | 1.4 | 5.9 | 6.5 | 0.84 | 1.73 | 3 | 8 | 2 | 20 | 12 | 16 | 39 | 6 | 10 | 34 | 6 | 44 |
| 0.55 | 0.29 | 1.5 | 5.9 | 6.6 | 0.85 | 1.76 | 3 | 7 | 2 | 20 | 12 | 16 | 40 | 6 | 10 | 34 | 6 | 44 |
| 0.56 | 0.29 | 1.5 | 6.0 | 6.7 | 0.86 | 1.80 | 3 | 7 | 2 | 20 | 12 | 15 | 42 | 6 | 9 | 35 | 6 | 44 |
| 0.57 | 0.30 | 1.6 | 6.1 | 6.8 | 0.88 | 1.83 | 2 | 6 | 2 | 20 | 11 | 15 | 43 | 6 | 9 | 35 | 6 | 44 |
| 0.58 | 0.30 | 1.7 | 6.2 | 6.9 | 0.88 | 1.82 | 2 | 6 | 2 | 19 | 11 | 15 | 44 | 6 | 9 | 35 | 6 | 44 |
| 0.59 | 0.31 | 1.7 | 6.3 | 7.0 | 0.89 | 1.83 | 2 | 6 | 3 | 20 | 11 | 14 | 45 | 5 | 9 | 36 | 5 | 45 |
| 0.60 | 0.31 | 1.8 | 6.5 | 7.2 | 0.90 | 1.84 | 3 | 6 | 3 | 21 | 10 | 13 | 45 | 5 | 9 | 36 | 5 | 45 |
| 0.61 | 0.31 | 1.9 | 6.7 | 7.4 | 0.90 | 1.85 | 3 | 6 | 3 | 21 | 10 | 13 | 46 | 5 | 9 | 36 | 5 | 45 |
| 0.62 | 0.31 | 1.9 | 6.9 | 7.6 | 0.90 | 1.85 | 2 | 6 | 3 | 19 | 12 | 13 | 45 | 5 | 9 | 36 | 5 | 45 |
| 0.63 | 0.31 | 2.0 | 7.1 | 7.8 | 0.91 | 1.85 | 2 | 6 | 3 | 19 | 14 | 12 | 45 | 5 | 9 | 36 | 5 | 45 |
| 0.64 | 0.31 | 2.1 | 7.4 | 8.1 | 0.90 | 1.87 | 2 | 5 | 3 | 20 | 14 | 10 | 45 | 5 | 9 | 36 | 5 | 45 |
| 0.65 | 0.31 | 2.1 | 7.7 | 8.4 | 0.90 | 1.87 | 3 | 5 | 3 | 22 | 13 | 10 | 45 | 5 | 9 | 36 | 5 | 45 |
| 0.66 | 0.31 | 2.2 | 7.9 | 8.6 | 0.90 | 1.86 | 3 | 5 | 3 | 22 | 14 | 10 | 44 | 5 | 9 | 36 | 5 | 45 |
| 0.67 | 0.31 | 2.3 | 8.2 | 8.9 | 0.90 | 1.85 | 3 | 5 | 3 | 23 | 14 | 10 | 43 | 5 | 9 | 36 | 5 | 45 |
| 0.68 | 0.31 | 2.4 | 8.5 | 9.2 | 0.91 | 1.84 | 3 | 5 | 3 | 23 | 15 | 8 | 44 | 5 | 9 | 36 | 5 | 45 |
| 0.69 | 0.31 | 2.5 | 8.7 | 9.5 | 0.91 | 1.84 | 3 | 5 | 3 | 23 | 15 | 7 | 43 | 5 | 9 | 36 | 5 | 45 |
| 0.70 | 0.31 | 2.5 | 9.0 | 9.7 | 0.91 | 1.87 | 3 | 5 | 3 | 25 | 15 | 8 | 42 | 5 | 9 | 36 | 5 | 45 |
| 0.71 | 0.31 | 2.6 | 9.3 | 10.0 | 0.91 | 1.87 | 3 | 5 | 3 | 24 | 16 | 8 | 41 | 5 | 9 | 36 | 5 | 45 |
| 0.72 | 0.31 | 2.7 | 9.5 | 10.2 | 0.92 | 1.87 | 3 | 5 | 3 | 23 | 18 | 7 | 42 | 5 | 9 | 36 | 5 | 45 |

| Max. depth (m) | Ave. depth (m) | Discharge ($m^3/s$) | Width (m) | Perimeter (m) | Ave. velocity (m/s) | Max. velocity (m/s) | Fish flow class (%) | | | | | | Macroinvertebrate flow class (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SVS[1] | SS[2] | SD[3] | FVS[4] | FS[5] | FI[6] | FD[7] | SCS[8] | FCS[9] | VFCS[10] | SFS[11] | FFS[12] |
| 0.73 | 0.32 | 2.8 | 9.6 | 10.4 | 0.93 | 1.90 | 3 | 5 | 3 | 23 | 16 | 8 | 42 | 5 | 8 | 37 | 5 | 45 |
| 0.74 | 0.32 | 3.0 | 9.8 | 10.6 | 0.94 | 1.92 | 3 | 5 | 2 | 24 | 13 | 13 | 41 | 5 | 8 | 37 | 5 | 45 |
| 0.75 | 0.31 | 3.0 | 10.6 | 11.4 | 0.91 | 1.86 | 3 | 5 | 3 | 24 | 15 | 12 | 39 | 5 | 9 | 36 | 5 | 45 |
| 0.76 | 0.30 | 3.0 | 11.4 | 12.2 | 0.89 | 1.79 | 3 | 5 | 3 | 26 | 15 | 10 | 37 | 6 | 9 | 35 | 6 | 44 |
| 0.77 | 0.30 | 3.1 | 11.6 | 12.4 | 0.90 | 1.82 | 3 | 5 | 3 | 27 | 14 | 11 | 37 | 5 | 9 | 36 | 5 | 45 |
| 0.78 | 0.31 | 3.3 | 11.8 | 12.6 | 0.91 | 1.86 | 3 | 5 | 3 | 24 | 17 | 11 | 37 | 5 | 9 | 36 | 5 | 45 |
| 0.79 | 0.31 | 3.4 | 11.9 | 12.8 | 0.92 | 1.90 | 3 | 5 | 3 | 24 | 17 | 11 | 37 | 5 | 8 | 37 | 5 | 45 |
| 0.80 | 0.32 | 3.6 | 12.1 | 12.9 | 0.93 | 1.92 | 2 | 5 | 3 | 22 | 19 | 12 | 37 | 5 | 8 | 37 | 5 | 45 |
| 0.81 | 0.32 | 3.7 | 12.3 | 13.1 | 0.94 | 1.90 | 2 | 5 | 3 | 20 | 20 | 11 | 39 | 5 | 8 | 37 | 5 | 45 |
| 0.82 | 0.33 | 3.9 | 12.5 | 13.3 | 0.95 | 1.92 | 2 | 5 | 3 | 20 | 20 | 10 | 40 | 5 | 8 | 37 | 5 | 45 |
| 0.83 | 0.33 | 4.1 | 12.7 | 13.5 | 0.96 | 1.93 | 2 | 5 | 3 | 19 | 20 | 12 | 40 | 5 | 8 | 37 | 5 | 45 |
| 0.84 | 0.34 | 4.2 | 12.9 | 13.7 | 0.97 | 1.98 | 2 | 4 | 3 | 21 | 17 | 13 | 41 | 4 | 8 | 38 | 4 | 46 |
| 0.85 | 0.34 | 4.4 | 13.0 | 13.9 | 0.98 | 1.98 | 2 | 5 | 3 | 18 | 18 | 14 | 41 | 4 | 8 | 38 | 4 | 46 |
| 0.86 | 0.35 | 4.6 | 13.2 | 14.1 | 0.99 | 2.04 | 2 | 4 | 3 | 18 | 18 | 15 | 41 | 4 | 8 | 38 | 4 | 46 |
| 0.87 | 0.35 | 4.7 | 13.4 | 14.3 | 1.00 | 2.04 | 1 | 5 | 3 | 14 | 21 | 15 | 42 | 4 | 8 | 38 | 4 | 46 |
| 0.88 | 0.36 | 4.9 | 13.6 | 14.5 | 1.01 | 2.07 | 1 | 5 | 2 | 12 | 23 | 16 | 42 | 4 | 7 | 38 | 4 | 46 |
| 0.89 | 0.36 | 5.1 | 13.8 | 14.7 | 1.02 | 2.10 | 1 | 5 | 2 | 13 | 21 | 16 | 42 | 4 | 7 | 39 | 4 | 46 |
| 0.90 | 0.37 | 5.3 | 14.0 | 14.9 | 1.03 | 2.08 | 1 | 5 | 3 | 12 | 21 | 16 | 43 | 4 | 7 | 39 | 4 | 46 |
| 0.91 | 0.37 | 5.5 | 14.2 | 15.1 | 1.04 | 2.10 | 1 | 5 | 3 | 11 | 22 | 15 | 44 | 4 | 7 | 39 | 4 | 46 |
| 0.92 | 0.38 | 5.7 | 14.4 | 15.3 | 1.05 | 2.13 | 1 | 5 | 3 | 11 | 20 | 16 | 44 | 4 | 7 | 39 | 4 | 46 |
| 0.93 | 0.38 | 5.9 | 14.6 | 15.5 | 1.06 | 2.17 | 1 | 5 | 2 | 11 | 20 | 16 | 45 | 4 | 7 | 39 | 4 | 46 |
| 0.94 | 0.39 | 6.1 | 14.7 | 15.7 | 1.07 | 2.18 | 1 | 5 | 2 | 11 | 16 | 17 | 47 | 4 | 7 | 39 | 4 | 46 |
| 0.95 | 0.39 | 6.3 | 14.9 | 15.9 | 1.08 | 2.18 | 1 | 4 | 2 | 11 | 12 | 21 | 48 | 4 | 7 | 39 | 4 | 46 |
| 0.96 | 0.40 | 6.5 | 15.1 | 16.1 | 1.09 | 2.22 | 1 | 4 | 2 | 11 | 12 | 20 | 48 | 4 | 6 | 40 | 4 | 46 |
| 0.97 | 0.40 | 6.8 | 15.3 | 16.3 | 1.09 | 2.19 | 1 | 4 | 2 | 10 | 11 | 20 | 51 | 4 | 7 | 40 | 4 | 46 |
| 0.98 | 0.41 | 7.0 | 15.4 | 16.4 | 1.11 | 2.23 | 1 | 4 | 2 | 9 | 12 | 19 | 52 | 4 | 6 | 40 | 4 | 46 |
| 0.99 | 0.42 | 7.3 | 15.5 | 16.5 | 1.12 | 2.30 | 1 | 4 | 2 | 10 | 11 | 19 | 52 | 4 | 6 | 40 | 4 | 46 |
| 1.00 | 0.43 | 7.5 | 15.6 | 16.7 | 1.13 | 2.33 | 1 | 4 | 2 | 9 | 11 | 20 | 53 | 4 | 6 | 40 | 4 | 46 |

1 SVS: Slow very shallow 2 SS: Slow shallow 3 SD: Slow deep 4 FVS: Fast very shallow

| | | | |
|---|---|---|---|
| 5 FS Fast shallow | 6 FI: Fast intermediate | 7 FD: Fast deep | 8 SCS: Shallow over coarse substrate |
| 9 FCS: Fast over coarse substrate | 10 VFCS: Vey fast over coarse substrate | 11 SFS: Shallow over fine substrate | 12 FFS: Fast over fine substrate |

## C.4 REFERENCES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# APPENDIX D: RDRM OUTPUT FILES

A report is generated as part of the RDRM to provide:

- the hydrology summary;
- the parameters that were adjusted from the default;
- and the final output results (EWR rules) for all categories.

This report is provided for all the EWR sites in the following sections.

