REPORT NUMBER: RDM/WMA06/00/CON/COMP/0216

PROJECT NUMBER: WP 10974

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

EWR REPORT

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

AUGUST 2016

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

RIVER EWR REPORT

Report Number: RDM/WMA06/00/CON/COMP/0216

AUGUST 2016

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa, August 2016. Determination of Ecological Water Requirements for Surface water (river, estuaries and wetlands) and Groundwater in the Lower Orange WMA.River EWR report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Authored by Louw D, Birkhead D, Koekemoer S, Mare M. DWS Report No: RDM/WMA06/00/CON/COMP/0216.

DOCUMENT INDEX

Index Number	DWS Report Number	Report Title
1	RDM/WMA06/00/CON/COMP/0115	Inception report
2	RDM/WMA06/00/CON/COMP/0116	Resource Unit report
3	**RDM/WMA06/00/CON/COMP/0216**	**River EWR report**
4	RDM/WMA06/00/CON/COMP/0316	Buffels, Sout, Swartlintjies, Spoeg, Groen Estuary EWR report
5	RDM/WMA06/00/CON/COMP/0416	Groundwater EWR report
6	RDM/WMA06/00/CON/COMP/0516	BHNR report
7	RDM/WMA06/00/CON/COMP/0616	Wetland EWR report
8	RDM/WMA06/00/CON/COMP/0117	Report on consequences of scenarios
9	RDM/WMA06/00/CON/COMP/0217	EcoSpecs and monitoring report
10	RDM/WMA06/00/CON/COMP/0317	Main Summary report
11	RDM/WMA06/00/CON/COMP/0417	Close-out report
12	RDM/WMA06/00/CON/COMP/0517	Electronic data

DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

RIVER EWR REPORT

Approved for RFA by:

………………………………….. …12 October 2016…….

Delana Louw Date

Project Manager

DEPARTMENT OF WATER AND SANITATION (DWS)

Approved for DWS by:

………………………………….. …………………………………..

Chief Director: Water Ecosystems Date

ACKNOWLEDGEMENTS

The following persons contributed to this report:

Authors	Company
Louw, Delana	Rivers for Africa eFlows Consulting (Pty) Ltd.
Birkhead, Drew	Streamflow Solutions
Koekemoer, Shael	Koekemoer Aquatic Services
Mare, Manie	WRP

Report editor: Shael Koekemoer

REPORT SCHEDULE

Version	Date
First draft	31 August 2016
Final	

EXECUTIVE SUMMARY

BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the 'Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries and wetlands) and Groundwater in the Lower Orange Water Management Area (WMA). Rivers for Africa was appointed as the Professional Service Provider (PSP) to undertake this study.

PURPOSE OF REPORT

The purpose of this report is to:

- Summarise the Orange River Ecological Water Requirements (EWRs).
- Provide the desktop EWRs for the quaternary catchments focussing on the tributaries of the Lower Orange River.

QUATERNARY CATCHMENT SYSTEMS HYDROLOGY

Results from the Gap analysis recommended the use of the following hydrology datasets to provide the natural and present day flows required for this study:

- ORASECOM Integrated Water Resources Management Plan (IWRMP) Phase 2 study (ORASECOM, 2014) Pitman Model setup for natural and current day flows per quaternary for the Lower Orange excluding the Molopo River and the small coastal rivers.
- The Water Resource Yield Model setup as prepared for the ORASECOM IWRMP Phase 2 study (ORASECOM, 2014) for Molopo River catchment, as this network detail was at a quaternary level.
- Pitman Model Setup and data from the WR2012 Study recently completed for the Small West Coast Rivers.

EWR SITES: ECOCLASSIFICATION RESULT SUMMARY (ORANGE RIVER)

The results from Louw and Koekemoer (2010) and Louw *et al*. (2013) are summarised below.

EcoClassification result summary of EWR sites located in the Orange River

EWR site	PES	EIS	REC	Comment
EFR O2	**C**	High	**C**	The PES is a result of the loss of frequency of large floods, agricultural return flows, higher low flows than natural in the dry season (droughts and dry periods), decreased low flows in other times, release of sediments and presence of alien fish species and the barrier effect of the dam. As the EIS is High, the REC should be an improvement of the EIS. Due to the constraints of the dam, it is however not possible to achieve the REC.
EFR O3	**C**	High	**B**	The PES is a result of the same impacts listed above. As the EIS is High, the REC should be an improvement of the EIS. To achieve this, it will be required to reinstate droughts (i.e., lower flows than present during the dry season, to improve (increase) the wet season base flows and to clear alien vegetation and improve agricultural practices.
EFR O4	**C**	High	**B/C**	The PES is a result of the same activities as above and mining activities also play a role in this area. As the EIS is High, the REC should be an improvement of the EIS. To achieve the improved REC, wet season base flows must be increased, alien vegetation must be cleared and grazing and trampling must be controlled.
EFR O5	**B/C**	High	**B**	The PES is again the result of the same issues as listed for EFR O2. As the EIS is High, the REC should be an improvement of the EIS. To achieve the improved REC, wet season base flows must be increased and dry season droughts must be reinstated.

Estuary	**D**	Very High	**C**	The PES is a result of the following: Flow-related impacts: Decreased frequency of small and moderate floods. Higher low flows than natural in the dry season preventing mouth closure and related back flooding. Agricultural return flows cause water quality problems. Non-flow-related impacts: Road infrastructure (crossing salt marsh) and levees. Recreational fishing (specifically, uncontrolled catches a few orders of magnitude greater than legal bag limits) and gill netting. Mining activities. Grazing and hunting on the flood plain. Improvement requires decreased (from present) dry season base flows and droughts to be reinstated, i.e. decreased flow at times during the dry season to facilitate mouth closure two to four times in 10 years. Institute non-flow-related measures (e.g. remove causeway, reduce nutrient input and fishing pressure).

EWR SITES: EWR RESULT SUMMARY

The results for the EWR sites located in the Orange River are provided below (Louw and Koekemoer, 2010;Louw *et al*., 2013) are summarised below. The final flow requirements, expressed as a percentage of the natural MAR (nMAR).

Summary of EWR results as a percentage of the natural MAR

Site	EC	Maintenance low flows		Drought low flows		High flows		Long-term mean	
		(%nMAR)	Mm^3	(%nMAR)	Mm^3	(%nMAR)	Mm^3	(% nMAR)	Mm^3
EWR O2	PES/REC	11.6	1226.55	4.4	465.24	5.4	570.98	15.2	1607.20
EWR O3	PES: C	8.4	883.10	2.6	273.34	4.7	494.12	11.9	1251.06
	REC: B	17.6	1850.31	3.4	157.37	4.7	494.12	19.2	2018.52
EWR O4	PES: C	6.3	651.11	0.9	35.16	4.2	434.07	8.9	919.82
	REC: B/C	10.1	1043.85	1.3	134.36	4.2	434.07	12.2	1260.88
EWR O5	PES: B/C	6.35	721.63	0.96	109.42	4.51	512.85	10.85	1234.48
	REC: B	10.15	1154.46	1.32	149.64	4.51	512.85	14.66	1667.32

DESKTOP BIOPHYSICAL NODES: ECOCLASSIFICATION RESULTS

The Table below summarises the EcoClassification results used in this study, based on both the 2010 EWR (Louw and Koekemoer, 2010) and the PESEIS 2012 assessment and forms the basis for the EWR estimation.

Desktop biophysical nodes: EcoClassification summary results (PESEIS 2012 - DWS, 2014a)

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
Molopo River					
D42A-01082	D42A (910)	Nossob	**B**	**High**	**B**
D42D-02283	D42D	Molopo River	**B/C**		**B/C**
D42E-03047	D42D	Molopo River	**C**		**C**
Vis, Sak and Hartbees Rivers					
D51B-07208	D51B	Renoster RIver: Onderplaas to Sterkfontein	**B/C**		**B/C**

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
D51B-06782	D51C	Renoster River	B/C		B/C
D51C-06594	D51C	Renoster River	B/C		B/C
D52A-07274	D52A	Vis	D		D
D52C-06920	D52C	Vis	C/D		C/D
D52E-06758	D52C/E	Vis	C/D		C/D
D52D-06761	D52D	Muiskraal	C		C
D52F-06591	D52E	Vis	D		D
D52F-06306	D52F	Vis	C		C
D53A-04197	D53A	Hartbees[1]	B		B
D53B-04104	D53B	Hartbees	D		D
D53C-03807	D53C	Hartbees: Kenhardt to Tuins River confluence	B		B
D53D-03879	D53D	Tuins	A/B		A/B
D53E-03557	D53E	Hartbees: Tuins to Sout River confluence	A/B		A/B
D53H-03564	D53H	Sout	A		A
D53J-03408	D53J	Hartbees	B		B
D54B-05160	D54A	Holsloot	B		B
D54D-04896	D54B	Carnaveronleegte	C		C
D54D-04630	D54D	Carnaveronleegte	C		C
D54F-05004	D54E	Botterslaagte	B		B
D54F-04645	D54F	Verneukpan	B		B
D54G-04407	D54G	Hartbeespoort	B		B
D55B-06707	D55A	Sak River	C		C
D55B-06615	D55B	Sak River	C		C
D55D-06429	D55C	Brak River	B		B
D55D-06524	D55D	Brak River	B		B
D55E-06496	D55E	Brak River	B/C		B/C
D55F-06209	D55F	Gansvlei River	C		C
D55G-06308	D55G	Gansvlei River	C		C
D55J-06243	D55H	Sak River	B		B
D55J-06180	D55J	Sak River	B/C		B/C
D55K-06347	D55K	Klein Sak	B		B
D55L-06115	D55L	Sak River	C		C
D55M-05697	D55M	Sak River	B/C		B/C
D56A-07453	D56A	Portugals R	B/C		B/C
D56B-07428	D56B	Riet River	B		B
D56D-07091	D56C	Portugals R	B		B
D56D-06822	D56D	Portugals R	B		B
D56F-07144	D56E	Klein Riet	B		
D56G-06932	D56F	Klein Riet	B		B
D56G-06753	D56G	Klein Riet	B		B
D56J-06649	D56H	Riet	B		B
D56J-06522	D56J	Riet	B/C		B/C

[1]No EWR to be estimated for this node as it is situated immediately DS of a large dam with no outlet capacities.

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
D57A-05387	D57A	Sak River	C		C
D57B-05325	D57B	Soutloot	B/C		B/C
D57C-05254	D57C	Sak	C		C
D57E-04534	D57D	Sak	B		B
D57E-04374	D57E	Sak	B		B
D58A-06302	D58A	Vis	C		C
D58C-05932	D58B	Vis	C		C
D58C-05390	D58C	Vis	C		C
Brak Ongers River					
D61A-06062	D61A	Laken	C		C
D61B-05841	D61B	Laken tributary	C		C
D61C-05866	D61C	Laken	C		C
D61D-06156	D61D	Brakpoort	B		B
D61E-06164	D61E	Brak	C		C
D61G-06223	D61F	Klein Brak	C		C
D61H-05960	D61G	Klein Brak	C		C
D61H-05865	D61H	Brak	B/C		B/C
D61J-05654	D61J	Groen	B		B
D61K-05388	D61K	Groen	B		B
D61L-05453	D61L	Perdepoortsleegte	B		B
D61M-05343	D61M	Ongers	C		C
D62A-05078	D62A	Ongers	C		C
D62B-04701	D62B	Ongers	B/C		B/C
D62C-05303	D62C	Elandsfontein	B/C		B/C
D62D-05183	D62D	Brak	B/C		B/C
D62G-04755	D62E	Brak	B		B
D62G-04703	D62G	Brak	A/B		A/B
D62J-04231	D62J	Ongers	B/C	High	B (B/C)
D71B-03620	D71B	Orange tributary	B		B
Small West coast rivers					
F10B-03391		Holgat	B	High	B
F20E-04290		Kwaganap	C	High	B (C)
F30A-04782		Buffels	B		B
F30B-04742		Brak	B		B
F30C-04823		Buffels	B		B
F30D-04598		Buffels	B		B
F30E-04444		Skaap	B		B
F30G-04539		Buffles	B/C		B/C
F40B-04917		WildeperdehoekseBrak	B		B
F40C-05007		Swartlintjies	B		B
F40D-04789		Swartlintjies	B		B
F40F-05159		Spoeg	B		B
F40G-05320		Bitter	C	High	B (C)

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
F40H-05480		Bitter	D		D
F50A-05626		Hartbees	C		C
F50B-05636		Swart-Doring	B		B
F50C-05764		Swart-Doring	B		B
F50D-05726		Swart-Doring	B		B
F50F-05560		Groen	B/C		B/C
F50G-05620		Groen	B		B
F60A-05886		Brak	B		B
F60C-06147		Sout	B		B
F60D-06231		Sout	B		B

The nodes that require improvement and the associated issues that will have to be addressed are provided below.