## D.1 H8DUIW-EWR1: RDRM REPORT FOR A PES AND REC: D

```
TITLE: RDMR Report
DATE: 07/30/2014

Revised Desktop Model outputs for site: Duiw_1
```

**HYDROLOGY DATA SUMMARY**

```
Natural Flows:                          Present Day Flows:
   Area     MAR   Ann.SD    Q75   Ann.     Area     MAR   Ann.SD    Q75   Ann.
  (km^2)       (m^3 * 10^6)        CV     (km^2)       (m^3 * 10^6)        CV
    0.00   83.67   37.35    2.42  0.45      0.00   79.80   37.63    1.99  0.47

% Zero flows =   0.0                    % Zero flows =   0.0
Baseflow Parameters: A = 0.960, B = 0.43Baseflow Parameters: A = 0.960, B = 0.430
BFI = 0.39 : Hydro Index =   5.5        BFI = 0.35 : Hydro Index =   6.7

MONTH   MEAN      SD     CV             MONTH   MEAN      SD     CV
        (m^3 * 10^6)                            (m^3 * 10^6)
 Oct    9.96    8.42    0.85             Oct    9.60    8.55    0.89
 Nov    8.71    9.14    1.05             Nov    8.24    9.28    1.13
 Dec    5.30    8.29    1.56             Dec    4.71    8.38    1.78
 Jan    3.49    5.42    1.55             Jan    2.98    5.45    1.83
 Feb    3.71    5.34    1.44             Feb    3.23    5.33    1.65
 Mar    6.02    7.52    1.25             Mar    5.61    7.52    1.34
 Apr    7.62   10.15    1.33             Apr    7.34   10.15    1.38
 May    6.79    6.36    0.94             May    6.60    6.38    0.97
 Jun    5.73    3.71    0.65             Jun    5.58    3.73    0.67
 Jul    6.77    4.08    0.60             Jul    6.64    4.12    0.62
 Aug   10.14    9.76    0.96             Aug   10.03    9.81    0.98
 Sep    9.43    7.34    0.78             Sep    9.24    7.38    0.80

Critical months: WET : Oct, DRY : Feb
Using  20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET :      2.180, DRY :      1.198
```

**FLOW - STRESSOR RESPONSE DATA SUMMARY**

```
Table of initial SHIFT factors for the Stress Frequency Curves

Category  High SHIFT  Low SHIFT
    A        0.011      0.130
  A/B        0.017      0.195
    B        0.023      0.260
  B/C        0.028      0.325
    C        0.034      0.390
  C/D        0.039      0.455
    D        0.045      0.520

Perenniality Rules
```

Non-Perennial Allowed

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

| Stress | Wet Season Flow | Dry Season Flow |
|---|---|---|
| 0 | 2.252 | 1.273 |
| 1 | 1.950 | 1.017 |
| 2 | 1.758 | 0.847 |
| 3 | 1.622 | 0.708 |
| 4 | 1.400 | 0.497 |
| 5 | 1.017 | 0.300 |
| 6 | 0.591 | 0.150 |
| 7 | 0.352 | 0.114 |
| 8 | 0.220 | 0.089 |
| 9 | 0.140 | 0.048 |
| 10 | 0.000 | 0.000 |

**HIGH FLOW ESTIMATION SUMMARY DETAILS**

No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 30.30
Maximum high flows are 250% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

| Category | A | A/B | B | B/C | C | C/D | D |
|---|---|---|---|---|---|---|---|
| Annual | 15.462 | 14.196 | 12.998 | 11.864 | 10.792 | 9.778 | 8.820 |
| Oct | 1.305 | 1.198 | 1.097 | 1.001 | 0.911 | 0.825 | 0.745 |
| Nov | 0.727 | 0.668 | 0.611 | 0.558 | 0.508 | 0.460 | 0.415 |
| Dec | 0.315 | 0.290 | 0.265 | 0.242 | 0.220 | 0.199 | 0.180 |
| Jan | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Feb | 0.416 | 0.382 | 0.350 | 0.319 | 0.291 | 0.263 | 0.237 |
| Mar | 1.563 | 1.435 | 1.314 | 1.199 | 1.091 | 0.988 | 0.891 |
| Apr | 1.770 | 1.625 | 1.488 | 1.358 | 1.235 | 1.119 | 1.009 |
| May | 1.916 | 1.759 | 1.611 | 1.470 | 1.337 | 1.212 | 1.093 |
| Jun | 1.501 | 1.378 | 1.262 | 1.152 | 1.048 | 0.949 | 0.856 |
| Jul | 1.806 | 1.658 | 1.518 | 1.386 | 1.261 | 1.142 | 1.030 |
| Aug | 2.304 | 2.115 | 1.937 | 1.768 | 1.608 | 1.457 | 1.314 |
| Sep | 1.838 | 1.688 | 1.545 | 1.411 | 1.283 | 1.162 | 1.049 |

**FINAL RESERVE SUMMARY DETAILS**

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

| Category | Low Flows | | Total Flows | |
|---|---|---|---|---|
| | Mill. m3 | %MAR | Mill. m3 | %MAR |
| A | 25.256 | 30.2 | 39.854 | 47.6 |
| A/B | 23.442 | 28.0 | 36.959 | 44.2 |
| B | 21.604 | 25.8 | 34.060 | 40.7 |
| B/C | 19.781 | 23.6 | 31.198 | 37.3 |
| C | 17.912 | 21.4 | 28.314 | 33.8 |
| C/D | 16.070 | 19.2 | 25.500 | 30.5 |
| D | 14.195 | 17.0 | 22.704 | 27.1 |

**FLOW DURATION and RESERVE ASSURANCE TABLES**

Columns are FDC precentage points:

**Natural Total flow duration curve (mill. $m^3$)**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 24.833 | 13.311 | 10.689 | 7.798 | 6.791 | 6.039 | 5.348 | 4.545 | 3.718 | 2.446 |
| Nov | 19.013 | 13.935 | 9.004 | 6.573 | 5.418 | 4.316 | 3.704 | 3.174 | 2.428 | 1.953 |
| Dec | 9.306 | 6.563 | 4.879 | 3.853 | 3.167 | 2.271 | 1.946 | 1.421 | 1.196 | 0.538 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 8.099 | 4.091 | 3.116 | 2.021 | 1.681 | 1.311 | 0.985 | 0.710 | 0.456 | 0.219 |
| Feb | 10.796 | 5.031 | 3.345 | 2.130 | 1.675 | 1.380 | 1.105 | 0.690 | 0.425 | 0.194 |
| Mar | 13.854 | 10.344 | 6.738 | 4.732 | 3.502 | 2.361 | 1.945 | 1.230 | 0.790 | 0.297 |
| Apr | 17.660 | 11.615 | 7.993 | 5.262 | 4.122 | 2.911 | 2.371 | 1.840 | 1.316 | 0.520 |
| May | 15.281 | 10.745 | 7.516 | 6.223 | 4.969 | 3.851 | 2.962 | 1.901 | 1.351 | 0.936 |
| Jun | 11.102 | 8.926 | 6.834 | 5.888 | 4.559 | 4.062 | 3.360 | 2.711 | 1.737 | 0.989 |
| Jul | 13.600 | 9.429 | 7.748 | 6.480 | 5.837 | 5.056 | 4.214 | 3.713 | 2.943 | 1.822 |
| Aug | 17.502 | 13.053 | 10.393 | 8.687 | 7.990 | 6.728 | 5.739 | 4.553 | 3.810 | 2.499 |
| Sep | 15.847 | 13.752 | 10.066 | 8.641 | 7.336 | 6.497 | 5.684 | 4.746 | 4.294 | 2.500 |

**Natural Baseflow flow duration curve (mill. m$^3$)**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 6.697 | 5.524 | 4.395 | 3.787 | 3.508 | 3.124 | 2.664 | 2.414 | 1.979 | 1.354 |
| Nov | 6.117 | 4.781 | 4.071 | 3.782 | 3.447 | 3.145 | 2.845 | 2.383 | 1.997 | 1.586 |
| Dec | 4.941 | 3.723 | 3.128 | 2.751 | 2.431 | 2.162 | 1.770 | 1.421 | 1.196 | 0.538 |
| Jan | 3.782 | 2.911 | 2.406 | 1.970 | 1.405 | 1.191 | 0.946 | 0.680 | 0.456 | 0.219 |
| Feb | 3.626 | 2.868 | 2.149 | 1.680 | 1.235 | 0.992 | 0.772 | 0.550 | 0.418 | 0.194 |
| Mar | 3.874 | 3.185 | 2.709 | 2.295 | 1.711 | 1.446 | 0.931 | 0.740 | 0.532 | 0.220 |
| Apr | 4.283 | 3.372 | 2.865 | 2.407 | 1.839 | 1.589 | 1.269 | 0.855 | 0.648 | 0.384 |
| May | 4.676 | 3.392 | 2.809 | 2.520 | 2.119 | 1.792 | 1.314 | 1.200 | 0.950 | 0.635 |
| Jun | 4.158 | 3.294 | 2.884 | 2.545 | 2.212 | 1.862 | 1.432 | 1.282 | 1.063 | 0.633 |
| Jul | 4.651 | 3.482 | 3.142 | 2.893 | 2.522 | 2.240 | 1.876 | 1.516 | 1.317 | 0.974 |
| Aug | 5.600 | 4.426 | 3.758 | 3.304 | 2.930 | 2.624 | 2.475 | 1.989 | 1.597 | 1.135 |
| Sep | 5.830 | 4.730 | 3.904 | 3.627 | 3.205 | 2.853 | 2.512 | 2.322 | 1.924 | 1.158 |

**Category Low Flow Assurance curves (mill. m$^3$)**
**D Category**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 2.775 | 2.585 | 2.336 | 2.058 | 1.784 | 1.536 | 1.329 | 1.166 | 1.046 | 0.967 |
| Nov | 2.514 | 2.232 | 2.057 | 1.920 | 1.686 | 1.376 | 1.109 | 1.081 | 0.880 | 0.680 |
| Dec | 2.047 | 1.706 | 1.578 | 1.416 | 1.157 | 0.917 | 0.703 | 0.477 | 0.383 | 0.068 |
| Jan | 1.628 | 1.332 | 1.164 | 0.936 | 0.651 | 0.444 | 0.285 | 0.153 | 0.042 | 0.020 |
| Feb | 1.370 | 1.187 | 0.954 | 0.712 | 0.495 | 0.319 | 0.192 | 0.105 | 0.021 | 0.013 |
| Mar | 1.621 | 1.484 | 1.371 | 1.125 | 0.786 | 0.548 | 0.305 | 0.163 | 0.100 | 0.013 |
| Apr | 1.779 | 1.534 | 1.391 | 1.175 | 0.867 | 0.621 | 0.417 | 0.216 | 0.136 | 0.091 |
| May | 1.955 | 1.572 | 1.393 | 1.253 | 0.985 | 0.720 | 0.460 | 0.350 | 0.252 | 0.193 |
| Jun | 1.711 | 1.523 | 1.382 | 1.228 | 1.018 | 0.783 | 0.526 | 0.387 | 0.310 | 0.247 |
| Jul | 1.923 | 1.646 | 1.590 | 1.482 | 1.212 | 0.954 | 0.754 | 0.541 | 0.465 | 0.405 |
| Aug | 2.388 | 2.087 | 1.963 | 1.723 | 1.432 | 1.211 | 1.129 | 0.843 | 0.796 | 0.795 |
| Sep | 2.398 | 2.142 | 2.040 | 1.849 | 1.529 | 1.306 | 1.180 | 1.047 | 0.874 | 0.819 |

**Category Total Flow Assurance curves (mill. m$^3$)**
**D Category**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 4.231 | 3.558 | 3.129 | 2.806 | 2.527 | 2.234 | 1.886 | 1.492 | 1.056 | 0.967 |
| Nov | 3.326 | 2.774 | 2.499 | 2.337 | 2.101 | 1.765 | 1.420 | 1.263 | 0.885 | 0.680 |
| Dec | 2.398 | 1.941 | 1.770 | 1.597 | 1.337 | 1.086 | 0.837 | 0.556 | 0.385 | 0.068 |
| Jan | 1.628 | 1.332 | 1.164 | 0.936 | 0.651 | 0.444 | 0.285 | 0.153 | 0.042 | 0.020 |
| Feb | 1.835 | 1.497 | 1.207 | 0.950 | 0.732 | 0.542 | 0.369 | 0.209 | 0.021 | 0.013 |
| Mar | 3.365 | 2.649 | 2.320 | 2.020 | 1.676 | 1.384 | 0.972 | 0.553 | 0.112 | 0.013 |
| Apr | 3.754 | 2.853 | 2.466 | 2.189 | 1.874 | 1.567 | 1.172 | 0.657 | 0.150 | 0.091 |
| May | 4.093 | 3.001 | 2.558 | 2.351 | 2.076 | 1.745 | 1.278 | 0.828 | 0.267 | 0.193 |
| Jun | 3.386 | 2.641 | 2.294 | 2.088 | 1.873 | 1.586 | 1.167 | 0.762 | 0.322 | 0.247 |
| Jul | 3.938 | 2.993 | 2.688 | 2.516 | 2.240 | 1.920 | 1.525 | 0.991 | 0.479 | 0.405 |
| Aug | 4.958 | 3.805 | 3.363 | 3.043 | 2.744 | 2.443 | 2.112 | 1.418 | 0.814 | 0.795 |
| Sep | 4.449 | 3.512 | 3.157 | 2.902 | 2.575 | 2.289 | 1.964 | 1.506 | 0.888 | 0.819 |

## D.2 H9GOUK-EWR2: RDRM REPORT FOR A PES AND REC: C/D

TITLE: RDMR Report
DATE: 07/30/2014

Revised Desktop Model outputs for site: Gouk_2

**HYDROLOGY DATA SUMMARY**

Natural Flows: Present Day Flows:

| Area (km^2) | MAR | Ann.SD (m^3 * 10^6) | Q75 | Ann. CV | Area (km^2) | MAR | Ann.SD (m^3 * 10^6) | Q75 | Ann. CV |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 54.09 | 19.99 | 1.57 | 0.37 | 0.00 | 46.04 | 20.34 | 0.52 | 0.44 |

% Zero flows = 0.0 % Zero flows = 19.4
Baseflow Parameters: A = 0.960, B = 0.43Baseflow Parameters: A = 0.960, B = 0.430
BFI = 0.37 : Hydro Index = 5.2 BFI = 0.27 : Hydro Index = 9.4

| MONTH | MEAN (m^3 * 10^6) | SD | CV | MONTH | MEAN (m^3 * 10^6) | SD | CV |
|---|---|---|---|---|---|---|---|
| Oct | 5.72 | 5.24 | 0.92 | Oct | 4.86 | 5.58 | 1.15 |
| Nov | 5.62 | 5.45 | 0.97 | Nov | 4.51 | 5.71 | 1.27 |
| Dec | 3.76 | 4.89 | 1.30 | Dec | 2.45 | 5.04 | 2.06 |
| Jan | 3.04 | 3.71 | 1.22 | Jan | 1.85 | 3.72 | 2.01 |
| Feb | 3.53 | 3.95 | 1.12 | Feb | 2.29 | 4.00 | 1.74 |
| Mar | 5.38 | 4.88 | 0.91 | Mar | 4.46 | 5.01 | 1.12 |
| Apr | 5.73 | 5.83 | 1.02 | Apr | 5.33 | 5.90 | 1.11 |
| May | 4.74 | 4.00 | 0.84 | May | 4.53 | 4.05 | 0.89 |
| Jun | 3.22 | 2.43 | 0.75 | Jun | 3.09 | 2.46 | 0.79 |
| Jul | 3.48 | 2.73 | 0.79 | Jul | 3.34 | 2.73 | 0.82 |
| Aug | 5.23 | 5.22 | 1.00 | Aug | 5.05 | 5.24 | 1.04 |
| Sep | 4.65 | 3.94 | 0.85 | Sep | 4.26 | 4.08 | 0.96 |

Critical months: WET: Oct, DRY: Jul
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 1.110, DRY : 0.782

**FLOW - STRESSOR RESPONSE DATA SUMMARY**
Table of initial SHIFT factors for the Stress Frequency Curves

| Category | High SHIFT | Low SHIFT |
|---|---|---|
| A | 0.063 | 0.114 |
| A/B | 0.094 | 0.171 |
| B | 0.126 | 0.229 |
| B/C | 0.157 | 0.286 |
| C | 0.189 | 0.343 |
| C/D | 0.220 | 0.400 |
| D | 0.251 | 0.457 |

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

| Stress | Wet Season Flow | Dry Season Flow |
|---|---|---|
| 0 | 1.116 | 0.790 |
| 1 | 0.980 | 0.620 |
| 2 | 0.830 | 0.500 |
| 3 | 0.670 | 0.400 |
| 4 | 0.520 | 0.330 |
| 5 | 0.410 | 0.250 |
| 6 | 0.320 | 0.180 |
| 7 | 0.240 | 0.110 |
| 8 | 0.160 | 0.058 |
| 9 | 0.080 | 0.031 |
| 10 | 0.000 | 0.000 |

**HIGH FLOW ESTIMATION SUMMARY DETAILS**
No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 6.27
Maximum high flows are 185% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

| Category | A | A/B | B | B/C | C | C/D | D |
|---|---|---|---|---|---|---|---|
| Annual | 7.527 | 7.021 | 6.530 | 6.055 | 5.595 | 5.150 | 4.719 |
| Oct | 0.663 | 0.618 | 0.575 | 0.533 | 0.493 | 0.454 | 0.416 |
| Nov | 0.543 | 0.507 | 0.471 | 0.437 | 0.404 | 0.372 | 0.341 |
| Dec | 0.361 | 0.337 | 0.314 | 0.291 | 0.269 | 0.247 | 0.227 |
| Jan | 0.473 | 0.441 | 0.410 | 0.380 | 0.351 | 0.324 | 0.296 |
| Feb | 0.597 | 0.556 | 0.517 | 0.480 | 0.443 | 0.408 | 0.374 |
| Mar | 0.847 | 0.790 | 0.735 | 0.682 | 0.630 | 0.580 | 0.531 |
| Apr | 0.686 | 0.640 | 0.595 | 0.552 | 0.510 | 0.469 | 0.430 |
| May | 0.902 | 0.841 | 0.783 | 0.726 | 0.671 | 0.617 | 0.566 |
| Jun | 0.382 | 0.356 | 0.331 | 0.307 | 0.284 | 0.261 | 0.239 |
| Jul | 0.605 | 0.564 | 0.525 | 0.487 | 0.450 | 0.414 | 0.379 |
| Aug | 0.770 | 0.718 | 0.668 | 0.619 | 0.572 | 0.527 | 0.483 |
| Sep | 0.698 | 0.651 | 0.606 | 0.562 | 0.519 | 0.478 | 0.438 |

**FINAL RESERVE SUMMARY DETAILS**

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

| Category | Low Flows | | Total Flows | |
|---|---|---|---|---|
| | Mill. m3 | %MAR | Mill. m3 | %MAR |
| A | 12.869 | 23.8 | 18.877 | 34.9 |
| A/B | 11.570 | 21.4 | 17.225 | 31.8 |
| B | 10.311 | 19.1 | 15.615 | 28.9 |
| B/C | 9.143 | 16.9 | 14.107 | 26.1 |
| C | 8.072 | 14.9 | 12.700 | 23.5 |
| C/D | 7.077 | 13.1 | 11.373 | 21.0 |
| D | 6.138 | 11.3 | 10.100 | 18.7 |

**FLOW DURATION and RESERVE ASSURANCE TABLES**

Columns are FDC precentage points:

**Natural Total flow duration curve (mill. $m^3$)**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 15.461 | 8.942 | 6.484 | 4.982 | 4.093 | 2.855 | 2.306 | 1.985 | 1.507 | 0.706 |
| Nov | 13.158 | 9.779 | 6.686 | 4.773 | 3.569 | 2.873 | 2.184 | 1.583 | 1.109 | 0.305 |
| Dec | 7.590 | 5.755 | 3.919 | 2.990 | 2.461 | 1.858 | 1.221 | 0.745 | 0.456 | 0.147 |
| Jan | 7.005 | 4.930 | 3.155 | 2.459 | 2.053 | 1.451 | 0.810 | 0.570 | 0.213 | 0.117 |
| Feb | 9.963 | 5.602 | 4.191 | 2.932 | 2.190 | 1.776 | 1.005 | 0.734 | 0.351 | 0.154 |
| Mar | 11.393 | 8.673 | 6.422 | 5.663 | 4.139 | 3.122 | 2.264 | 1.234 | 0.734 | 0.178 |
| Apr | 13.133 | 9.825 | 5.721 | 4.610 | 3.616 | 2.811 | 2.414 | 1.882 | 1.164 | 0.204 |
| May | 10.917 | 7.561 | 5.719 | 4.773 | 4.064 | 2.923 | 1.954 | 1.023 | 0.755 | 0.310 |
| Jun | 6.756 | 5.051 | 3.943 | 3.291 | 2.470 | 2.151 | 1.671 | 1.266 | 0.784 | 0.300 |
| Jul | 7.194 | 5.242 | 3.736 | 3.166 | 2.729 | 2.419 | 1.869 | 1.439 | 1.036 | 0.531 |
| Aug | 9.885 | 7.736 | 5.887 | 4.448 | 3.720 | 3.028 | 2.386 | 1.744 | 1.339 | 0.651 |
| Sep | 9.348 | 6.923 | 5.556 | 4.109 | 3.457 | 3.200 | 2.466 | 2.153 | 1.221 | 0.507 |

**Natural Baseflow flow duration curve (mill. $m^3$)**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 3.748 | 2.884 | 2.560 | 2.077 | 1.881 | 1.562 | 1.448 | 1.189 | 0.965 | 0.579 |
| Nov | 3.662 | 2.793 | 2.483 | 2.165 | 1.858 | 1.631 | 1.386 | 1.228 | 0.811 | 0.305 |
| Dec | 2.826 | 2.326 | 1.913 | 1.755 | 1.479 | 1.163 | 1.045 | 0.689 | 0.456 | 0.147 |
| Jan | 2.586 | 2.109 | 1.707 | 1.511 | 1.145 | 0.853 | 0.669 | 0.434 | 0.213 | 0.117 |
| Feb | 2.545 | 2.222 | 1.800 | 1.404 | 1.108 | 0.828 | 0.644 | 0.487 | 0.262 | 0.128 |
| Mar | 2.789 | 2.447 | 2.187 | 1.861 | 1.646 | 1.388 | 0.873 | 0.657 | 0.449 | 0.159 |
| Apr | 3.254 | 2.542 | 2.153 | 1.873 | 1.701 | 1.303 | 1.090 | 0.763 | 0.612 | 0.204 |
| May | 3.197 | 2.483 | 2.108 | 1.882 | 1.584 | 1.289 | 1.042 | 0.727 | 0.651 | 0.266 |
| Jun | 2.833 | 2.174 | 1.884 | 1.632 | 1.485 | 1.213 | 0.982 | 0.782 | 0.447 | 0.300 |
| Jul | 3.152 | 2.073 | 1.671 | 1.557 | 1.360 | 1.217 | 1.018 | 0.897 | 0.638 | 0.422 |
| Aug | 3.106 | 2.618 | 2.158 | 1.781 | 1.639 | 1.442 | 1.323 | 1.153 | 0.758 | 0.461 |
| Sep | 3.071 | 2.773 | 2.305 | 1.872 | 1.582 | 1.497 | 1.355 | 1.168 | 0.844 | 0.482 |