Aspects to be addressed to achieve the REC improvement

Biophysical Node name	River	PES	EI	REC	Improvements
D42A-01082	Nossob	B	High	B	No improvements required as the PES is already in a B EC.
D62J-04231	Ongers	B/C	High	B	Livestock, roads and crossings, irrigation in lower reach - from Orange River.
F10B-03391	Holgat	B	High	B	No improvements required as the PES is already in a B EC.
F20E-04290	Kwaganap	B/C	High	B	Roads and crossings, livestock, lower reach rivers do not exist due to mining activities, estuary.
F40G-05320	Bitter	C	**High**	B	Roads and crossings, dryland agriculture.

DESKTOP BIOPHYSICAL NODES: EWR ESTIMATION AND RESULTS

Desktop EWRs are provided for 91 of the 99 desktop nodes identified. None of the desktop biophysical nodes have an improved REC relative to the PES, and thus requirements are constrained to PD flows (i.e. there is no improvement in the PES through hydrology).

Summary of Desktop EWRs for the biophysical nodes in the lower Orange River

Node	River name	Annual Runoff (10^6 m^3)				REC	Long-term EWR requirements			
		Mean		Median			(10^6 m^3)		% Natural	
		Natural	PD	Natural	PD		Mean	Median	Mean	Median
Small Orange River tributary										
D71B-03620		9.862	9.862	3.650	3.650	B	1.540	0.963	15.6	26.4
Brak/Ongers River systems										
D61A-06062	Laken	3.430	3.224	1.280	1.190	C	0.364	0.183	10.6	14.3
D61B-05841	Laken tributary	2.688	2.688	0.980	0.980	C	0.286	0.143	10.6	14.6
D61C-05866	Laken	7.634	7.145	2.800	2.610	C	0.811	0.408	10.6	14.6
D61D-06156	Brakpoort	0.920	0.920	0.310	0.310	B	0.138	0.068	15.0	21.9
D61E-06164	Brak	1.961	1.285	0.430	0.250	C	0.206	0.081	10.5	18.8

Node	River name	Annual Runoff ($10^6 m^3$)				REC	Long-term EWR requirements			
		Mean		Median			($10^6 m^3$)		% Natural	
		Natural	PD	Natural	PD		Mean	Median	Mean	Median
D61G-06223	Klein Brak	0.966	0.484	0.180	0.060	C	0.087	0.029	9.0	16.1
D61H-05865	Brak	6.829	5.483	1.670	1.310	B/C	0.893	0.371	13.1	22.2
D61H-05960	Klein Brak	1.996	1.326	0.400	0.220	C	0.208	0.077	10.4	19.3
D61J-05654	Groen	2.122	2.122	0.430	0.430	B	0.324	0.127	15.2	29.5
D61K-05388	Groen	4.826	4.826	1.010	1.010	B	0.736	0.290	15.3	28.7
D61L-05453	Perdepoortsleegte	0.474	0.474	0.170	0.170	B	0.070	0.033	14.8	19.4
D61M-05343	Ongers	22.124	5.015	6.690	0.000	C	0.297	0.000	1.3	na
D62A-05078	Ongers	22.904	5.795	7.180	0.310	C	0.810	0.260	3.5	3.6
D62B-04701	Ongers	23.529	6.420	7.690	0.520	B/C	1.249	0.494	5.3	6.4
D62C-05303	Elandsfontein	4.529	4.529	1.840	1.840	B/C	0.609	0.339	13.5	18.4
D62D-05183	Brak	7.544	7.399	3.190	2.920	B/C	1.013	0.569	13.4	17.8
D62G-04703	Brak	17.366	17.22	7.210	6.850	A/B	3.352	1.959	19.3	27.2
D62G-04755	Brak	16.132	15.98	6.660	6.300	B	2.579	1.452	16.0	21.8
D62J-04231	Ongers	42.331	25.07	17.140	8.050	B	6.225	3.077	14.7	18.0
Vis River system										
D51B-06782	Renoster	13.403	12.62	2.690	2.520	B/C	1.384	0.826	10.3	30.7
D51B-07208	Renoster	6.397	6.025	1.284	1.203	B/C	0.661	0.395	10.3	30.8
D51C-06594	Renoster	14.033	13.25	2.820	2.650	B/C	1.447	0.865	10.3	30.7
D52A-07274	Vis	2.933	2.633	0.435	0.397	D	0.168	0.113	5.7	26.0
D52C-06920	Vis	8.054	7.312	1.195	1.092	C/D	0.547	0.362	6.8	30.3
D52D-06761	Muiskraal	2.655	2.356	0.393	0.343	C	0.195	0.130	7.3	33.1
D52E-06758	Vis	11.662	10.58	1.730	1.580	C/D	0.791	0.524	6.8	30.3
D52F-06306	Vis	17.337	15.60	2.661	2.409	C	1.387	0.909	8.0	34.2
D52F-06591	Vis	16.852	15.19	2.500	2.250	D	0.940	0.632	5.6	25.3
D56A-07453	Portugals	1.639	1.586	0.314	0.317	B/C	0.178	0.079	10.9	25.2
D56D-06822	Portugals	8.257	7.994	1.585	1.595	B	1.049	0.476	12.7	30.0
D56D-07091	Portugals	6.262	6.062	1.201	1.206	B	0.794	0.360	12.7	30.0
D56G-06753	Klein Riet	3.544	3.432	0.880	0.840	B	0.516	0.297	14.6	33.7
D56G-06932	Klein Riet	2.564	2.483	0.636	0.608	B	0.373	0.214	14.6	33.6
D56J-06522	Riet	13.932	13.33	3.130	3.030	B/C	1.597	0.865	11.5	27.6
D56J-06649	Riet	13.237	12.81	2.950	2.910	B	1.772	0.984	13.4	33.4
D58A-06302	Vis	28.190	21.52	6.450	0.640	C	1.893	0.382	6.7	5.9
D58C-05390	Vis	46.373	37.77	10.330	4.190	C	3.768	1.686	8.1	16.3
D58C-05932	Vis	45.943	37.32	10.278	4.051	C	3.699	1.628	8.1	15.8
Sak River system										
D55B-06615	Sak	4.498	3.357	1.570	1.170	C	0.479	0.235	10.6	15.0
D55B-06707	Sak	2.688	2.007	0.939	0.699	C	0.286	0.141	10.6	15.0
D55D-06429	Brak	1.542	1.317	0.304	0.192	B	0.233	0.095	15.1	31.3
D55D-06524	Brak	5.249	4.482	1.030	0.650	B	0.793	0.325	15.1	31.6
D55E-06496	Brak	11.352	8.892	3.320	2.220	B/C	1.507	0.674	13.3	20.3
D55F-06209	Gansvlei	3.135	3.134	0.552	0.553	C	0.341	0.139	10.9	25.2
D55G-06308	Gansvlei	4.661	3.427	0.820	0.190	C	0.421	0.063	9.0	7.7
D55J-06180	Sak	18.928	15.10	5.140	3.070	B/C	2.479	1.192	13.1	23.2
D55J-06243	Sak	17.079	13.33	4.350	2.637	B	2.621	1.204	15.3	27.7

Node	River name	Annual Runoff ($10^6 m^3$)				REC	Long-term EWR requirements			
		Mean		Median			($10^6 m^3$)		% Natural	
		Natural	PD	Natural	PD		Mean	Median	Mean	Median
D55K-06347	Klein Sak	1.100	1.100	0.240	0.240	B	0.159	0.057	14.5	23.7
D55L-06115	Sak	20.876	16.99	5.354	3.184	C	2.258	1.046	10.8	19.5
D55M-05697	Sak	22.115	18.14	5.420	3.410	B/C	2.874	1.300	13.0	24.0
D57A-05387	Sak	68.804	56.07	20.742	13.199	C	6.648	3.567	9.7	17.2
D57B-05325	Soutloot	0.886	0.456	0.174	0.093	B/C	0.101	0.037	11.3	21.3
D57C-05254	Sak	69.813	56.59	20.790	13.230	C	6.775	3.604	9.7	17.3
D57E-04374	Sak	72.377	47.13	21.850	16.440	B	9.793	6.069	13.5	27.8
D57E-04534	Sak	70.972	57.69	21.002	13.429	B	9.588	5.530	13.5	26.3
Hartbees River system										
D53B-04104	Hartbees	84.236	66.80	29.150	20.222	D	5.964	2.764	7.1	9.5
D53C-03807	Hartbees	86.535	68.62	29.648	20.297	B	12.591	6.346	14.6	21.4
D53D-03879	Tuins	2.008	1.906	0.204	0.193	A/B	0.253	0.079	12.6	38.7
D53E-03557	Hartbees	89.543	71.48	30.300	20.879	A/B	15.648	7.803	17.5	25.8
D53H-03564	Sout	1.783	1.783	0.090	0.090	A	0.237	0.050	13.3	55.6
D53J-03408	Hartbees	91.687	69.19	30.660	16.665	B	11.959	5.492	13.0	17.9
D54B-05160	Holsloot	2.790	1.194	0.553	0.225	B	0.363	0.130	13.0	23.5
D54D-04630	Carnaveronleegte	10.060	5.250	1.981	0.992	C	1.020	0.454	10.1	22.9
D54D-04896	Carnaveronleegte	8.335	3.567	1.653	0.670	C	0.826	0.341	9.9	20.6
D54F-04645	Verneukpan	6.342	4.703	1.229	0.895	B	0.919	0.404	14.5	32.9
D54F-05004	Botterslaagte	2.713	1.161	0.538	0.218	B	0.353	0.126	13.0	23.4
D54G-04407	Hartbeespoort	21.295	14.72	4.141	2.798	B	3.061	1.346	14.4	32.5
Small West Coast Rivers										
F10B-03391		0.064	0.064	0.000	0.000	B	0.006	0.000	8.8	na
F20E-04290		0.738	0.738	0.140	0.140	B	0.090	0.057	12.2	40.7
F30A-04782		2.313	2.313	0.737	0.737	B	0.345	0.225	14.9	30.5
F30B-04742		1.731	1.731	0.553	0.553	B	0.258	0.168	14.9	30.4
F30C-04823		6.003	6.003	1.914	1.914	B	0.896	0.585	14.9	30.6
F30D-04598		7.158	7.158	2.282	2.282	B	1.068	0.697	14.9	30.5
F30E-04444		1.492	1.492	0.476	0.476	B	0.222	0.145	14.9	30.5
F30G-04539		11.199	11.19	3.570	3.570	B/C	1.407	0.909	12.6	25.5
F40B-04917		0.345	0.345	0.178	0.178	B	0.047	0.034	13.8	19.1
F40C-05007		0.519	0.519	0.268	0.268	B	0.072	0.052	14.0	19.4
F40D-04789		1.215	1.215	0.629	0.629	B	0.172	0.125	14.2	19.9
F40F-05159		1.282	1.282	0.664	0.664	B	0.181	0.132	14.2	19.9
F40G-05320		0.297	0.297	0.154	0.154	B	0.041	0.030	13.7	19.5
F40H-05480		0.630	0.630	0.326	0.326	D	0.041	0.027	6.5	8.3
F50A-05626		1.546	1.546	0.779	0.779	C	0.164	0.116	10.6	14.9
F50B-05636		0.715	0.715	0.360	0.360	B	0.107	0.077	15.0	21.4
F50C-05764		2.782	2.782	1.402	1.402	B	0.424	0.313	15.2	22.3
F50D-05726		3.597	3.597	1.813	1.813	B	0.550	0.405	15.3	22.3
F50F-05560		1.260	1.260	0.635	0.635	B/C	0.162	0.117	12.8	18.4
F50G-05620		5.458	5.458	2.750	2.750	B	0.835	0.615	15.3	22.4
F60A-05886		0.177	0.177	0.064	0.064	B	0.027	0.017	15.1	26.6
F60C-06147		0.450	0.450	0.161	0.161	B	0.068	0.042	15.2	26.1