**Category Low Flow Assurance curves (mill. $m^3$)**

**C/D Category**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 1.348 | 1.279 | 1.163 | 1.015 | 0.845 | 0.675 | 0.502 | 0.343 | 0.000 | 0.000 |
| Nov | 1.215 | 1.167 | 1.104 | 0.985 | 0.811 | 0.649 | 0.474 | 0.000 | 0.000 | 0.000 |
| Dec | 0.946 | 0.943 | 0.893 | 0.806 | 0.182 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Jan | 0.880 | 0.861 | 0.794 | 0.498 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Feb | 0.819 | 0.817 | 0.757 | 0.600 | 0.150 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Mar | 1.055 | 1.055 | 1.011 | 0.891 | 0.730 | 0.563 | 0.320 | 0.000 | 0.000 | 0.000 |
| Apr | 1.102 | 1.048 | 0.962 | 0.856 | 0.731 | 0.553 | 0.367 | 0.214 | 0.141 | 0.000 |
| May | 1.064 | 1.046 | 0.975 | 0.870 | 0.694 | 0.519 | 0.368 | 0.217 | 0.155 | 0.000 |
| Jun | 0.887 | 0.863 | 0.850 | 0.741 | 0.634 | 0.495 | 0.340 | 0.209 | 0.112 | 0.017 |
| Jul | 0.865 | 0.836 | 0.784 | 0.703 | 0.602 | 0.486 | 0.361 | 0.256 | 0.180 | 0.125 |
| Aug | 1.161 | 1.120 | 0.992 | 0.838 | 0.733 | 0.614 | 0.462 | 0.324 | 0.202 | 0.118 |
| Sep | 1.144 | 1.138 | 1.021 | 0.857 | 0.695 | 0.611 | 0.467 | 0.314 | 0.200 | 0.000 |

**Category Total Flow Assurance curves (mill. $m^3$)**

**C/D Category**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 2.104 | 1.898 | 1.688 | 1.485 | 1.299 | 1.100 | 0.842 | 0.536 | 0.000 | 0.000 |
| Nov | 1.834 | 1.674 | 1.534 | 1.370 | 1.182 | 0.997 | 0.552 | 0.000 | 0.000 | 0.000 |
| Dec | 1.358 | 1.280 | 1.179 | 1.063 | 0.182 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Jan | 1.419 | 1.303 | 1.038 | 0.498 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Feb | 1.499 | 1.374 | 1.229 | 0.870 | 0.150 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Mar | 2.021 | 1.846 | 1.683 | 1.492 | 1.309 | 1.106 | 0.743 | 0.000 | 0.000 | 0.000 |
| Apr | 1.884 | 1.689 | 1.505 | 1.343 | 1.200 | 0.993 | 0.718 | 0.419 | 0.148 | 0.000 |
| May | 2.093 | 1.888 | 1.690 | 1.511 | 1.311 | 1.098 | 0.830 | 0.487 | 0.163 | 0.000 |
| Jun | 1.322 | 1.220 | 1.153 | 1.012 | 0.895 | 0.739 | 0.535 | 0.323 | 0.116 | 0.017 |
| Jul | 1.554 | 1.401 | 1.264 | 1.133 | 1.016 | 0.874 | 0.671 | 0.437 | 0.186 | 0.125 |
| Aug | 2.039 | 1.839 | 1.602 | 1.385 | 1.259 | 1.108 | 0.856 | 0.555 | 0.209 | 0.118 |
| Sep | 1.940 | 1.790 | 1.574 | 1.352 | 1.173 | 1.058 | 0.824 | 0.523 | 0.207 | 0.000 |

## D.3 J1DORI-EWR7: RDRM REPORT FOR A PES AND REC: C/D

```
TITLE: RDMR Report
DATE: 07/31/2014

Revised Desktop Model outputs for site: Dori_7
```

**HYDROLOGY DATA SUMMARY**

```
Natural Flows:                          Present Day Flows:
   Area     MAR   Ann.SD    Q75   Ann.     Area     MAR   Ann.SD    Q75   Ann.
  (km^2)       (m^3 * 10^6)        CV     (km^2)       (m^3 * 10^6)        CV
    0.00    4.52    4.67    0.02  1.03      0.00    2.01    2.89    0.00  1.43

% Zero flows =   1.2                    % Zero flows =   1.2
Baseflow Parameters: A = 0.990, B = 0.44Baseflow Parameters: A = 0.990, B = 0.440
BFI = 0.20 : Hydro Index =  29.6        BFI = 0.16 : Hydro Index =  46.0

MONTH   MEAN      SD     CV             MONTH   MEAN      SD     CV
        (m^3 * 10^6)                            (m^3 * 10^6)
 Oct    0.50    1.26    2.54             Oct    0.20    0.60    2.98
 Nov    0.51    1.01    1.98             Nov    0.19    0.47    2.42
 Dec    0.39    0.77    2.00             Dec    0.13    0.36    2.67
 Jan    0.37    1.31    3.55             Jan    0.15    0.64    4.36
 Feb    0.44    1.77    4.02             Feb    0.25    1.52    6.06
 Mar    0.41    0.99    2.45             Mar    0.19    0.75    3.88
 Apr    0.57    1.46    2.55             Apr    0.26    0.70    2.70
 May    0.39    0.65    1.69             May    0.19    0.35    1.84
 Jun    0.16    0.22    1.39             Jun    0.08    0.12    1.47
 Jul    0.20    0.71    3.61             Jul    0.09    0.34    3.60
 Aug    0.37    1.00    2.69             Aug    0.17    0.48    2.74
 Sep    0.24    0.44    1.86             Sep    0.10    0.21    2.19

Critical months: WET: Apr, DRY: Jul
```

Using 10th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 0.107, DRY : 0.046

**FLOW - STRESSOR RESPONSE DATA SUMMARY**
Table of initial SHIFT factors for the Stress Frequency Curves

| Category | High SHIFT | Low SHIFT |
|---|---|---|
| A | 0.003 | 0.086 |
| A/B | 0.004 | 0.129 |
| B | 0.006 | 0.171 |
| B/C | 0.007 | 0.214 |
| C | 0.009 | 0.257 |
| C/D | 0.010 | 0.300 |
| D | 0.011 | 0.343 |

Perenniality Rules
Non-Perennial Allowed

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

| Stress | Wet Season Flow | Dry Season Flow |
|---|---|---|
| 0 | 0.125 | 0.051 |
| 1 | 0.084 | 0.038 |
| 2 | 0.069 | 0.033 |
| 3 | 0.055 | 0.028 |
| 4 | 0.042 | 0.024 |
| 5 | 0.030 | 0.020 |
| 6 | 0.022 | 0.016 |
| 7 | 0.016 | 0.012 |
| 8 | 0.012 | 0.008 |
| 9 | 0.007 | 0.004 |
| 10 | 0.000 | 0.000 |

**HIGH FLOW ESTIMATION SUMMARY DETAILS**
No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 50.00
Maximum high flows are 490% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

| Category | A | A/B | B | B/C | C | C/D | D |
|---|---|---|---|---|---|---|---|
| Annual | 0.915 | 0.836 | 0.761 | 0.692 | 0.626 | 0.564 | 0.506 |
| Oct | 0.090 | 0.082 | 0.075 | 0.068 | 0.062 | 0.056 | 0.050 |
| Nov | 0.075 | 0.069 | 0.063 | 0.057 | 0.052 | 0.047 | 0.042 |
| Dec | 0.018 | 0.017 | 0.015 | 0.014 | 0.012 | 0.011 | 0.010 |
| Jan | 0.056 | 0.051 | 0.046 | 0.042 | 0.038 | 0.034 | 0.031 |
| Feb | 0.041 | 0.037 | 0.034 | 0.031 | 0.028 | 0.025 | 0.023 |
| Mar | 0.073 | 0.067 | 0.061 | 0.055 | 0.050 | 0.045 | 0.040 |
| Apr | 0.178 | 0.162 | 0.148 | 0.134 | 0.122 | 0.110 | 0.098 |
| May | 0.123 | 0.112 | 0.102 | 0.093 | 0.084 | 0.076 | 0.068 |
| Jun | 0.070 | 0.064 | 0.058 | 0.053 | 0.048 | 0.043 | 0.038 |
| Jul | 0.070 | 0.064 | 0.058 | 0.053 | 0.048 | 0.043 | 0.039 |
| Aug | 0.060 | 0.055 | 0.050 | 0.046 | 0.041 | 0.037 | 0.033 |
| Sep | 0.061 | 0.056 | 0.051 | 0.046 | 0.042 | 0.038 | 0.034 |

**FINAL RESERVE SUMMARY DETAILS**
EWR (low and total Flows) are constrained to be below Natural Flows

Long term mean flow requirements (Mill. m3 and %MAR)

| Category | Low Flows | | Total Flows | |
|---|---|---|---|---|
| | Mill. m3 | %MAR | Mill. m3 | %MAR |

| | | | | |
|---|---|---|---|---|
| A | 0.556 | 12.3 | 1.496 | 33.1 |
| A/B | 0.522 | 11.5 | 1.399 | 30.9 |
| B | 0.487 | 10.8 | 1.303 | 28.8 |
| B/C | 0.453 | 10.0 | 1.209 | 26.7 |
| C | 0.418 | 9.2 | 1.117 | 24.7 |
| C/D | 0.386 | 8.5 | 1.030 | 22.8 |
| D | 0.356 | 7.9 | 0.944 | 20.9 |

**FLOW DURATION and RESERVE ASSURANCE TABLES**

Columns are FDC precentage points:

**Natural Total flow duration curve (mill. $m^3$)**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 1.517 | 0.529 | 0.265 | 0.154 | 0.083 | 0.054 | 0.034 | 0.020 | 0.013 | 0.007 |
| Nov | 1.461 | 0.844 | 0.409 | 0.214 | 0.097 | 0.060 | 0.033 | 0.027 | 0.013 | 0.006 |
| Dec | 1.035 | 0.570 | 0.355 | 0.127 | 0.060 | 0.047 | 0.027 | 0.020 | 0.013 | 0.006 |
| Jan | 0.674 | 0.281 | 0.114 | 0.074 | 0.047 | 0.034 | 0.020 | 0.020 | 0.013 | 0.006 |
| Feb | 0.737 | 0.214 | 0.107 | 0.060 | 0.040 | 0.034 | 0.020 | 0.013 | 0.007 | 0.006 |
| Mar | 1.243 | 0.348 | 0.245 | 0.147 | 0.064 | 0.040 | 0.034 | 0.013 | 0.013 | 0.006 |
| Apr | 1.366 | 0.543 | 0.362 | 0.194 | 0.111 | 0.060 | 0.036 | 0.020 | 0.013 | 0.000 |
| May | 1.160 | 0.603 | 0.341 | 0.234 | 0.120 | 0.074 | 0.031 | 0.020 | 0.013 | 0.000 |
| Jun | 0.459 | 0.241 | 0.181 | 0.107 | 0.064 | 0.040 | 0.020 | 0.013 | 0.007 | 0.007 |
| Jul | 0.308 | 0.147 | 0.090 | 0.060 | 0.050 | 0.034 | 0.023 | 0.013 | 0.013 | 0.000 |
| Aug | 1.021 | 0.288 | 0.150 | 0.080 | 0.057 | 0.047 | 0.031 | 0.020 | 0.013 | 0.007 |
| Sep | 0.791 | 0.295 | 0.164 | 0.074 | 0.047 | 0.033 | 0.027 | 0.020 | 0.007 | 0.007 |