Node	River name	Annual Runoff (10^6 m^3)				REC	Long-term EWR requirements			
		Mean		Median			(10^6 m^3)		% Natural	
		Natural	PD	Natural	PD		Mean	Median	Mean	Median
F60D-06231		0.675	0.675	0.246	0.246	B	0.106	0.064	15.6	26.0

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AEC	Alternative Ecological Categories
BHN	Basic Human Needs
BBM	Building Block Methodology
CD: WE	Chief Directorate: Water Ecosystems
CERM	Comprehensive Ecological Reserve Methodology
DWS	Department of Water and Sanitation
DWA	Department Water and Sanitation
DWAF	Department Water and Sanitation and Forestry
DRM	Desktop Reserve Model
EC	Ecological Category
EI	Ecological Importance
EIS	Ecological Importance and Sensitivity
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
EFR	Environmental Flow Requirement
FRAI	Fish Response Assessment Index
FDI	Flow dependent macroinvertebrates
GAI	Geomorphology Assessment Index
HFSR	Habitat Flow Stressor Response
HF	Hydraulic fracturing
IHI	Index of Habitat Integrity
IWRMP	Integrated Water Resources Management Plan
LSR	Large semi-rheophilic fish guild
MIRAI	Macroinvertebrate Response Assessment Index
MRU	Management Resource Unit
MVI	Marginal vegetation macroinvertebrates
MAR	Mean Annual Runoff
NFEPA	National Freshwater Ecosystem Priority Area
NWRCS	National Water Resource Classification System
nMAR	Natural Mean Annual Runoff
ORASECOM	Orange-Senqu River Commission
PAI	Physico-chemical Driver Assessment Index
PD	Present Day
PES	Present Ecological State
PSP	Professional Service Provider
REC	Recommended Ecological Category
RSA	Republic of South Africa
RDRM	Revised Desktop Reserve Model
VEGRAI	Riparian Vegetation Response Assessment Index
SCI	Socio-Cultural Importance
SPATSIM	Spatial and Time Series Modelling
SQ	Sub Quaternary
TOR	Terms of Reference
WMA	Water Management Area
WRC	Water Research Commission
WRPM	Water Resource Planning Model

WRYM	Water Resource Yield Model
WR2012	Water Resources of South Africa, 2012
WARMS	Water Use Authorisation and Registration Management System

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the 'Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries, and Wetlands) and Groundwater in the Lower Orange Water Management Area (WMA).The appointed Professional Service Provider (PSP) to undertake this studywasRivers for Africa.

As per the Terms of Reference (TOR), thereis a need to undertake detailed Ecological Water Requirement (EWR) and Basic Human Needs (BHN) studies for various water resource components due to mainly:

- Planned hydraulic fracturing (HF) undertaken in the WMA.
- Various water use licence applications.
- The conservation status of various Resources in this catchment; and
- The associated impacts of proposed developments will have on the availability of water.

1.2 STUDY AREA

As indicated in the TOR, the study area is the Lower Orange River WMA (previous WMA 14). It is the largest WMA in the country and covers almost the entire Northern Cape Province. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States, i.e. Lesotho (Senqu River originating in the highlands), Botswana in the north-eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa. The focus area of the study comprises only the South African portion of the Lower Orange River Catchment. The Eastern Boundary starts where the Vaal River enters the Orange River, and the Western Boundary is the Atlantic Ocean. The study area is downstream of the Upper Orange, Senqu, and the Integrated Vaal River System and as such, affected by the upstream activities in the highly developed river basin. The Orange River forms the border between the Republic of South Africa (RSA) and Namibia to the west of 20 degrees longitude over a distance of approximately 550 km.

1.3 PURPOSE OF THIS TASK

This task consists of the EcoClassification and EWR determination at various biophysical nodes in the system. EcoClassification and EWR determinations addressed during previous studies, applicable to the current study area are outlined below.

- **GIZ Integrated Water Resources Management Plan (IWRMP) Phase 2: Work Package 5: Assessment of Environmental Flow Requirements (EFR[2]) -** referenced as the **2010 EWR study** (Louw and Koekemoer, 2010) in this report.
  The main objective for this Work Package was to assess EWRsat a "Comprehensive Level", at selected key areas of the Orange-Senqu River Basin – the Orange River upstream of the Fish River confluence, excluding the Vaal River. The study outcomes amongst others were:
  - A Desktop EcoClassification assessment on quaternary scale to determine the integrated Environmental Importance in terms of three components, Ecological Importance and Sensitivity (EIS), Socio-Cultural Importance (SCI), the Present Ecological State (PES) and

[2] ORASECOM commissioned studies refer to the term Environmental Flow Requirement (EFR) rather than EWR.

Water Resource Use Importance for the whole study area (excluding rivers within the F primary catchment) (Louw *et al*., 2010).

- o Determination of the EWR for different ecological states at three EWR sites located within the current study area. EWRs were determined applying the Comprehensive Ecological Reserve Methodology (CERM) (DWAF, 1999) which consisted of the EcoClassification process (Kleynhans and Louw, 2007) to determine the Present Ecological State and applying the Habitat Flow StressorResponse (HFSR) (Hughes and Louw, 2010) to evaluate EWRs for various ecological states.

- **UNDP-GEF Orange-Senqu Strategic Action Programme EFR Study: Orange-Senqu River Basin Research project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth** - referenced as the **2013 EWR study** (Louw *et al.*, 2013) in this report.

  The study area covered the Fish River in Namibia, Orange River downstream of the Fish River confluence and the Orange River Mouth. Two of the main objectives of the study were to determine the PES and set the EWR at various sites selected in the study area. The study outcomes amongst others were:

  - o Determining the EWR for different ecological states at oneEWR site located within the current study area as well as theOrange River Estuary. EWRs were determined,applying the CERM (DWAF, 1999) which consisted of the EcoClassification process (Kleynhans and Louw, 2007) to determine the PES and applying theHFSR (Hughes and Louw, 2010) to evaluate EWRs for various ecological states.

- **PESEIS study: Desktop level PES, EI, and ES study undertaken at SQ level for the Lower Orange WMA -** referenced as the **PESEIS 2012 study** (DWS, 2014a). This study formed part of a national assessment, and the Lower Orange WMA (the old WMA 14) results were available during 2012. The desktop level study provided the PES, Ecological Importance (EI) and Ecological Sensitivity (ES)including a summary of the main causes for the PES for Sub Quaternary reaches (SQs) throughout the WMA. One of the problems with the results of the study was that no SQs thatwere deemed to be ephemeral (i.e. all seasonal rivers without a base flow) were assessed.

  Apart from the EWR sites, EWR estimates were required at 91 desktop biophysical nodes. The PES for these nodes were available from the 2010 EWR study at quaternary basis (Louw *et al*., 2010) and from the national PESEIS study (DWS, 2014b) that was undertaken at SQ level. However, SQs deemed seasonal, were not evaluated and furthermore, many evaluations were provided for SQs that were highly likely to be seasonal. This was problematic, and as indicated in the Inception Report, the quaternary-based information from the 2010 EWR study (Louw *et al*., 2010) used as a basis. Based on the national PESEIS study (DWS, 2014b),data were modified where applicable. The desktop level EcoClassification determination and associated EWR estimates, undertaken as a sub-task during this study consisted of the following components:

- **Setting up the system model and provision of natural and present day data**

One of the outcomes of the Orange-Senqu River Commission (ORASECOM) Integrated Water Resources Management Plan (IWRMP) Phase 2 study (ORASECOM, 2014) was the extension and in some places, the complete update of the hydrology of the entire Orange Senqu. The study deliverable resulted in the complete update of the hydrology of Lower Orange River and inclusion in the integrated OrangeSenqu models. This was the most recent detailed updated hydrology available for the Lower Orange and used for the EWR assessments as part of this study. However, the small coastal rivers along the west coast were excluded from the ORASECOM IWRMP Phase 2 study (ORASECOM, 2014). The latest available hydrology for these coastal rivers along the west coast was from the Water Resources of South Africa, 2012 (WR2012) Study recently completed by the Water Research Commission (WRC). The natural and present day flows at the selected biophysical nodes were determined, using this hydrology and latest system models setups (see Section 2 for more detail).

- **EWRs of desktop biophysical nodes: EcoClassification**
  The PES, EIS and Recommended Ecological Category (REC) for each quaternary catchment were determined and documented in a spreadsheet.
- **EWRs of desktop biophysical nodes: EWR**
  An appropriate desktop model estimated the EWRs.

1.4 PURPOSE OF THIS REPORT

The purpose of this report is to:

- Summarise the Orange River EWRs.
- Provide the desktop EWRs for the quaternary catchments focussing on the tributaries of the Lower Orange River.

1.5 OUTLINE OF THIS REPORT

The report outline is provided below.

Chapter 1: Introduction
This Chapter provides ageneral background to the project, study area and purpose of the report.

Chapter 2: Quaternary catchment systems hydrology
Chapter 2 provides an overview of the hydrology of the study area. The hydrological datasets used to determine the natural and present day flows for the biophysical nodes in the study area are also discussed.

Chapter 3: Summary of Orange River EWR results: EcoClassification
The EcoClassification results from the 2010 and 2013 EWR studies are summarised in this chapter. Applicable EWR site information is provided, and the approach applied during these studies are summarised. The EcoClassification results and associated confidence are provided as summary tables.

Chapter 4: Summary of Orange River EWR Results: Discharge Recommendations
The EWR results from the 2010 and 2013 EWR studies are summarised in this chapter and provides an explanation and discussion of the approach applied during these studies. The final flow requirements for the PES and REC are provided as an EWR table that shows the results for each month for high flows and low flows separately and an EWR rule table that provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case)..

Chapter 5: Desktop Biophysical Nodes: Resource Units, locality and EcoClassification
Desktop biophysical nodes are listed and a summary of EcoClassification results for the desktop biophysical nodes are provided.

Chapter 6: Desktop Biophysical Nodes: EWR Estimation and Results
This chapter provides the general approach used during this study to estimate the EWRs at the biophysical nodes using the Desktop Reserve Model (DRM).

Chapter 7: References

Chapter 8: Appendix A: Comparison between the 2010 and National 2014 PESEIS Results
A comparison between the 2010 and National 2014 PESEIS results are provided.

Chapter 9: Comments Register
Comments from the Client are provided.