**Natural Baseflow flow duration curve (mill. $m^3$)**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.235 | 0.112 | 0.083 | 0.060 | 0.042 | 0.033 | 0.022 | 0.017 | 0.008 | 0.007 |
| Nov | 0.219 | 0.133 | 0.108 | 0.079 | 0.053 | 0.034 | 0.027 | 0.018 | 0.011 | 0.006 |
| Dec | 0.218 | 0.105 | 0.076 | 0.060 | 0.047 | 0.034 | 0.024 | 0.013 | 0.011 | 0.006 |
| Jan | 0.134 | 0.064 | 0.047 | 0.043 | 0.032 | 0.024 | 0.020 | 0.015 | 0.008 | 0.006 |
| Feb | 0.123 | 0.072 | 0.041 | 0.038 | 0.028 | 0.022 | 0.013 | 0.013 | 0.007 | 0.006 |
| Mar | 0.222 | 0.071 | 0.054 | 0.045 | 0.034 | 0.027 | 0.017 | 0.013 | 0.011 | 0.005 |
| Apr | 0.268 | 0.126 | 0.073 | 0.060 | 0.036 | 0.029 | 0.020 | 0.013 | 0.009 | 0.000 |
| May | 0.226 | 0.114 | 0.078 | 0.055 | 0.047 | 0.027 | 0.020 | 0.014 | 0.011 | 0.000 |
| Jun | 0.127 | 0.074 | 0.055 | 0.047 | 0.035 | 0.021 | 0.017 | 0.013 | 0.007 | 0.001 |
| Jul | 0.121 | 0.060 | 0.054 | 0.034 | 0.028 | 0.021 | 0.013 | 0.013 | 0.008 | 0.000 |
| Aug | 0.216 | 0.080 | 0.057 | 0.044 | 0.033 | 0.026 | 0.020 | 0.014 | 0.012 | 0.005 |
| Sep | 0.156 | 0.082 | 0.059 | 0.040 | 0.029 | 0.025 | 0.020 | 0.013 | 0.007 | 0.007 |

**Category Low Flow Assurance curves (mill. $m^3$)**

**C/D Category**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.109 | 0.075 | 0.059 | 0.041 | 0.028 | 0.019 | 0.011 | 0.005 | 0.001 | 0.000 |
| Nov | 0.096 | 0.083 | 0.072 | 0.051 | 0.033 | 0.019 | 0.011 | 0.006 | 0.001 | 0.000 |
| Dec | 0.102 | 0.071 | 0.052 | 0.041 | 0.030 | 0.019 | 0.011 | 0.005 | 0.001 | 0.000 |
| Jan | 0.074 | 0.053 | 0.033 | 0.028 | 0.019 | 0.013 | 0.009 | 0.005 | 0.001 | 0.000 |
| Feb | 0.072 | 0.046 | 0.027 | 0.023 | 0.015 | 0.011 | 0.006 | 0.003 | 0.001 | 0.000 |
| Mar | 0.099 | 0.052 | 0.036 | 0.030 | 0.023 | 0.015 | 0.008 | 0.004 | 0.001 | 0.000 |
| Apr | 0.112 | 0.074 | 0.050 | 0.036 | 0.026 | 0.017 | 0.009 | 0.004 | 0.001 | 0.000 |
| May | 0.100 | 0.074 | 0.053 | 0.039 | 0.028 | 0.016 | 0.009 | 0.005 | 0.001 | 0.000 |
| Jun | 0.064 | 0.052 | 0.035 | 0.029 | 0.020 | 0.011 | 0.008 | 0.004 | 0.001 | 0.000 |
| Jul | 0.061 | 0.046 | 0.034 | 0.024 | 0.016 | 0.010 | 0.006 | 0.003 | 0.001 | 0.000 |
| Aug | 0.093 | 0.056 | 0.038 | 0.030 | 0.020 | 0.014 | 0.009 | 0.005 | 0.002 | 0.000 |
| Sep | 0.074 | 0.061 | 0.040 | 0.026 | 0.017 | 0.013 | 0.008 | 0.004 | 0.001 | 0.000 |

**Category Total Flow Assurance curves (mill. $m^3$)**

**C/D Category**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.290 | 0.162 | 0.119 | 0.097 | 0.082 | 0.054 | 0.034 | 0.020 | 0.002 | 0.000 |
| Nov | 0.247 | 0.155 | 0.122 | 0.098 | 0.079 | 0.060 | 0.033 | 0.026 | 0.002 | 0.000 |
| Dec | 0.139 | 0.088 | 0.064 | 0.052 | 0.042 | 0.030 | 0.019 | 0.010 | 0.002 | 0.000 |
| Jan | 0.186 | 0.106 | 0.071 | 0.063 | 0.047 | 0.034 | 0.020 | 0.020 | 0.002 | 0.000 |
| Feb | 0.154 | 0.085 | 0.055 | 0.048 | 0.040 | 0.034 | 0.020 | 0.013 | 0.001 | 0.000 |
| Mar | 0.246 | 0.123 | 0.085 | 0.075 | 0.064 | 0.040 | 0.034 | 0.013 | 0.002 | 0.000 |
| Apr | 0.469 | 0.245 | 0.169 | 0.146 | 0.111 | 0.060 | 0.036 | 0.020 | 0.003 | 0.000 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 0.347 | 0.192 | 0.135 | 0.115 | 0.103 | 0.074 | 0.031 | 0.020 | 0.003 | 0.000 |
| Jun | 0.204 | 0.119 | 0.082 | 0.072 | 0.062 | 0.040 | 0.020 | 0.013 | 0.001 | 0.000 |
| Jul | 0.202 | 0.114 | 0.081 | 0.060 | 0.050 | 0.034 | 0.023 | 0.013 | 0.002 | 0.000 |
| Aug | 0.214 | 0.114 | 0.078 | 0.067 | 0.056 | 0.047 | 0.031 | 0.020 | 0.002 | 0.000 |
| Sep | 0.197 | 0.120 | 0.081 | 0.064 | 0.047 | 0.033 | 0.027 | 0.020 | 0.002 | 0.000 |

## D.5 J3OLIF-EWR9: RDRM REPORT FOR A PES AND REC: C

```
TITLE: RDMR Report
DATE: 2014/12/03

Revised Desktop Model outputs for site: Olif_9

HYDROLOGY DATA SUMMARY

Natural Flows:                          Present Day Flows:
   Area     MAR   Ann.SD    Q75   Ann.     Area     MAR   Ann.SD    Q75   Ann.
  (km^2)      (m^3 * 10^6)         CV     (km^2)      (m^3 * 10^6)         CV
    0.00   13.76   15.16    0.15  1.10      0.00   11.32   14.83    0.00  1.31

% Zero flows =   0.0                    % Zero flows =   7.1
Baseflow Parameters: A = 0.990, B = 0.44Baseflow Parameters: A = 0.990, B = 0.440
BFI = 0.24 : Hydro Index =  19.9        BFI = 0.16 : Hydro Index =  35.5

MONTH   MEAN      SD     CV             MONTH   MEAN      SD     CV
        (m^3 * 10^6)                            (m^3 * 10^6)
 Oct    0.74    1.73    2.34             Oct    0.48    1.71    3.54
 Nov    1.13    3.74    3.31             Nov    0.82    3.72    4.52
 Dec    1.65    6.07    3.68             Dec    1.34    6.08    4.53
 Jan    0.90    2.52    2.79             Jan    0.65    2.37    3.65
 Feb    1.88    5.04    2.68             Feb    1.59    4.95    3.11
 Mar    2.24    4.51    2.02             Mar    1.92    4.42    2.30
 Apr    1.33    2.24    1.68             Apr    1.17    2.22    1.90
 May    1.18    2.83    2.40             May    1.07    2.81    2.63
 Jun    0.62    1.06    1.71             Jun    0.55    1.05    1.91
 Jul    0.63    1.56    2.48             Jul    0.55    1.52    2.77
 Aug    0.79    2.25    2.83             Aug    0.69    2.25    3.28
 Sep    0.67    1.49    2.23             Sep    0.48    1.47    3.08

Critical months: WET : Mar, DRY : Jan
Using  20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET :      0.231, DRY :      0.097


FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of initial SHIFT factors for the Stress Frequency Curves

Category  High SHIFT  Low SHIFT
Wet Season:    A        0.083      0.150
Dry Season:    A        0.658      0.050
Wet Season:  A/B        0.125      0.225
Dry Season:  A/B        0.995      0.125
Wet Season:    B        0.167      0.300
Dry Season:    B        1.333      0.200
Wet Season:  B/C        0.208      0.375
Dry Season:  B/C        1.666      0.275
Wet Season:    C        0.250      0.450
Dry Season:    C        2.000      0.350
Wet Season:  C/D        0.292      0.525
Dry Season:  C/D        2.500      0.425
Wet Season:    D        0.333      0.600
Dry Season:    D        3.000      0.500
```

Perenniality Rules
Non-Perennial Allowed

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

| Stress | Wet Season Flow | Dry Season Flow |
|---|---|---|
| 0 | 0.240 | 0.112 |
| 1 | 0.208 | 0.087 |
| 2 | 0.185 | 0.078 |
| 3 | 0.162 | 0.068 |
| 4 | 0.139 | 0.058 |
| 5 | 0.116 | 0.049 |
| 6 | 0.092 | 0.039 |
| 7 | 0.069 | 0.029 |
| 8 | 0.046 | 0.019 |
| 9 | 0.023 | 0.010 |
| 10 | 0.000 | 0.000 |

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are <  20% of total flows
Adjusted hydrological variability for high flows is  27.45
Maximum high flows are 1000% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

| Category | A | A/B | B | B/C | C | C/D | D |
|---|---|---|---|---|---|---|---|
| Annual | 2.498 | 2.296 | 2.104 | 1.922 | 1.750 | 1.588 | 1.433 |
| Oct | 0.176 | 0.162 | 0.148 | 0.136 | 0.123 | 0.112 | 0.101 |
| Nov | 0.206 | 0.189 | 0.174 | 0.159 | 0.144 | 0.131 | 0.118 |
| Dec | 0.133 | 0.122 | 0.112 | 0.102 | 0.093 | 0.084 | 0.076 |
| Jan | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Feb | 0.148 | 0.136 | 0.124 | 0.114 | 0.103 | 0.094 | 0.085 |
| Mar | 0.466 | 0.429 | 0.393 | 0.359 | 0.327 | 0.296 | 0.268 |
| Apr | 0.307 | 0.282 | 0.259 | 0.237 | 0.215 | 0.195 | 0.176 |
| May | 0.231 | 0.212 | 0.195 | 0.178 | 0.162 | 0.147 | 0.133 |
| Jun | 0.234 | 0.215 | 0.197 | 0.180 | 0.164 | 0.149 | 0.134 |
| Jul | 0.171 | 0.157 | 0.144 | 0.131 | 0.120 | 0.108 | 0.098 |
| Aug | 0.211 | 0.194 | 0.178 | 0.162 | 0.148 | 0.134 | 0.121 |
| Sep | 0.216 | 0.198 | 0.182 | 0.166 | 0.151 | 0.137 | 0.124 |

FINAL RESERVE SUMMARY DETAILS

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

| Category | Low Flows | | Total Flows | |
|---|---|---|---|---|
| | Mill. m3 | %MAR | Mill. m3 | %MAR |
| A | 1.263 | 9.2 | 4.822 | 35.0 |
| A/B | 1.065 | 7.7 | 4.543 | 33.0 |
| B | 0.876 | 6.4 | 4.243 | 30.8 |
| B/C | 0.699 | 5.1 | 3.922 | 28.5 |
| C | 0.542 | 3.9 | 3.586 | 26.1 |
| C/D | 0.397 | 2.9 | 3.241 | 23.6 |
| D | 0.282 | 2.0 | 2.898 | 21.1 |

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:
10 20 30 40 50 60 70 80 90 99

Natural Total flow duration curve (mill. m3)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 1.258 | 0.647 | 0.470 | 0.362 | 0.322 | 0.266 | 0.209 | 0.191 | 0.119 | 0.081 |
| Nov | 2.005 | 1.126 | 0.595 | 0.404 | 0.339 | 0.236 | 0.192 | 0.141 | 0.103 | 0.062 |
| Dec | 2.274 | 1.073 | 0.637 | 0.431 | 0.269 | 0.221 | 0.182 | 0.125 | 0.085 | 0.033 |
| Jan | 2.251 | 0.664 | 0.373 | 0.241 | 0.156 | 0.128 | 0.107 | 0.085 | 0.053 | 0.010 |
| Feb | 6.210 | 1.233 | 0.625 | 0.303 | 0.194 | 0.118 | 0.091 | 0.065 | 0.044 | 0.013 |
| Mar | 8.008 | 2.951 | 1.276 | 0.690 | 0.452 | 0.243 | 0.169 | 0.118 | 0.055 | 0.033 |
| Apr | 4.229 | 1.956 | 1.035 | 0.564 | 0.365 | 0.243 | 0.176 | 0.128 | 0.085 | 0.033 |
| May | 2.520 | 1.237 | 0.574 | 0.422 | 0.302 | 0.226 | 0.174 | 0.141 | 0.107 | 0.054 |
| Jun | 1.674 | 0.651 | 0.386 | 0.319 | 0.285 | 0.239 | 0.183 | 0.131 | 0.118 | 0.075 |
| Jul | 0.915 | 0.652 | 0.517 | 0.364 | 0.288 | 0.236 | 0.188 | 0.151 | 0.131 | 0.084 |
| Aug | 1.019 | 0.650 | 0.492 | 0.377 | 0.319 | 0.262 | 0.236 | 0.206 | 0.146 | 0.085 |
| Sep | 1.200 | 0.605 | 0.409 | 0.362 | 0.310 | 0.249 | 0.213 | 0.184 | 0.141 | 0.095 |

Natural Baseflow flow duration curve (mill. m3)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.424 | 0.313 | 0.259 | 0.213 | 0.190 | 0.159 | 0.119 | 0.109 | 0.086 | 0.046 |
| Nov | 0.459 | 0.339 | 0.298 | 0.231 | 0.196 | 0.168 | 0.137 | 0.108 | 0.087 | 0.040 |
| Dec | 0.399 | 0.274 | 0.240 | 0.211 | 0.175 | 0.151 | 0.129 | 0.108 | 0.076 | 0.033 |
| Jan | 0.416 | 0.258 | 0.181 | 0.140 | 0.125 | 0.101 | 0.095 | 0.074 | 0.053 | 0.010 |
| Feb | 0.889 | 0.381 | 0.217 | 0.155 | 0.124 | 0.106 | 0.078 | 0.054 | 0.043 | 0.013 |
| Mar | 1.098 | 0.616 | 0.353 | 0.200 | 0.157 | 0.131 | 0.114 | 0.076 | 0.054 | 0.030 |
| Apr | 0.689 | 0.498 | 0.306 | 0.194 | 0.168 | 0.134 | 0.110 | 0.096 | 0.057 | 0.030 |
| May | 0.617 | 0.420 | 0.255 | 0.188 | 0.150 | 0.123 | 0.105 | 0.093 | 0.072 | 0.049 |
| Jun | 0.448 | 0.355 | 0.219 | 0.184 | 0.151 | 0.124 | 0.099 | 0.086 | 0.074 | 0.052 |
| Jul | 0.406 | 0.310 | 0.248 | 0.199 | 0.173 | 0.141 | 0.122 | 0.092 | 0.070 | 0.051 |
| Aug | 0.398 | 0.321 | 0.239 | 0.194 | 0.178 | 0.145 | 0.127 | 0.103 | 0.077 | 0.051 |
| Sep | 0.407 | 0.324 | 0.253 | 0.201 | 0.174 | 0.148 | 0.128 | 0.100 | 0.081 | 0.049 |

Category Low Flow Assurance curves (mill. m3)

C Category

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.126 | 0.094 | 0.054 | 0.042 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Nov | 0.128 | 0.103 | 0.073 | 0.036 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Dec | 0.127 | 0.082 | 0.045 | 0.011 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Jan | 0.131 | 0.066 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Feb | 0.222 | 0.119 | 0.024 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Mar | 0.301 | 0.229 | 0.143 | 0.060 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Apr | 0.182 | 0.162 | 0.106 | 0.044 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| May | 0.171 | 0.132 | 0.046 | 0.034 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Jun | 0.127 | 0.105 | 0.034 | 0.032 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Jul | 0.116 | 0.093 | 0.046 | 0.044 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Aug | 0.116 | 0.093 | 0.044 | 0.044 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Sep | 0.115 | 0.095 | 0.042 | 0.037 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Category Total Flow Assurance curves (mill. m3)

C Category

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.760 | 0.342 | 0.141 | 0.099 | 0.053 | 0.028 | 0.003 | 0.002 | 0.000 | 0.000 |
| Nov | 1.114 | 0.530 | 0.152 | 0.102 | 0.021 | 0.003 | 0.002 | 0.001 | 0.000 | 0.000 |
| Dec | 0.762 | 0.356 | 0.179 | 0.011 | 0.003 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 |
| Jan | 0.131 | 0.066 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Feb | 0.929 | 0.425 | 0.118 | 0.003 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 |
| Mar | 2.534 | 1.196 | 0.614 | 0.248 | 0.082 | 0.003 | 0.002 | 0.001 | 0.001 | 0.000 |
| Apr | 1.654 | 0.799 | 0.417 | 0.266 | 0.204 | 0.104 | 0.013 | 0.002 | 0.001 | 0.000 |
| May | 1.277 | 0.611 | 0.280 | 0.201 | 0.165 | 0.118 | 0.078 | 0.009 | 0.001 | 0.000 |
| Jun | 1.246 | 0.576 | 0.271 | 0.201 | 0.167 | 0.154 | 0.114 | 0.072 | 0.002 | 0.000 |
| Jul | 0.814 | 0.447 | 0.218 | 0.167 | 0.122 | 0.112 | 0.089 | 0.052 | 0.002 | 0.000 |
| Aug | 0.915 | 0.530 | 0.258 | 0.196 | 0.150 | 0.139 | 0.110 | 0.065 | 0.002 | 0.000 |
| Sep | 1.094 | 0.322 | 0.213 | 0.160 | 0.107 | 0.080 | 0.056 | 0.025 | 0.001 | 0.000 |

## D.5 J3KAMM-EWR10: RDRM REPORT FOR A PES AND REC: C/D

TITLE: RDMR Report
DATE: 07/31/2014

Revised Desktop Model outputs for site: Kamm_10

**HYDROLOGY DATA SUMMARY**

| Natural Flows: | | | | | Present Day Flows: | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area | MAR | Ann.SD | Q75 | Ann. | Area | MAR | Ann.SD | Q75 | Ann. |
| (km^2) | (m^3 * 10^6) | | | CV | (km^2) | (m^3 * 10^6) | | | CV |
| 0.00 | 20.57 | 26.92 | 0.20 | 1.31 | 0.00 | 19.63 | 30.47 | 0.00 | 1.55 |

% Zero flows = 0.0 % Zero flows = 42.3
Baseflow Parameters: A = 0.990, B = 0.44Baseflow Parameters: A = 0.990, B = 0.440
BFI = 0.23 : Hydro Index = 24.9 BFI = 0.15 : Hydro Index = 50.7

| MONTH | MEAN | SD | CV | MONTH | MEAN | SD | CV |
|---|---|---|---|---|---|---|---|
| | (m^3 * 10^6) | | | | (m^3 * 10^6) | | |
| Oct | 1.86 | 3.06 | 1.64 | Oct | 1.53 | 3.66 | 2.40 |
| Nov | 2.01 | 5.23 | 2.60 | Nov | 1.68 | 6.13 | 3.66 |
| Dec | 1.09 | 2.12 | 1.95 | Dec | 0.63 | 2.42 | 3.84 |
| Jan | 0.58 | 1.24 | 2.15 | Jan | 0.28 | 1.39 | 4.96 |
| Feb | 0.87 | 2.96 | 3.39 | Feb | 0.68 | 3.34 | 4.91 |
| Mar | 1.31 | 4.09 | 3.13 | Mar | 1.21 | 4.70 | 3.89 |
| Apr | 1.13 | 2.91 | 2.58 | Apr | 1.09 | 3.28 | 3.00 |
| May | 2.65 | 7.66 | 2.90 | May | 2.84 | 8.60 | 3.03 |
| Jun | 1.68 | 3.77 | 2.25 | Jun | 1.84 | 4.44 | 2.41 |
| Jul | 2.26 | 8.46 | 3.75 | Jul | 2.41 | 9.30 | 3.86 |
| Aug | 3.05 | 7.33 | 2.40 | Aug | 3.39 | 8.33 | 2.46 |
| Sep | 2.10 | 3.12 | 1.49 | Sep | 2.05 | 3.67 | 1.79 |

Critical months: WET: Sep, DRY: Feb
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 0.273, DRY : 0.108

**FLOW - STRESSOR RESPONSE DATA SUMMARY**

Table of initial SHIFT factors for the Stress Frequency Curves

| Category | High SHIFT | Low SHIFT |
|---|---|---|
| A | 0.086 | 0.086 |
| A/B | 0.129 | 0.129 |
| B | 0.171 | 0.171 |
| B/C | 0.214 | 0.214 |
| C | 0.257 | 0.257 |
| C/D | 0.300 | 0.300 |
| D | 0.343 | 0.343 |

Perenniality Rules
Wet Season Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

| Stress | Wet Season Flow | Dry Season Flow |
|---|---|---|
| 0 | 0.296 | 0.110 |
| 1 | 0.240 | 0.095 |
| 2 | 0.200 | 0.080 |
| 3 | 0.160 | 0.070 |
| 4 | 0.130 | 0.060 |
| 5 | 0.105 | 0.052 |
| 6 | 0.080 | 0.045 |

| | | |
|---|---|---|
| 7 | 0.063 | 0.038 |
| 8 | 0.047 | 0.028 |
| 9 | 0.028 | 0.016 |
| 10 | 0.000 | 0.000 |

**HIGH FLOW ESTIMATION SUMMARY DETAILS**

No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 50.00
Maximum high flows are 362% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

| Category | A | A/B | B | B/C | C | C/D | D |
|---|---|---|---|---|---|---|---|
| Annual | 4.160 | 3.800 | 3.462 | 3.144 | 2.846 | 2.566 | 2.303 |
| Oct | 0.540 | 0.493 | 0.449 | 0.408 | 0.369 | 0.333 | 0.299 |
| Nov | 0.332 | 0.303 | 0.276 | 0.251 | 0.227 | 0.205 | 0.184 |
| Dec | 0.340 | 0.311 | 0.283 | 0.257 | 0.233 | 0.210 | 0.188 |
| Jan | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Feb | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Mar | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Apr | 0.269 | 0.245 | 0.224 | 0.203 | 0.184 | 0.166 | 0.149 |
| May | 0.307 | 0.281 | 0.256 | 0.232 | 0.210 | 0.190 | 0.170 |
| Jun | 0.499 | 0.456 | 0.416 | 0.378 | 0.342 | 0.308 | 0.276 |
| Jul | 0.575 | 0.526 | 0.479 | 0.435 | 0.394 | 0.355 | 0.319 |
| Aug | 0.654 | 0.597 | 0.544 | 0.494 | 0.447 | 0.403 | 0.362 |
| Sep | 0.644 | 0.588 | 0.536 | 0.487 | 0.440 | 0.397 | 0.356 |

**FINAL RESERVE SUMMARY DETAILS**

EWR (low and total Flows) are constrained to be below Natural Flows

Long term mean flow requirements (Mill. m3 and %MAR)

| Category | Low Flows | | Total Flows | |
|---|---|---|---|---|
| | Mill. m3 | %MAR | Mill. m3 | %MAR |
| A | 2.792 | 13.6 | 7.030 | 34.2 |
| A/B | 2.566 | 12.5 | 6.510 | 31.6 |
| B | 2.367 | 11.5 | 6.014 | 29.2 |
| B/C | 2.177 | 10.6 | 5.531 | 26.9 |
| C | 1.999 | 9.7 | 5.065 | 24.6 |
| C/D | 1.831 | 8.9 | 4.607 | 22.4 |
| D | 1.673 | 8.1 | 4.168 | 20.3 |