2 QUATERNARY CATCHMENT SYSTEMS HYDROLOGY

2.1 INTRODUCTION

The flow in the Orange main River is almost entirely dependent on the flows generated in the Upper Orange, Senqu River in Lesotho and the Vaal River along with the related operating rules system management procedures. The hydrological data, updated and extended as part of the ORASECOM IWRMP Phase 2 study (ORASECOM, 2014), applied for all the areas upstream of the Orange-Vaal confluence covers an 85-year period from 1920 to 2004 hydrological years. The hydrology information in the upstream catchments is generally of high to very high confidence. The hydrology from the catchments upstream of the Orange-Vaal confluence has a major impact on the flows available along the main Orange River downstream of the confluence and taken into account when considering flows and related environmental impacts at any of the key points along the lower main Orange River.

Due to the erratic nature of the runoff and very low to zero monthly river flows in the arid tributary catchments within the Lower Orange WMA, several of the quaternary catchments were grouped together to form larger catchments. These quaternary catchment monthly flow records were added together to represent the flows for the related combined catchments providing flow records at key water resource locations within the Lower Orange WMA as configured in the Water Resource Yield Model (WRYM) and Water Resource Planning Model (WRPM) networks.

Hydrological information is however still available at quaternary catchment scale from the river-runoff modelling and calibration undertaken during the ORASECOM IWRMP Phase 2 study (ORASECOM, 2014). This, in fact, formed the basis of the hydrology used as input to the WRYM and WRPM networks.

The Molopo River hydrological data was obtained from the Feasibility Study of the Potential for sustainable Water Resources Development in the Molopo-Nossob Water Course by ORASECOM (ORASECOM, 2009) and is regarded as low confidence due to absence of observed flow data in this area and the extremely high losses that occurs naturally, which is difficult to estimate accurately.

2.2 APPROACH

In this study, the latest and best available hydrology datasets were selected. Results from the Gap analysis recommended the use of the following hydrology datasets to provide the natural and present day flows required for this study:

- ORASECOM IWRMP Phase 2 study (ORASECOM, 2014) Pitman Model setup for natural and current day flows per quaternary for the Lower Orange excluding the Molopo River and the small coastal rivers.
- The WRYM setup as prepared for the ORASECOM IWRMP Phase 2 study (ORASECOM, 2014) for Molopo River catchment, as this network detail was at a quaternary level.
- Pitman Model Setup and data from the WR2012 Study recently completed for the Small West Coast Rivers.

High losses occur in the Lower Orange along the main Orange the Molopo River, Sak andHartbees Rivers and other lower Orange River tributaries that take place under natural and developed conditions. In the preparation of the cumulative natural and present day flows these losses were taken into account.

Water requirements within the tributary catchments were updated, using the most recent urban/industrial requirements from the All Town Study (DWS, 2015). Irrigation requirements from the tributary catchments were limited but updated where required by using the latest available data from Water Use Authorisation and Registration Management System (WARMS).

The models as listed above and the related system setups were analysed for natural conditions and present day development level. These flow sequences are required as input to the Revised Desktop Reserve Model (RDRM) (Hughes *et al*., 2012; Hughes *et al*., 2014) and/or the original Desktop Reserve Model (DRM) (Hughes and Hannart, 2003).

Biophysical Nodes

The RUs, defined as part of Task 2 of this study, (DWS, 2016), for the arid sections in the Lower Orange River tributaries, represented by quaternary catchments, and consists of a number of SQ reaches. This also linked to the groundwater units and the previous assessments undertaken at a quaternary basis. The biophysical nodes represent the outflow point at each of these quaternary catchments in most cases, with some exceptions particularly in the case of endoreic areas. Ninety-nine (99) biophysical nodes were defined within the Lower Orange tributaries including the small coastal rivers along the west coast and presented in Figure 2.1.

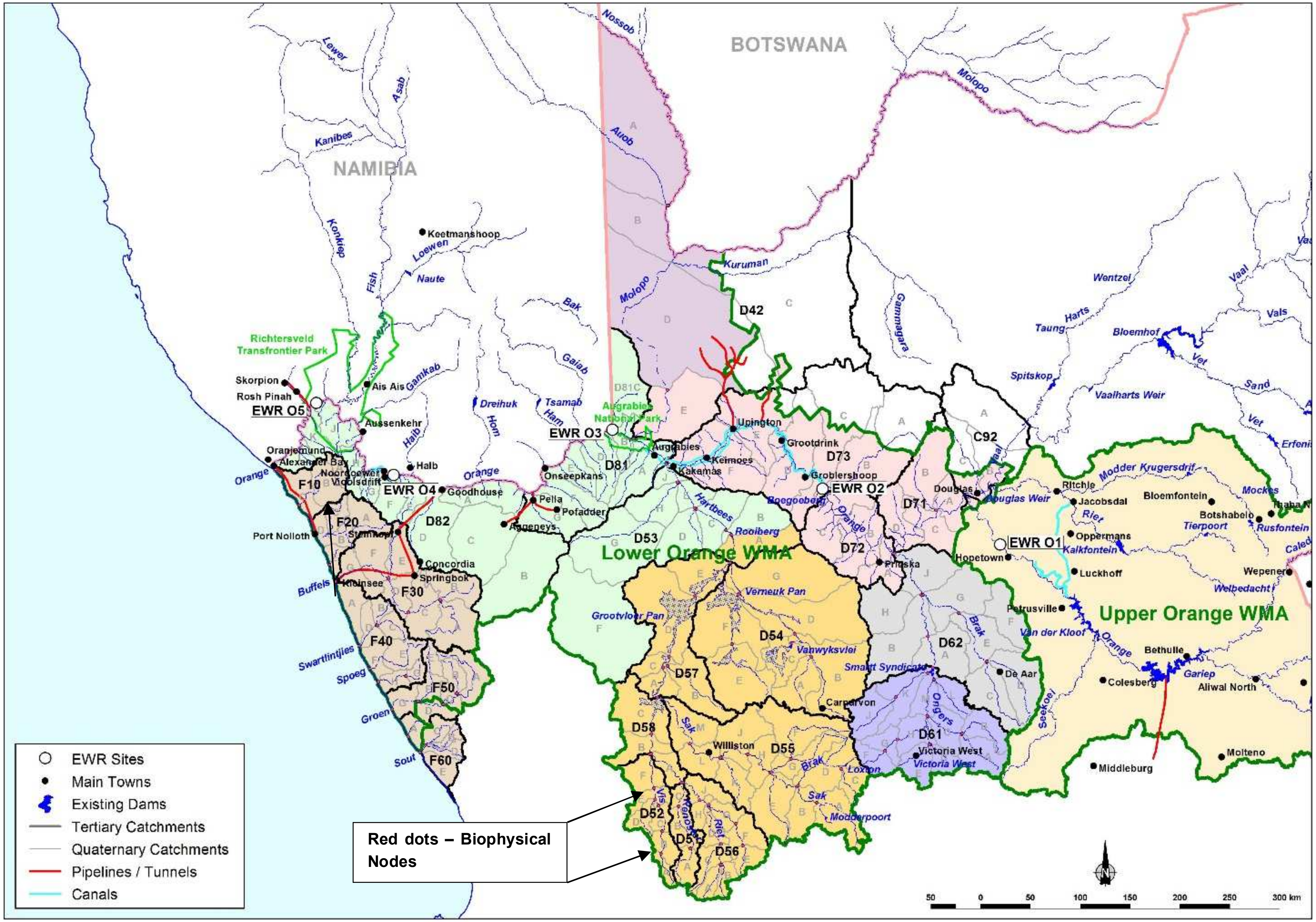

Figure 2.1 Location of Biophysical Nodes in the Lower Orange River

2.3 RESULTS

2.3.1 Natural flows

Under natural conditions, the flows generated within the Lower Orange River are very small in comparison with that entering the Lower Orange River from the Vaal River and the Upper Orange River. The MAR under natural conditions from the Vaal River amounts to 4 024 million m^3/a with 6 695 million m^3/a from the Upper Orange River, in total thus 10 719million m^3/a, with only 198 million m^3/a reaching the Orange River from the natural flow generated in the lower Orange RSA tributaries. These flows are represented in Table 2.1 by the cumulative flows for catchment numbers 20 (Brak River), 72 (Hartbees River) as well as the 50.1 million m3/a from the small tributaries feeding directly into the main Orange River from D71, D72, D73 and 13.8 million m3/a from the small tributaries located in D81 and D82. The natural inflow from the RSA Lower Orange tributaries, therefore, represents only about 1.9% of the total natural flow entering the Lower Orange River. Another 21.4 million m^3/a is generated within the small coastal rivers along the west coast (Figure 2.2). Table 2.1 provides a summary of the cumulative natural and present day flows at the selected biophysical nodes per quaternary catchment as well as the location of each biophysical node. Large volumes of the generated natural flows are lost in the enormous pans/wetlands found in the Sak, Hartbees and Molopo rivers. The volumes lost in the Lower Molopo wetlands and Kalahari sand is so high that none of the Molopo flows reaches the Orange River. Only a small portion of the local runoff generated close to the confluence of the Molopo and Orange rivers physically enters the main Orange River. Figure 2.2 provides an indication of the natural flow generated within the Lower Orange tributaries and small rivers along the West coast.

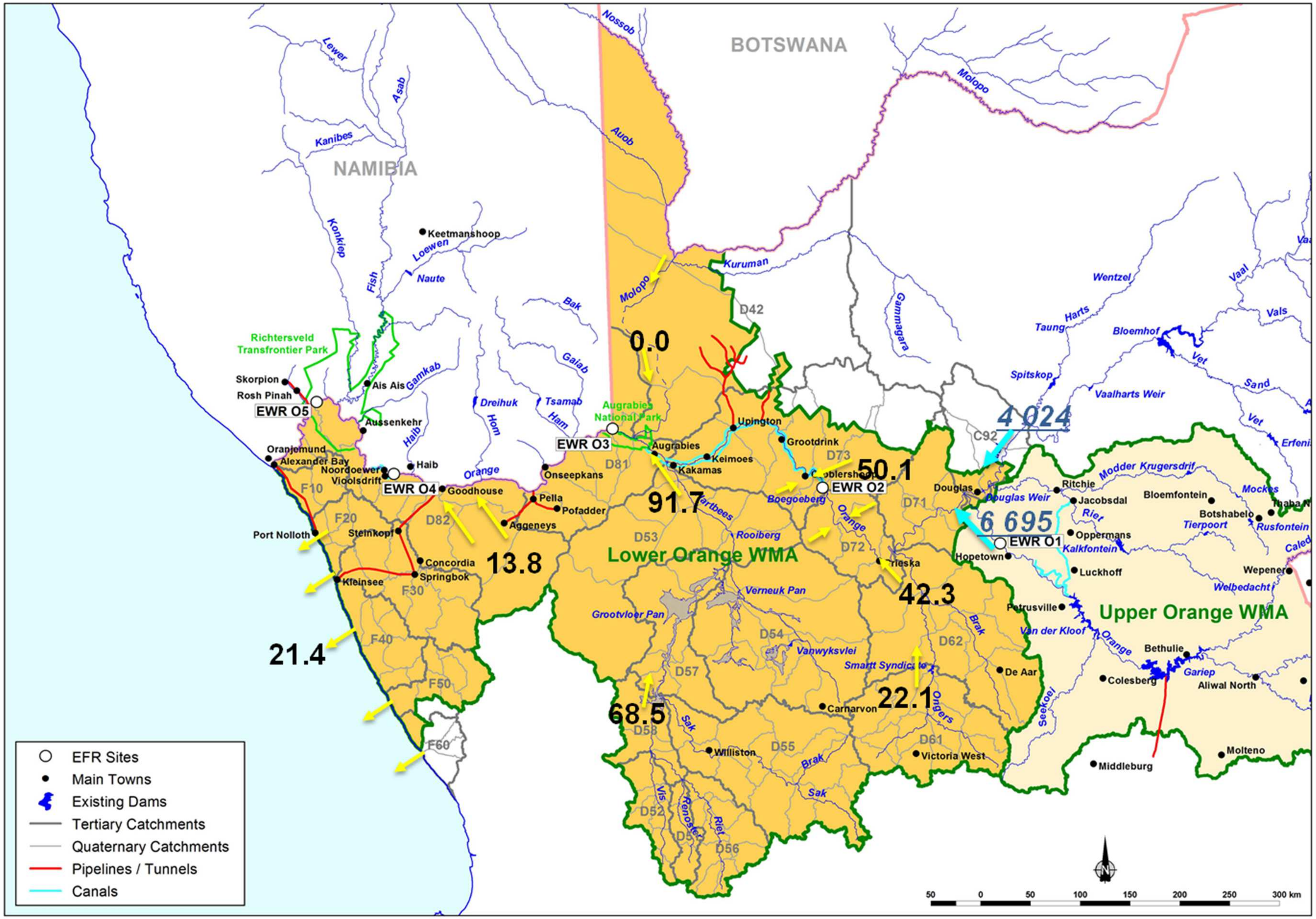

Figure 2.2 Natural flows generated from the Lower Orange

2.3.2 Present day flows

Due to the low rainfall and related runoff within the Lower Orange River tributaries, limited developments exist that utilise surface water as a resource. Ground water resources supply most of the water requirements those of the towns. Table 2.1 provides a summary of the present day and natural flows at each of the biophysical nodes.