**FLOW DURATION and RESERVE ASSURANCE TABLES**

Columns are FDC precentage points:
10 20 30 40 50 60 70 80 90
99

**Natural Total flow duration curve (mill. m$^3$)**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 3.995 | 2.259 | 1.743 | 1.189 | 0.984 | 0.850 | 0.700 | 0.516 | 0.393 | 0.132 |
| Nov | 4.042 | 2.089 | 1.262 | 0.943 | 0.733 | 0.595 | 0.483 | 0.390 | 0.264 | 0.083 |
| Dec | 2.293 | 1.364 | 0.991 | 0.684 | 0.552 | 0.382 | 0.253 | 0.189 | 0.132 | 0.064 |
| Jan | 1.542 | 0.585 | 0.388 | 0.321 | 0.233 | 0.197 | 0.157 | 0.111 | 0.073 | 0.033 |
| Feb | 1.570 | 0.560 | 0.259 | 0.230 | 0.181 | 0.145 | 0.100 | 0.067 | 0.051 | 0.031 |
| Mar | 2.702 | 0.881 | 0.497 | 0.281 | 0.177 | 0.145 | 0.117 | 0.066 | 0.050 | 0.033 |
| Apr | 3.045 | 0.943 | 0.511 | 0.403 | 0.276 | 0.178 | 0.149 | 0.123 | 0.067 | 0.022 |
| May | 5.095 | 2.215 | 1.216 | 0.539 | 0.329 | 0.264 | 0.188 | 0.155 | 0.105 | 0.023 |
| Jun | 2.930 | 1.533 | 1.000 | 0.708 | 0.544 | 0.382 | 0.264 | 0.199 | 0.142 | 0.052 |
| Jul | 3.918 | 1.967 | 1.359 | 0.976 | 0.771 | 0.463 | 0.356 | 0.298 | 0.232 | 0.118 |
| Aug | 4.900 | 2.921 | 1.858 | 1.296 | 1.042 | 0.683 | 0.536 | 0.388 | 0.332 | 0.173 |
| Sep | 6.715 | 2.362 | 1.738 | 1.274 | 1.010 | 0.833 | 0.619 | 0.507 | 0.387 | 0.165 |

**Natural Baseflow flow duration curve (mill. m$^3$)**

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 99 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.937 | 0.660 | 0.501 | 0.428 | 0.347 | 0.292 | 0.233 | 0.188 | 0.143 | 0.082 |
| Nov | 0.854 | 0.668 | 0.506 | 0.426 | 0.358 | 0.283 | 0.232 | 0.188 | 0.139 | 0.078 |
| Dec | 0.610 | 0.508 | 0.427 | 0.352 | 0.267 | 0.235 | 0.188 | 0.157 | 0.112 | 0.064 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 0.413 | 0.348 | 0.278 | 0.241 | 0.203 | 0.159 | 0.131 | 0.100 | 0.067 | 0.033 |
| Feb | 0.423 | 0.258 | 0.226 | 0.189 | 0.150 | 0.134 | 0.089 | 0.067 | 0.045 | 0.031 |
| Mar | 0.556 | 0.308 | 0.243 | 0.175 | 0.145 | 0.133 | 0.093 | 0.066 | 0.046 | 0.032 |
| Apr | 0.593 | 0.307 | 0.235 | 0.204 | 0.150 | 0.135 | 0.110 | 0.082 | 0.053 | 0.022 |
| May | 0.967 | 0.493 | 0.339 | 0.216 | 0.166 | 0.146 | 0.124 | 0.106 | 0.063 | 0.022 |
| Jun | 0.790 | 0.392 | 0.333 | 0.250 | 0.200 | 0.157 | 0.130 | 0.106 | 0.070 | 0.026 |
| Jul | 0.916 | 0.556 | 0.367 | 0.328 | 0.253 | 0.178 | 0.151 | 0.127 | 0.089 | 0.049 |
| Aug | 0.937 | 0.650 | 0.506 | 0.388 | 0.297 | 0.238 | 0.180 | 0.139 | 0.114 | 0.054 |
| Sep | 1.199 | 0.632 | 0.502 | 0.359 | 0.292 | 0.259 | 0.206 | 0.166 | 0.123 | 0.076 |

**Category Low Flow Assurance curves (mill. $m^3$)**
**C/D Category**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 0.379 | 0.379 | 0.318 | 0.272 | 0.218 | 0.140 | 0.070 | 0.043 | 0.025 | 0.013 |
| Nov | 0.374 | 0.371 | 0.317 | 0.264 | 0.214 | 0.135 | 0.068 | 0.043 | 0.024 | 0.013 |
| Dec | 0.291 | 0.291 | 0.264 | 0.214 | 0.164 | 0.129 | 0.092 | 0.062 | 0.034 | 0.012 |
| Jan | 0.216 | 0.216 | 0.185 | 0.158 | 0.126 | 0.073 | 0.029 | 0.019 | 0.008 | 0.004 |
| Feb | 0.164 | 0.154 | 0.138 | 0.116 | 0.090 | 0.049 | 0.000 | 0.000 | 0.000 | 0.000 |
| Mar | 0.227 | 0.199 | 0.166 | 0.117 | 0.091 | 0.059 | 0.017 | 0.015 | 0.005 | 0.003 |
| Apr | 0.239 | 0.201 | 0.155 | 0.128 | 0.092 | 0.054 | 0.015 | 0.006 | 0.001 | 0.001 |
| May | 0.377 | 0.285 | 0.219 | 0.150 | 0.107 | 0.060 | 0.025 | 0.017 | 0.006 | 0.001 |
| Jun | 0.330 | 0.251 | 0.208 | 0.162 | 0.119 | 0.066 | 0.029 | 0.019 | 0.008 | 0.002 |
| Jul | 0.325 | 0.305 | 0.242 | 0.208 | 0.156 | 0.092 | 0.047 | 0.036 | 0.018 | 0.004 |
| Aug | 0.396 | 0.359 | 0.316 | 0.242 | 0.189 | 0.132 | 0.083 | 0.054 | 0.033 | 0.010 |
| Sep | 0.383 | 0.335 | 0.282 | 0.221 | 0.175 | 0.139 | 0.104 | 0.074 | 0.040 | 0.017 |

**Category Total Flow Assurance curves (mill. $m^3$)**
**C/D Category**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct | 1.217 | 0.837 | 0.670 | 0.606 | 0.551 | 0.452 | 0.320 | 0.189 | 0.030 | 0.013 |
| Nov | 0.889 | 0.652 | 0.534 | 0.469 | 0.418 | 0.327 | 0.221 | 0.133 | 0.027 | 0.013 |
| Dec | 0.818 | 0.579 | 0.485 | 0.424 | 0.373 | 0.325 | 0.248 | 0.154 | 0.037 | 0.012 |
| Jan | 0.216 | 0.216 | 0.185 | 0.158 | 0.126 | 0.073 | 0.029 | 0.019 | 0.008 | 0.004 |
| Feb | 0.164 | 0.154 | 0.138 | 0.116 | 0.090 | 0.049 | 0.000 | 0.000 | 0.000 | 0.000 |
| Mar | 0.227 | 0.199 | 0.166 | 0.117 | 0.091 | 0.059 | 0.017 | 0.015 | 0.005 | 0.003 |
| Apr | 0.656 | 0.429 | 0.330 | 0.294 | 0.257 | 0.178 | 0.138 | 0.079 | 0.003 | 0.001 |
| May | 0.854 | 0.546 | 0.419 | 0.340 | 0.296 | 0.238 | 0.167 | 0.100 | 0.008 | 0.001 |
| Jun | 1.105 | 0.675 | 0.533 | 0.470 | 0.427 | 0.354 | 0.259 | 0.153 | 0.012 | 0.002 |
| Jul | 1.218 | 0.794 | 0.617 | 0.563 | 0.511 | 0.425 | 0.313 | 0.191 | 0.023 | 0.004 |
| Aug | 1.411 | 0.914 | 0.743 | 0.646 | 0.591 | 0.510 | 0.385 | 0.230 | 0.038 | 0.010 |
| Sep | 1.382 | 0.882 | 0.702 | 0.619 | 0.572 | 0.511 | 0.402 | 0.248 | 0.046 | 0.017 |

# APPENDIX E: COMMENTS AND RESPONSE REGISTER

| Section | Report Statement | Comments | Addressed in Report? | Author Comment |
|---|---|---|---|---|
| **Comments: Andrew Gordon – DWS WC: Resource Protection, received 22 April 2015** | | | | |
| Executive Summary | EcoClassification summary table | As this section is written in italics shouldn't all genus and species names be in normal font?<br>Need genus name written in full. | Yes | |
| | EWR quantification table | Discrepancy between Doring_EWR7 pMAR (MCM) value provided and pMAR (MCM) provided in Table 7.1 | Yes | |
| Table of Contents | | Chapter 6 – page numbers incorrect. | Yes | |
| Acronyms | | Add details for FDI | Yes | |
| 2.1 | Different processes are followed to assign a category (A→F; A = Natural, and F = critically modified) to each component. | Might also be useful to present a description of the ecological categories in table form too. | No | |
| 3.1 | | As a more general comment, I was surprised that the EIS for the Duiwenhoks and Doring sites were rated as Low. I know that there is a model which is followed to produce these, but in the context of the Western Cape where alien fish species completely dominate so many rivers, I feel that any river still possessing indigenous fish is of more than Low importance. I notice that the desktop PES/EIS study undertaken in 2013 rated the Duiwenhoks EI as Moderate and ES as Very High, and the Doring EI also Moderate and ES as High (it also rated the Kammanassie EI as High and ES as Very High while the Gouritz Reserve Study rated it as Low). I realise the | | One cannot compare EIS results with ES results. The one includes importance and the other only relates to sensitivity. The way the model works is if there is a single macroinvertebrate taxon which rates a 5 for sensitivity, then it overrides all other results and come out as Very High. If there is a 4, then High. This is usually related to invertebrates as there is almost always some sensitive invertebrate taxa that occurs in all rivers that are seasonal or perennial (not ephemeral). The rating therefore has nothing to do with the issues raised in the |

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| | | 2013 study was desktop and the Gouritz Reserve Study actually visited the sites, but to me it's problematic that the two studies arrive at such different conclusions. I imagine that changing the EIS from Low to Moderate (for example) won't change the Reserve, but it does make quite a difference in the perception of the importance of those rivers within the Department and among the public. Perhaps the Project Team could check their EIS assessment for these sites and ensure they are confident with their conclusions? | | comment.<br><br>The way the EIS model works is that it is an average. So if you want to see what the fish ratings are, you have to look at the individual relevant metric. For the instream biota, the importance will reflect whichever reflects the highest rating between fish and invertebrates.<br><br>Whatever the case may be, as is rightly indicated, changing to Moderate will not change the result. Furthermore, the REASON why it was rated Low was, amongst others, the presence of alien fish. Therefore, the EIS does not indicate threats or compare the fact that some indigenous fish survive in this river and not in others – this is a conservation and management issue. These results (following consistent model rules) are purely there to indicate whether one needs to improve the category or maintain it (by means of flow). Moderate will imply maintenance of the present state, as do a Low EIS. One therefore has to look at the context of what the DWS EIS model tells you and how it is used and not confuse it with biodiversity or |

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| | | | | conservation aims, which although of course important, should be addressed by DEA or CapeNature. They should share the concern raised here, and the fact that the importance is Low should encourage them to do something about it to increase importance. |
| 3.1 | Species intolerant to physico-chemical changes: *Pseudobarbus burchelli* (one of three fish species sampled which was sensitive to water quality). | But on the next page under the fish section it is mentioned that *P burchelli* wasn't actually sampled – just considered likely to occur there at low FROC? Perhaps this should be made a bit explicit, otherwise the reader of this summary thinks this species was actually sampled. Some text change is suggested. | Yes | |
| Table 3.1 | Diatom data indicates Moderate water quality with nutrient levels, organic pollution and salinity levels being high and problematic. Moderate oxygenation rates and heavy pollution levels prevailed. | The contrast between the "moderate water quality" and in next sentence "heavy pollution levels" has confused me at other places in the report where this info is presented. Only when I read the Diatom report in the appendix was it clear that 2 classification methods were used for diatoms (Van Dam and the SPI). In this case the SPI says Moderate while Van Dam approach says heavily polluted. I think if these few sentences are rewritten to reflects this then a lot of confusion will be avoided. | Yes | |
| 3.2 | The PES EcoStatus is a C/D EC and the EcoStatus models are provided electronically. The major issues that have caused | EC is a D according to Table 3.2. It is not clear whether the issues are both flow and non-flow, or mainly flow and to some extent non-flow. If the | Yes | |