Table 2.1 Average natural and present day flows at the selected biophysical nodes

No	Quaternary Catchment	Node	Latitude	Longitude	Average annual cumulative flow (million m³)			Present Day (% of natural)
					Natural	Present Day	Difference	
Orange Small tributaries								
1	D71B	D71B03620	-29.20724	23.34363	9.862	9.862	0.000	100%
Brak Ongers River								
2	D61A	D61A06062	-31.20947	23.60141	3.430	3.226	0.204	94%
3	D61B	D61B05841	-31.2038	23.60679	2.690	2.690	0.000	100%
4	D61C	D61C05866	-31.05066	23.24582	7.634	7.145	0.489	94%
5	D61D	D61D06156	-31.30007	23.26646	0.920	0.920	0.000	100%
6	D61E	D61E06164	-31.30064	23.25767	1.960	1.285	0.675	66%
7	D61F	D61G06223	-31.35528	22.78456	0.970	0.484	0.486	50%
8	D61G	D61H05960	-31.252603	22.919494	1.996	1.326	0.670	66%
9	D61H	D61H05865	-31.044787	23.240097	6.829	5.483	1.346	80%
10	D61J	D61J05654	-30.87568	22.90351	2.110	2.110	0.000	100%
11	D61K	D61K05388	-30.661076	23.248275	4.826	4.826	0.000	100%
12	D61L	D61L05453	-30.72082	23.30871	0.470	0.470	0.000	100%
13	D61M	D61M05343	-30.61084	23.29821	22.124	5.015	17.109	23%
14	D62A	D62A05078	-30.33245	23.25014	22.904	5.795	17.109	25%
15	D62B	D62B04701	-29.9643	23.18373	23.529	6.420	17.109	27%
16	D62C	D62C05303	-30.56393	23.86438	4.529	4.529	0.000	100%
17	D62D	D62D05183	-30.55835	23.87186	7.544	7.399	0.146	98%
18	D62E	D62G04755	-30.12453	23.57422	16.132	15.986	0.146	99%
19	D62G	D62G04703	-29.9619	23.20277	17.366	17.220	0.146	99%
20	D62J	D62J04231	-29.58993	22.9062	42.331	25.077	17.255	59%
Vis River								
21	D56A	D56A07453	-32.35131	21.00809	1.639	1.586	0.052	97%
22	D56B	D56B07428	-32.34862	21.0213	1.667	1.614	0.053	97%
23	D56C	D56D0791	-32.16351	21.01843	6.262	6.062	0.200	97%
24	D56D	D56D06822	-31.81654	20.89108	8.257	7.994	0.263	97%
25	D56E	D56F07144	-32.18088	21.25144	1.002	0.971	0.032	97%
26	D56F	D56G06932	-31.98243	21.1828	2.564	2.483	0.081	97%
27	D56G	D56G06753	-31.81039	20.90019	3.544	3.432	0.112	97%
28	D56H	D56J06649	-31.76611	20.80411	13.237	12.816	0.421	97%
29	D56J	D56J06522	-31.60344	20.62585	13.932	13.334	0.599	96%
30	D51A	D51B07208	-32.196087	20.690202	6.397	6.025	0.372	94%
31	D51C	D51B06782	-31.81523	20.57795	13.403	12.624	0.779	94%
32	D51C	D51C06594	-31.607192	20.616258	14.033	13.254	0.779	94%
33	D52A	D52A07274	-32.2338	20.3713	2.933	2.633	0.300	90%
34	D52B	D52C06920	-32.034583	20.392677	8.054	7.312	0.743	91%
35	D52C	D52E06758	-31.80475	20.36033	11.662	10.587	1.075	91%
36	D52D	D52D06761	-31.747605	20.329598	2.655	2.356	0.299	89%
37	D52E	D52F06591	-31.64769	20.32002	16.852	15.192	1.660	90%

No	Quaternary Catchment	Node	Latitude	Longitude	Average annual cumulative flow (million m³)			Present Day (% of natural)
					Natural	Present Day	Difference	
38	D52F	D52F06306	-31.342123	20.286009	17.337	15.604	1.733	90%
39	D58A	D58A06302	-31.33839	20.30058	28.190	21.528	6.662	76%
40	D58B	D58C05932	-31.16235	20.30892	45.943	37.325	8.618	81%
41	D58C	D58C05390	-30.83714	20.38228	46.373	37.774	8.598	81%
Sak River								
42	D55A	D55B06707	-31.81091	22.05219	2.688	2.007	0.682	75%
43	D55B	D55B06615	-31.6658	21.84276	4.498	3.357	1.141	75%
44	D55C	D55D06429	-31.514518	22.321611	1.542	1.317	0.226	85%
45	D55D	D55D06524	-31.65441	21.85421	5.249	4.482	0.768	85%
46	D55E	D55E06496	-31.53304	21.56503	11.352	8.892	2.460	78%
47	D55F	D55F06209	-31.41459	21.783169	1.950	1.950	0.000	100%
48	D55G	D55G06308	-31.52921	21.57471	4.661	3.427	1.234	74%
49	D55H	D55J06243	-31.365849	21.32659	17.079	13.337	3.742	78%
50	D55J	D55J06180	-31.38729	21.04388	18.928	15.104	3.824	80%
51	D55K	D55K06347	-31.3921	21.03468	1.100	1.100	0.000	100%
52	D55L	D55L06115	-31.25786	20.71239	20.876	16.991	3.885	81%
53	D55M	D55M05697	-30.83767	20.39273	22.115	18.140	3.974	82%
54	D57A	D57A05387	-30.57032	20.45329	68.804	56.077	12.726	82%
55	D57B	D57B05325	-30.55522	20.49942	0.886	0.456	0.430	51%
56	D57C	D57C05254	-30.47333	20.51714	69.813	56.596	13.217	81%
57	D57D	D57E04534	-29.93926	20.81221	70.972	57.696	13.276	81%
58	D57E	D57E04374	-29.65111	21.18345	72.377	47.134	25.243	65%
Hartbees River								
59	D54A	D54B05160	-30.502431	22.014179	2.790	1.194	1.596	43%
60	D54B	D54D04896	-30.2966	21.8473	8.335	3.567	4.769	43%
61	D54C	D54B05129	-30.377384	21.814306	0.000	0.000	0.000	100%
62	D54D	D54D04630	-29.92641	21.2768	10.060	5.250	4.810	52%
63	D54E	D54F05004	-30.37747	21.18407	2.713	1.161	1.552	43%
64	D54F	D54F04645	-29.93643	21.26027	6.342	4.703	1.639	74%
65	D54G	D54G04407	-29.65312	21.18988	21.295	14.729	6.566	69%
66	D53A	D53A04099	-29.39973	21.20478	82.162	64.835	17.327	79%
67	D53B	D53B04104	-29.357025	21.148597	84.236	66.803	17.433	79%
68	D53C	D53C03807	-29.16175	20.84653	86.535	68.628	17.907	79%
69	D53D	D53D03879	-29.15301	20.82764	2.008	1.906	0.103	95%
70	D53E	D53E03557	-28.92011	20.66884	89.543	71.482	18.060	80%
71	D53H	D53H03564	-28.91865	20.65892	1.783	1.783	0.000	100%
72	D53J	D53J03408	-28.752278	20.547549	91.687	69.195	22.492	75%
Molopo River								
73	D42A	D42A01082	-26.435639	20.64088	2.266	2.087	0.178	92%
74	D42D	D42D02283	-28.08516	20.58034	0.000	0.000	0.000	100%
75	D42E	D42E03047	-28.5143	20.21567	0.000	0.000	0.000	100%
Small West Coast rivers								
76	F10A	F10B03391	-28.71823	17.10232	0.022	0.022	0.000	100%
77	F10C	F10B03391(2)	-28.97699	16.72195	0.064	0.064	0.000	100%
78	F20E	F20E04290	-29.52422	17.00079	0.738	0.738	0.000	100%
79	F30A	F30A04782	-29.89982	18.14349	2.313	2.313	0.000	100%
80	F30B	F30B04742	-29.89061	18.13899	1.731	1.731	0.000	100%

No	Quaternary Catchment	Node	Latitude	Longitude	Average annual cumulative flow (million m³)			Present Day (% of natural)
					Natural	Present Day	Difference	
81	F30C	F30C04823	-29.98675	17.79761	6.003	6.003	0.000	100%
82	F30D	F30D04598	-29.67807	17.60292	7.158	7.158	0.000	100%
83	F30E	F30E04444	-29.66987	17.60944	1.492	1.492	0.000	100%
84	F30G	F30G04539	-29.67664	17.05329	11.199	11.199	0.000	100%
85	F40B	F40B04916	-30.08611	17.45965	0.345	0.345	0.000	100%
86	F40C	F40C05007	-30.09004	17.46775	0.519	0.519	0.000	100%
87	F40D	F40D04789	-30.264	17.26102	1.215	1.215	0.000	100%
88	F40F	F40F05159	-30.4723	17.36051	1.282	1.282	0.000	100%
89	F40G	F40G05320	-30.55411	17.73929	0.297	0.297	0.000	100%
90	F40H	F40H05480	-30.59577	17.44355	0.630	0.630	0.000	100%
91	F50A	F50A05626	-30.73706	18.27257	1.546	1.546	0.000	100%
92	F50B	F50B05636	-30.7319	18.26622	0.715	0.715	0.000	100%
93	F50C	F50C05764	-30.82303	18.11749	2.782	2.782	0.000	100%
94	F50D	F50D05726	-30.78946	17.85192	3.597	3.597	0.000	100%
95	F50F	F50F05560	-30.78446	17.85221	1.260	1.260	0.000	100%
96	F50G	F50G05620	-30.84514	17.57622	5.458	5.458	0.000	100%
97	F60A	F60A05886	-31.09686	17.72978	0.177	0.177	0.000	100%
98	F60C	F60C06147	-31.17986	17.90619	0.450	0.450	0.000	100%
99	F60D	F60D06231	-31.24218	17.84726	0.675	0.675	0.000	100%

3 SUMMARY OF ORANGE RIVER EWR RESULTS: ECOCLASSIFICATION

3.1 LOCALITY AND DESCRIPTION OF SITES

Table 3.1 provides the locality of the EWR sites nestled within the identified Management Resource Units (MRUs) (Figure 3.1). For additional information regarding EWR sites, please consult DWS (2016).

Table 3.1 Locality and characteristics of EWR sites

EWR site number	EWR site name	River	Co-ordinates		EcoRegion (Level II)	Geomorphic zone	Altitude (m)	MRU	Quaternary Catchment	Gauge
			Latitude	Longitude						
EWR O2	Boegoeberg	Orange	-29.0055	22.16225	26.05	Lowland	871	MRU Orange D, RAU D.1	D73C	D7H008
EWR O3	Augrabies	Orange	-28.4287	19.9983	28.01	Lowland	433	MRU Orange E	D81B	D7H014
EWR O4	Vioolsdrift	Orange	-28.7553	17.71696	28.01	Lowland	167	MRU Orange F	D82F	D8H003 D8H013
EWR O5	Sendelingsdrift	Orange	-28.0718	16.95951	28.01	Lowland	47	MRU Orange G	D82L	D8H015

Figure 3.1 provides the locality of the EWR sites within the study area.

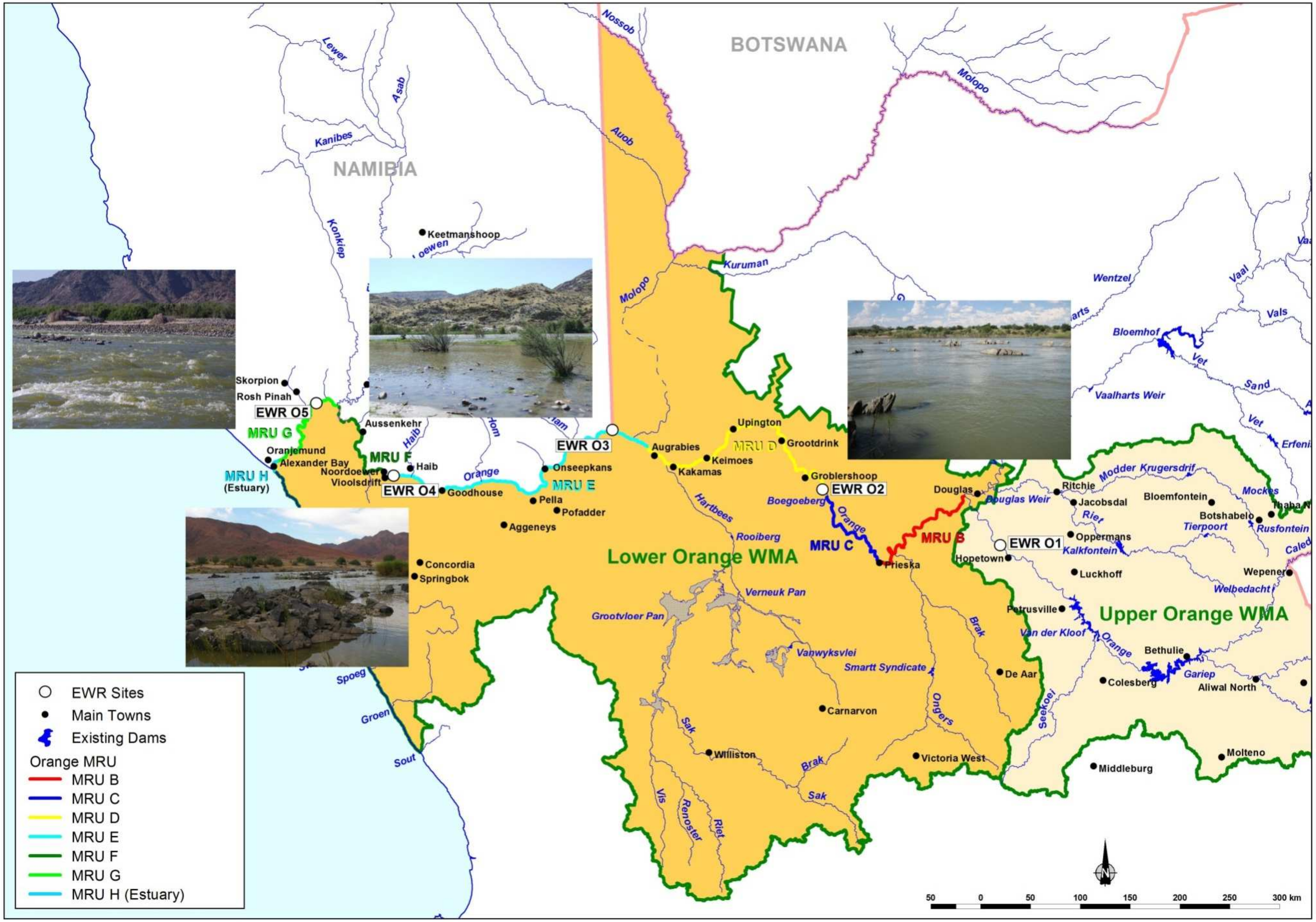

Figure 3.1 Locality and view of EWR sites in context of the MRUs

3.2 ECOCLASSIFICATION LEVEL IV APPROACH

The EcoClassification process followed the methods of Kleynhans and Louw (2007). Information provided in the following sections is a summary of the EcoClassification approach. For additional 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).
- Geomorphology Assessment Index (GAI): Rowntree and du Preez (2006 – Draft report).
- 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 (health or integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) reference condition. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. 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 has to be considered.

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

- Drivers (physico-chemical, geomorphology, 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 = Natural, and F = critically modified) to each component (See box below). Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river. Therefore, the EcoStatus can 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.

ECOLOGICAL CATEGORY	DESCRIPTION
A	Unmodified, near natural.
B	Largely natural with few modifications.
C	Moderately modified.
D	Largely modified.
E	Seriously modified.
F	Critically / Extremely modified.

3.2.1 Present Ecological State

The steps followed in the EcoClassification process are as follows:

- Determine reference conditions for each component.
- Determine the PES for each component, as well as for the EcoStatus that represents an integrated PES for all components.
- Determine the trend for each component, as well as for the EcoStatus.

- Determine the reasons for the PES and whether these are flow or non-flow related.
- Determine the EIS for the biota and habitat.
- Considering the PES and the EIS, suggest a realistic REC for each component, as well as for the EcoStatus.

Following standard methods, the Level 4 EcoStatus assessment was applied and Figure 3.2 (modified from Kleynhans and Louw, 2007) shows the minimum required for this assessment.

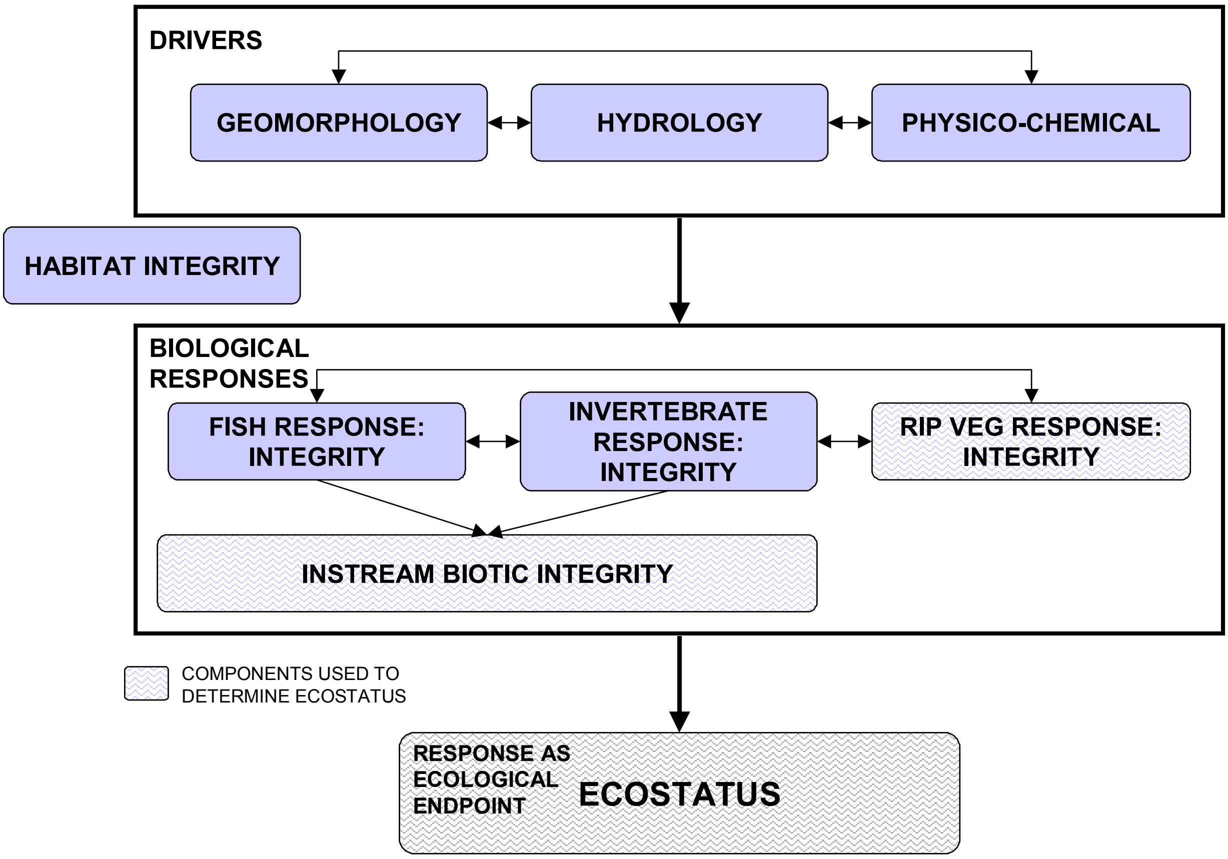

Figure 3.2 EcoStatus Level 4 determination

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 are determined for a range of ECs 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 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. An attempt is made to create a realistic scenario; however, it must be acknowledged that there are many scenarios that could result in a changed EC.

3.2.2 Ecological Importance and Sensitivity

The EIS was calculated using a refined (from Kleynhans and Louw, 2007 and Louw *et al*., 2010) EIS model, developed during 2010 by Dr. Kleynhans. This approach estimates and classifies the EIS of the streams in a catchment by considering a number of components surmised to be indicative of these characteristics.

As the basis for the estimation of EIS, the following ecological aspects are considered:

- For both the instream and riparian components of the river, the presence of rare and endangered species, unique species (i.e., endemic or isolated populations) and communities, intolerant species and species diversity were taken into account.
- Habitat diversity, which included specific habitat types such as reaches with a high diversity of habitat types, i.e., pools, riffles, runs, rapids, waterfalls, riparian forests, etc.

With reference to the bullets above, biodiversity in its general form (i.e. Noss, 1990) takes into account as far as the available information allows:

- Considering the importance of a particular river or stretch of river in providing connectivity between different sections of the river, i.e., whether it provides a migration route or corridor for species,
- The presence of conservation or relatively natural areas along the river section also served as an indication of ecological importance and sensitivity.
- The sensitivity (or fragility) of the system and its resilience (i.e., the ability to recover, following disturbance) of the system to environmental changes was also considered. Consideration of both the biotic and abiotic components was included here.

This report summarises the EIS results of the study and the models provided electronically. EIS categories are summarised in Table 3.2.

Table 3.2 EIS categories (Modified from DWAF, 1999)

EIS Categories	General Description
Very high	Quaternaries/delineations considered 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 considered 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 considered 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 not considered 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.

3.2.3 Recommended Ecological Category

The REC is a recommendation from an ecological viewpoint, considered within the decision-making process in the National Water Resource Classification System (NWRCS). The recommendation is based on, either maintenance of the PES, or an improvement thereof. An improved REC is considered only if the EIS is HIGH or VERY HIGH. The guidelines to derive the REC based on the level of the PES and the EIS as indicated in Table 3.3. Note that in all cases the restoration potential and practicalities of the ecological attainability of recommendations that require improvements are considered.

Table 3.3 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.

3.3 ECOCLASSIFICATION RESULTS (ORANGE RIVER)

The results from Louw and Koekemoer (2010) and Louw *et al*.(2013)are provided as summary tables for each EWR site.