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| | the change from reference condition were mainly flow and non-flow related issues. | former, then I think take out "mainly". If the latter then add "some" before "non-flow". | | |
| 4.2 | The wettest and driest months were identified as October and February. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow). | Please check that this is correct. The Goukou's driest month is stated as July, and it is the adjacent secondary catchment. | No | According to the baseflow separation undertaken within the RDRM model, February is the driest base flow month for the Duiwenhoks. The mean flows (without baseflow separation) for February are much lower than June/July, according to the hydrological data. |
| Table 4.5; 4.6 | * Refers to frequency of occurrence per year, i.e. how often will the flood occur per year. | Perhaps mention that 1:3 means once every three years. | Yes | |
| Table 8.3 | **Fish stress: 8.6.** Very limited fast very shallow habitat in riffles, allowing very limited fish movement. No migration or fish spawning habitat required. Poor to moderate water quality. | Is this correct? The sentence states very limited fish movement at this flow, but then if no migration habitat required the stress would be lower? | Yes | |
| Relevant tables | Add stress values for fish and macroinvertebrates where applicable. | | Yes | |
| **Comments: Simon von Witt – AECOM SA (Pty) Ltd, received 6 May 2015** | | | | |
| | | General editorial comments and suggested changes. | Yes | |
| **Comments: Thapelo Machaba – DWS: CD: SWRR, received 12 June 2015** | | | | |
| | | No map indicating the EWR points, it must be added. | Yes | |
| Page 35 | | Page 35 error indicating that the PES Ecostatus is a C/D. | Yes | |

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| | | Number of spelling errors. | Yes | |
| **Comments: Dr cate Brown – External reviewer, received 22 April 2015** | | | | |
| | | The hydrological PES comments are full of contradictions. Please see Section-specific comments. | Yes | Agreed. Part this is due to the low confidence in the hydrology due to the lack of updated present day use. Hydrology has been changed to fit in some cases gauged data as well as anecdotal information. This was reviewed by the hydrologist. |
| | EcoClassification: Hydrology sections | I disagree that hydrology should be given a "B" in cases where a perennial river has become a seasonal river as a result of abstraction (please see the Section-specific comments):<br>▪ it masks a very serious problem with respect to river management/protection in the region;<br>▪ it has very serious implications for biota with life-cycles ≥ 1 year. | No | Regarding the B. We agree, however this is how the IHI model works. There is no threshold for these changes and if the other hydrology metrics show little changes, this is the result. Regarding the secondary bullets - and this comes up again in the review further - the 'rule' we follow is that if the importance is moderate, we will set the REC to maintain the PES. This means that we have no grounds for improving the hydrology with the resulting improved responses. |
| | | This is related to the confusing hydrology explanations. I have serious reservations about the EWR for the Goukou and Doring River. The main reasons for this are that some of the text in Section 5 and 7suggests that the river was perennial, but the EWR calls for zero low flows in some months of the year. Please see the Section- | No | See above. If the river drives up currently, and we are maintaining the PES (given the assumption that there is no negative trend) then we cannot recreate a perennial river. |

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| | | specific comments for Goukou River. | | |
| | | I do not think the EWRs for Doring and possibly also the Kammansie should be viewed as Intermediate because the confidence in the supporting hydrological data is so low. As indeed is the confidence for fish and macroinvertebrates. | Yes | Clarified in the report. The methods used and survey detail were the same as for the intermediate bar geomorph - this does not guarantee improved confidence. |
| Section 1.4 | | Data availability comes before any comment on the level of Reserve determination that was being done (Section 2). This meant I had to move to the next section in order to know the context in which to place the information given in Section 1.4. I am unsure of the solution to this – but suggest that if possible it should come after the first paragraph in Section 2. | Yes | |
| Whole report | | Use of which an that.<br>Data are plural.<br>The tenses vary between past and present in places in the document | Yes | |
| | | Please include a table given range of confidence scores and definitions | Yes | |
| Table 1.2 | "Data collected during site visit (June 2014). Other sites visits have been conducted by the author with regard to Environmental Impact Assessment related studies for Wind Farms (behalf of CSIR, 2012 and 2013), road upgrades for SANRAL and the Fibre Optic data cable (FibreCo) connecting Port Elizabeth, George, Uniondale, | Who is "the author"?<br>State number of surveys. | Yes | |

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| | Willomore and Riversdale.”<br><br>Surveys of the river topography at the EWR sites were done between January and June 2014”. | | | |
| Section 2 | “However, to increase the confidence and supply the needs for the estuarine scenarios, the Intermediate method was followed with the ony deviation from the method being the exclusion of geomorphology.” | Section 1.4 suggests that the Confidence for some of discipline is extremely low, e.g., Doring River PD = 1. Surely doing an Intermediate level assessment cannot lead to great confidence when the base data are so poor. | Yes | See author’s comments under EcoClassification: Hydrology sections. |
| Section 2.1 | | “The EcoClassification process was done in accordance with Kleynhans and Louw (2007b). | Yes | |
| Section 2.2 | | I think saying HSFR is “*a modification of the Building Block Methodology (BBM*)” is misleading. The two methods bear little resemblance to on another. | Yes | Modification should probably be something in the line of a further or subsequent development as many of the basic principles are still there. Reworded. |
| Section 2.2.1 | “A process using the hydraulic and hydrology information has been built into the RDRM (Hughes et al., 2011). | Please could you explain this more fully? What process? And what does do to assist compilation of stress indices? Not long – another sentence should do it. | Yes | |
| Section 2.2.2 | | Correct reference to DRIFT | Yes | The suggested reference was included: KING, J.M., BROWN, C.A. and SABET, H. 2003. A scenario-based holistic approach to environmental flow assessments for regulated rivers. *Rivers Research and Application*s 19 (5-6). Pg 619-640. |

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| Section 3.1 | The EIS evaluation resulted in a **LOW** importance. | Just a comment to say that I am surprised by this | | |
| Table 3.1 | “The baseflow volumes have decreased significantly in volume but not in seasonal distribution and appear to be continuous throughout the year.” In the paragraph after the table: “Abstraction has resulted in decreased base flows and possibly zero flows at times.” | There is an apparent contradiction in this section that would benefit from some additional explanation | Yes | |
| Section 3.2 – paragraph after Table 3.1 | | Suggested rewording. Applicable to all relevant sections in the report | Yes | |
| Section 3.4 – Table 3.2 | | It seems that the lowflows have been severely depleted even though the rest of the flow regime seems to be okay. This is typical of Western Cape Rivers, where the dry season coincides with the growing season. I disagree that hydrology should be given a “B” in these cases, as it masks a very serious problem with respect to river management/protection in the region. | | See author’s comments under EcoClassification: Hydrology sections |
| Section 5.1 – Table 5.1 - Hydrology | | There are apparent contradictions in this section that would benefit from some additional explanation. I cannot work out how you state that the river was perennial. I think this is important because the EWR (Table 6.6 and 6.7) has some zero flow for maintenance EWRs, which in my opinion should never be the case if the river was naturally perennial. | No | Although the sentiment has by sympathies, we cannot improve the PES without sufficient motivation. |
| Section 5.1 – Table 5.1 – Fish and Macroinvertebrates | Fish: “A further important impact includes the deterioration in water quality (probably significant during low summer | There are apparent contradictions in this section that would benefit from some additional explanation. | Yes | |

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| | flows) due to polluted return flows from agriculture".<br><br>Macroinvertebrates: "Heptageniid mayflies, five different species of baetid mayflies and > 2 hydropsychid species were present. These collectively indicate relatively good quality water." But also: "Change in water quality (cumulative effects of agriculture and return flows – e.g. elevated nutrients, salts and some toxicity)" | | | |
| Section 5.4 | | It seems that the lowflows have been severely depleted even though the rest of the flow regime seems to be okay. This is typical of Western Cape Rivers, where the dry season coincides with the growing season. I disagree that hydrology should be given a "B" in these cases, as it masks a very serious problem with respect to river management/protection in the region. | No | See author's comments under EcoClassification: Hydrology sections |
| Section 7.2- Table 7.1 - Hydrology | "The nMAR is 4.52 MCM and the pMAR is 0.86 MCM (19.03% of the nMAR). There is no available observed data. Baseflows have decreased significantly in volume and appear to be continuous throughout the year. The seasonal distribution has changed with peak flows now in March instead of May. Distribution of monthly flows is | There are apparent contradictions in this section that would benefit from some additional explanation.<br>Also: Suggested correction: (Withers Environmental Consultants, 2012). | Yes | This hydrology was a complete mess and it was difficult accommodating all the very emotional and localised information. But yes, due to the sensitivities around this system etc, it is essential to add additional explanations. |

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| | flattened throughout the year. These changes are mainly due to Tierpoort Dam, farm dams, irrigation and grazing. Small floods have changed due to dams and irrigation. Note that there is low confidence in the hydrology (reasons provided in Chapter 8). There is however substantial anacdotal evidence that the river has stopped flowing and that some pools have even dried up in recent years (Withers Environmentl Consultants, 2012)." | | | |
| Section 13.2.1 – Table 13.4 | | Overall confidence missing for Doring River. | Yes | |
| | | How does the overall confidence for the Kammanssie end up being a 5? | Yes | A mistake - must be 2.5 |
| Section 13.3 - Recommendations | "The confidence in the EcoClassification is generally moderate which is acceptable for a Rapid to Intermediate assessment." | I thought this was now "an Intermediate without geomorphology". | Yes | We have interpreted an intermediate without geomorph as lying between Rapid to Intermediate - Rephrased. |
| Section 14 - References | | The reference list is incomplete | Yes | |
| **Comments: Aldu le Grange – AECOM SA (Pty) Ltd, received 21 October 2015** | | | | |
| Whole report | | Address grammatical errors as provided. | Yes | |
| Executive summary | EWR sites | Check reference: DWA (2014a). Not listed in reference list | Yes | |
| | Conclusions and Recommendations | Check spelling of gauge throughout. Grammatical error. | Yes | |
| Table of contents | | Page numbering of References chapter incorrect. | Yes | |
| Acronyms | | Add unlisted acronyms | Yes | |
| 1.3 | | Check reference: DWA (2014a). Not | Yes | |

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| | | listed in reference list | | |
| 4.2 | The wettest and driest months were identified as October and February respectively. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow). | Wettest in October for a coastal River – is this current and is the catchment summer rainfall based.<br><br>Page A-3 states: The **Duiwenhoks catchment** has a lower rainfall spread evenly throughout the year (Ogden, 2013). The Fynbos Biome has all-year rainfall with slightly less rain in summer and highest rainfall in winter, mainly between March and August. | Yes | The team used the the hydrology data that AECOM provided. Its not a question of summer *versus* winter, as some of these catchments get a combination of summer and winter rainfall with variability thrown in! Page A3 statement is that the rainfall is spread more evenly across the year. |
| 4.5 | The DWS gauge H8001 was present in the reach and used to verify high flows. | How responsible was the gauge in verifying high flows. Or what is meant by high flows. | Yes | |
| 6.2; 8.2 | The wettest and driest months were identified as October and July, respectively. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow). | This relates to a summer rainfall pattern – is this correct? | No | The team used the the hydrology data that AECOM provided and assumed it was accurate. |
| Table 7.1 | Baseflows have decreased significantly in volume. | Why | Yes | |
| | Water quality at the site shows elevated salts and nutrients, with some impact on turbidity, oxygen and temperatures at low flows, exacerbated by abstraction and excavation activities in the Doring and Lemoenshoek tributary. | What kind of excavation and for what purpose | | |
| Appendices | | Editorial and Technical queries | Yes | |