3.3.1 EWR O2 (Boegoeberg): EcoClassification results

Table 3.4 EWR O2: EcoClassification results

EWR O2 (BOEGOEBERG)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique riparian biota, instream biota intolerant to flow, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, and migration corridor.

PES: C
Loss of large flood frequency, agricultural return flows, higher low flows than natural in the dry season, drought and dry periods, decreased low flows at other times, therelease of sediment, presence of alien fish species and barrier effect of dams.

REC: B/C
Instream improvement was not possible due to constraints and no EWR was set for the REC.

Driver Components	PES	TREND	REC
IHI HYDROLOGY	E		
WATER QUALITY	C		C
GEOMORPHOLOGY	C	0	C
INSTREAM IHI	C/D		
RIPARIAN IHI	B/C		
Response Components	**PES**	**TREND**	**REC**
FISH	C	0	C
MACRO INVERTEBRATES	C	0	C
INSTREAM	C	0	C
RIPARIAN VEGETATION	B	0	A/B
RIVERINE FAUNA	C	0	B
ECOSTATUS	C	0	B/C
EIS	HIGH		

3.3.2 EWR O3 (Augrabies)

Table 3.5 EWR O3: EcoClassification results

EWR O3 (AUGRABIES)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor, National Park.

PES: C

Driver Components	PES	TREND	REC
IHI HYDROLOGY	E		
WATER QUALITY	C		C
GEOMORPHOLOGY	C	0	C
INSTREAM IHI	D		
RIPARIAN IHI	C/D		

Decrease in large flood frequency. Agricultural return flows, agricultural activities and associated water quality impacts. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. The presence of alien fish and vegetation species. Barrier effect of dams. Decreased sedimentation.

REC: B
Reinstate droughts (i.e., lower flows than present during the drought season).Improve (higher) wet season base flows. Clear alien vegetation. Improve agricultural practices.

Response Components	PES	TREND	REC
FISH	C	0	B
MACRO INVERTEBRATES	C	0	B
INSTREAM	C	0	B
RIPARIAN VEGETATION	B/C	-	B
RIVERINE FAUNA	C	0	B
ECOSTATUS	C	0	B
EIS	HIGH		

3.3.3 EWR O4 (Vioolsdrift)

Table 3.6 EWR O4: EcoClassification results

EWR O4 (VIOOLSDRIF)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, migration corridor, Transfortier Park in the MRU.

PES: B/C
Decreased large floodfrequency. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. The presence of alien fish and vegetation species. Barrier effect of dams. Decreased sedimentation due to upstream dams and lack of large floods.

REC:
Improved (higher) wet season base flows. Clear alien vegetation. Control grazing and trampling.

Driver Components	PES	TREND	REC
IHI HYDROLOGY	D		
WATER QUALITY	C/D		C/D
GEOMORPHOLOGY	C	0	C
INSTREAM IHI	D		
RIPARIAN IHI	D		
Response Components	**PES**	**TREND**	**REC**
FISH	C	0	B/C
MACRO INVERTEBRATES	C	0	B/C
INSTREAM	C	0	B/C
RIPARIAN VEGETATION	C	-	B
RIVERINE FAUNA	C	-	B/C
ECOSTATUS	C	-	B/C
EIS	HIGH		

3.3.4 EWR O5 (Sendelingsdrift)

Table 3.7 EWR O5: EcoClassification results

EWR O5 (SENDLINGSDRIF)

EIS: HIGH
Highest scoring metrics are rare and endangered instream and riparian species. Unique instream and riparian species. Important migration corridor for various species.The site is situated in the /Ai-/Ais–Richtersveld Transfrontier Park.

PES: B/C
Decreased small and moderate flood frequency. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times.The presence of alien fish and vegetation species. Barrier effect of dams.

REC: B
Increased (from present) wet season base flows. Reinstate dry season droughts.

Driver Components	PES	REC
IHI HYDROLOGY	C	C
WATER QUALITY	C	C
GEOMORPHOLOGY	B/C	B
INSTREAM IHI	C	
RIPARIAN IHI	C	
Response Components	**PES**	**REC**
FISH	B/C	B
MACRO INVERTEBRATES	B/C	B
INSTREAM	B/C	B
RIPARIAN VEGETATION	B/C	B
RIVERINE FAUNA	B	B
ECOSTATUS	B/C	B
EIS	HIGH	

3.4 ECOCLASSIFICATION SUMMARY

The results are summarised for the PES, REC and EIS per site in Table 3.8.

Table 3.8 EcoClassification summary

EWR site	PES	REC	EIS
EWR O2	C	B/C	High
EWR O3	C	B	High
EWR O4	C	B/C	High
EWR O5	B/C	B	High

3.5 ECOCLASSIFICATION CONFIDENCE

Table 3.9 provides the confidence in the EcoClassification process, based on data availability and EcoClassification, where:

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

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

Table 3.9 Confidence in EcoClassification

	Data availability									EcoClassification								
EWR site	Hydrology	Physico-chemical	Geomorphology	IHI	Fish	Macro-invertebrates	Vegetation	Average	Median	Hydrology	Physico-chemical	Geomorphology	IHI	Fish	Macro-invertebrates	Vegetation	Average	Median
O2	2.5	3.3	4	3.5	3	4	4.5	3.5	3.5	3	3.5	3.5	2.6	3	4	4	3.4	3.5
O3	2	3	3	3.5	3	4	4.5	3.3	3	3	3.5	3	3	3.5	4	3.8	3.4	3.5
O4	2	2.3	3.5	3.5	3	4	4.5	3.3	3.5	3	2.5	3	3	3.5	4	3.8	3.3	3
O5	-	2	3	3.5	3	3	3.5	3	3	-	2.5	3	4.3	3	3	3.7	3.2	3

4 SUMMARY OF ORANGE RIVER EWR RESULTS: DISCHARGE RECOMMENDATIONS

4.1 APPROACH

The HFSR method (Hughes and Louw, 2010), a modification of the Building Block Methodology (BBM; King and Louw, 1998) was used to determine the low (base) flow EWRs. This method is one of the methods used to determine EWRs at the intermediate level.

EWRs were determined, using the following process outlined below:

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 first assessing the response of habitat availability and quality to flow reduction. The habitat flow index describes the instantaneous response of habitat to flow in terms of a 0 – 10 index relevant which is relevant for the specific site and described separately for fish and macroinvertebrates. The zero stress (best habitat) and 10 stress (worst habitat) is fixed to ensure that the range for fish and macroinvertebrates are similar:

- 0 –Optimum habitat represented by the maximum natural base flow. Note that without adequate hydrological data, this is difficult to identify.
- 10 – Zero discharge (Note: Surface water may still be present).
- 2 to 9 - Gradual decrease in habitat suitability because of decreased discharge.

The second step is to determine the biotic stress index that describes the instantaneous response of biota to change in habitat (and therefore flow) in terms of a 0 – 10 stress index. The description of the change in habitat availability at each stress level (as described in the habitat stress index) is then associated with the response of the fish and macroinvertebrate indicators. The biotic stress is,then described separately for fish and macroinvertebrates. The zero stress, representing optimum habitat, therefore, represents a situation of zero stress to biota with the maximum abundance of species present under these conditions.

The stress index, therefore, describes the habitat conditions and biotic response of fish and macroinvertebrates at a range of low flows. The fish and macroinvertebrate stress-flow relationship will not be similar, as the responses to the same flow will/can result in different stress for fish and macroinvertebrates.

Using fish and macroinvertebrate stress indices, natural and present day flow time-series are converted to a stress time-series. The resulting stress time-series is in turn, converted to a stress duration graph for the highest and lowest flow months. This provides the specialist with information on how much the stress has changed, due to changes in flow, from natural under present conditions.

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 are refined.

The tools used to determine the stress indices include, specialist knowledge and information regarding the indicator species or taxa and associated habitat requirements, hydraulics (required in a specific format), and the natural hydrology.

At this stage, the only assessment undertaken is the instantaneous response of habitat and biota to flow reduction. This means that the actual stress requirements **at specific durations and during specific seasons** to maintain the biota in a certain ecological state still needs assessment. Considering the information used to determine the EC for the instream biota, the stress required to maintain or achieve this ecological state is determined. The stress requirement is set for drought and maintenance conditions. Drought stress is set at 5% exceedance. Depending on the river, the maintenance stress is set at a percentage, which is determined based on the low flow hydrological variability of the assessed river. The more variable the river, the higher the percentage at which maintenance stress is set. Any stress requirements for other percentage points can also be provided.

However, the requirements are still provided in terms of the separate fish and macroinvertebrate indices. Obviously one can only deal with one stress-flow relationship, and an integrated stress index is required for this. The integrated stress curve comprises the highest stress of either the fish or macroinvertebrate component at any one flow. By converting the results for both fish and macroinvertebrates to integrated stress, the results are comparable.

Figure 4.1 illustrates an example of the interpolated individual component stresses as well as the integrated curve. The black line represents the integrated curve while the other curves represent the stress flow relationships for the various components. The integrated curve, in this case, consists of the flow dependant macroinvertebrates (FDI) (red curve) for the stress range 0 to 5, and fish (blue curve) for the stress range 5 to 10.

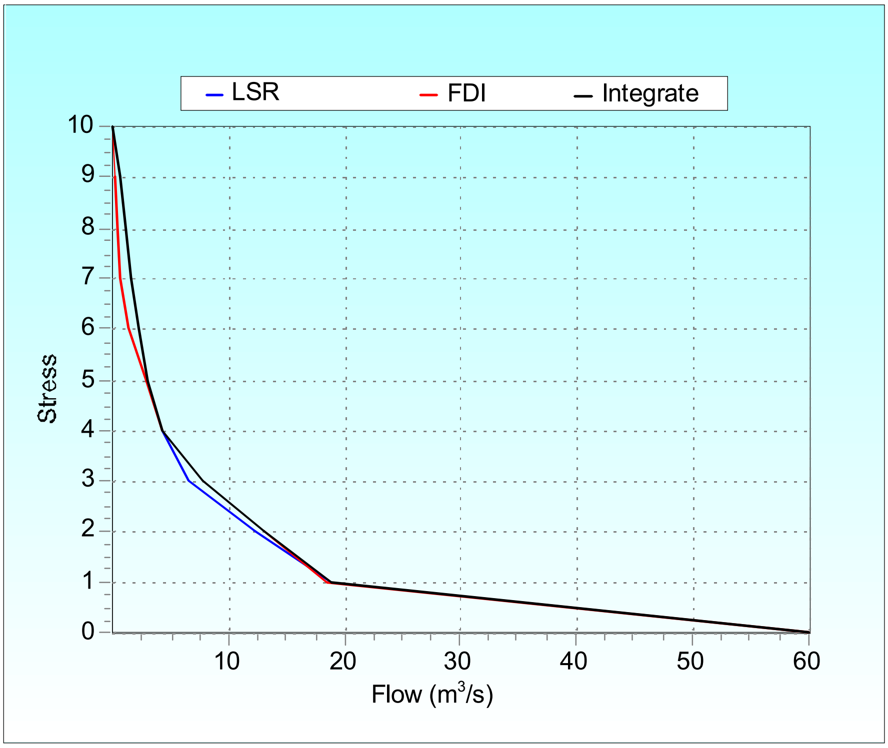

Figure 4.1 Component and integrated stress curves

Specialists determine the required stress (based on the habitat and biotic response) for different durations and for different ECs. The complexity here, as with all flow requirement methods, is to interpret an instantaneous response in terms of duration and seasonal requirements. A graph is produced that reflects the required stress, converted to integrated stress, along with the natural and present day flow that is also converted to integrated stress. This, therefore, supplies the 'hydrological check' to ensure that the requirements are realistic in terms of the natural hydrology and present day hydrology (only used when realistic and of reasonable confidence). The low flow stress requirement for an EC consists of the component with the lowest stress requirement (highest flow requirements). For example, if fish has a stress requirement of 6 at 5% duration to achieve an EC of a C, and similarly macroinvertebrates a stress of 8, the final requirement is a stress of 6. This makes provision for the macroinvertebrates, whereas the 8 stress would not cater for the fish and result in the fish being in a lower EC. These final requirements are therefore connected manually (a 'hand drawn line' as the required stress duration) and illustrated as a stress duration graph.

Figure 4.2 is an example of a stress duration graph and illustrates the stress requirements and stress points required for a D PES and REC (purple arrowed curve), and C AEC (green arrowed curve) during the dry season. The different coloured circles indicate the requirements of the instream biota for the specific EC. Each circle indicates a different biotic component with labels as follows:

- LSR – Large semi-reophilic fish guild.
- FDI – Flow dependent macroinvertebrates.
- MVI – Marginal vegetation macroinvertebrates.

In the example provided below (Figure 4.2), the drought flows (5%) of the different biotic components are the same for all ECs.

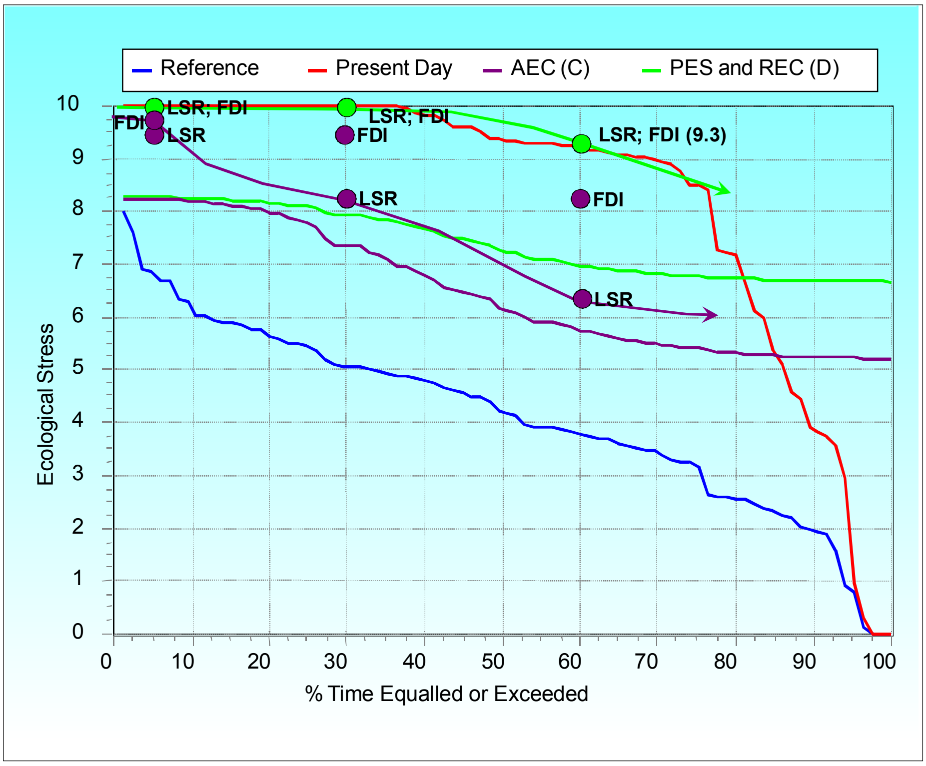

Figure 4.2 Stress duration curve for a D PES and REC, and C AEC up - DRY season

The provision of a complete low flow regime entails the manipulation of these stress requirements (provided for two key months or the high and low flow season), outlined below:

- Included in the above graph, Desktop estimates for the same assessed ECs, converted to stress, are included in the graph above.
- The hydrologist then uses the Desktop estimate and modifies it to fit the specialist requirements using the Desktop Reserve Model (DRM) and the Flow Stressor Response model within

SPATSIM[3] (Spatial and Time Series Modelling) (Hughes and Forsythe, 2006). The process is specifically designed this way, as the seasonal characteristics of the hydrology and rules of the different ECs are built into the Desktop estimate[4]. This ensures that the requirements set by specialists do not deviate significantly from the natural seasonal variability.

- There is a range of options that one can use to make these modifications to the DRM, such as changing the total volume required for the year, changing specific monthly volumes, changing durations of either drought or maintenance flows, changing the seasonal distribution and changing the category rules and shape factors.
- The DRM extrapolates the requirements to the other months or seasons and specialists can check these other months.
- Document changes made to the DRM in order to fit the specialist requirements.
- Document the graphs for the final low flow stress requirements.

4.1.1 High flows

The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; King *et al*., 2003) approach and BBM (King and Louw, 1998). The high flows are determined as follows:

- Specialists identify and table the flood ranges for each flood class and the associated geomorphology and riparian vegetation functions.
- This information is provided to the instream specialists who indicate:
  - which instream function these floods addresses;
  - whether additional instream functions are required; and
  - whether these require any additional flood classes to the ones already identified.
- Identification of the number of floods for each flood class as well as when (early, mid, late) in the season they should occur.
- Adjustment of the number of identified floods for the different ECs.
- To ensure realistic flooding regimes a hydrologist evaluates the floods. The assessment is undertaken using a nearby gauge with daily data. 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.
- Floods are then included in the DRM to provide the final .rul and .tab files.

4.1.2 Final flow requirements

After combining low and high flows, the final flow requirements for each EC consist of:

- An EWR table, which shows the results of high flows and low flows for each month separately. Modelled results exclude high frequency floods (higher than 1:1), as they are unmanageable.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). Supplied EWR rules are for total flows as well as for low flows only.

The low flow EWR rule table is useful for operating the system, whereas for the operation of high flows one uses the EWR table.

[3]SPATSIM is an integrated data management and modelling software package developed in Delphi using the spatial data handling functions of Map Objects. The design allows for the efficient management, processing and modelling of the type of data associated with a range of water resource assessment approaches used in South Africa, including streamflow and other time series data display and analysis, rainfall-runoff models (including the Pitman monthly model) and a variety of Ecological Reserve determination models.

[4]The desktop estimates for specific ECs include rules for these ECs based on long-term data records and expert information.

4.2 RESULTS

4.2.1 EWR O2 (Boegoeberg): EWR results

After combining low- and high flows, the final flow requirements for each EC consist of:

- An EWR table, which shows the results for each month for high flows and low flows separately (Table 4.1). Modelled results exclude high frequency floods, as they are unmanageable.
- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). Supplied EWR rules are for total flows as well as for low flows only (Table 4.2).

The low flow EWR rule table is used for the operation of low flows, whereas the EWR table is used for the operation of high flows.

Table 4.1 EWR O2: EWR table for PES and REC: C

Desktop version:		**2**	**Virgin Mean Annual Runoff (MAR) (Mm^3)**	**10573.7**
BFI	**0.329**	**Distribution type**		**Vaal**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
October	28.211	0.627		
November	36.708	13.665	150	6
December	39.92	19.512	150	6
January	47.269	21.408	150	6
February	61.393	31.478	350	8
March	60.014	31.051	850	12
April	53.153	11.705		
May	39.716	10.906		
June	30.813	11.3		
July	24.956	10.919		
August	23.653	10.171		
September	24.231	6.115		
Total Mm^3	1226.55	465.24	570.98	
% of natural MAR	11.6	4.4	5.5	
Total EWR	1607.2			
% of natural MAR	15.2			

Table 4.2 EWR O2: Assurance rules for PES and REC: C

Desktop Version 2, Printed on 2010/11/03
Summary of EWR rule curves for: EWRO2 Natural Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type: Vaal PES and REC = C

Data are given in m^3/s mean monthly flow

Reserve flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	78.886	73.772	68.755	63.201	53.796	46.506	37.174	27.231	19.120	15.301
Dec	81.831	76.003	70.433	64.246	54.201	46.139	36.811	28.390	22.927	21.077
Jan	86.915	81.014	75.267	68.727	58.092	49.246	39.134	30.201	24.623	22.993
Feb	167.673	147.682	130.734	114.213	88.708	72.594	55.999	43.593	37.338	35.992
Mar	212.180	209.565	202.463	186.957	160.086	123.942	87.367	60.804	48.008	41.514
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	51.211	50.561	49.289	46.994	43.219	37.667	30.560	22.988	16.810	13.902
Dec	53.136	52.548	51.243	48.705	44.449	38.431	31.468	25.182	21.104	19.723
Jan	58.221	57.564	56.095	53.229	48.428	41.677	33.959	27.141	22.883	21.639
Feb	71.576	70.962	69.309	65.713	59.466	50.988	42.256	35.728	32.437	31.729
Mar	67.585	67.014	65.465	62.082	56.221	48.336	40.357	34.563	31.771	31.280
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Natural Duration curves

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	631.571	345.904	243.160	171.151	109.282	82.788	63.762	40.931	25.336	5.780
Nov	918.985	673.117	500.725	372.319	254.479	224.730	170.517	136.802	59.047	17.191
Dec	1020.120	723.973	540.834	415.502	339.382	299.522	213.527	114.475	82.269	33.774
Jan	1270.557	903.875	638.303	521.184	395.508	298.484	227.173	172.547	96.210	43.003
Feb	2052.472	1278.741	891.353	538.802	436.872	319.498	273.276	229.588	135.235	45.705
Mar	1562.280	1034.289	698.014	607.411	468.765	335.738	252.647	200.396	126.176	41.514
Apr	899.541	636.867	406.590	319.606	288.630	238.515	170.093	119.487	75.598	29.344
May	353.271	265.091	197.431	133.277	106.732	82.154	72.353	47.551	34.606	11.470
Jun	192.647	140.895	91.454	71.937	60.683	56.296	43.534	33.029	22.477	11.617
Jul	149.578	100.896	84.569	67.040	47.525	39.221	32.818	26.329	19.108	15.084
Aug	152.337	106.582	83.796	60.140	50.881	34.069	27.770	23.466	18.246	14.445
Sep	229.946	126.123	86.844	65.251	48.935	39.734	28.403	21.748	13.353	8.333

4.2.2 EWR O3 (Augrabies): EWR results

After combining low- and high flows, the final flow requirements for each EC consist of:

- An EWR table, which shows the results for each month for high flows and low flows separately (Table 4.3 – 4.4). Modelled results exclude high frequency floods, as they are unmanageable.
- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). Supplied EWR rules are for total flows as well as for low flows only (Table 4.5 – 4.6).

The low flow EWR rule table is used for the operation of low flows, whereas the EWR table is used for the operation of high flows.

Table 4.3 EWR O3: EWR table for PES: C

Desktop version:		2	Virgin MAR (Mm^3)	10513.1
BFI	0.321	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
October	21.303	0		
November	26.529	4.996	150	6
December	28.289	11.503	150	6
January	32.818	12.649	150	6
February	41.932	18.259	350	8
March	40.759	17.993	680	12
April	36.835	8.171		
May	28.578	8.255		
June	23.44	8.872		
July	19.734	7.051		
August	18.906	6.62		
September	19.174	0.98		
Total Mm^3	883.1	273.34	494.12	
% of natural MAR	8.4	2.6	4.7	
Total EWR	1251.06			
% of natural MAR	11.9			

Table 4.4 EWR O3: EWR table for REC: B

Desktop version:		2	Virgin MAR (Mm^3)	10513.1
BFI	0.321	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
October	30.573	0		
November	50.997	4.996	150	6
December	60.593	15.102	150	6
January	80.058	12.649	150	6
February	112.695	29.315	350	8
March	114.188	30.552	680	12
April	95.29	8.171		
May	61.835	8.255		
June	37.721	9.622		
July	23.829	9.491		
August	20.268	9.14		
September	19.389	0.98		
Total Mm^3	1850.31	157.37	494.12	
% of natural MAR	17.6	3.4	4.7	
Total EWR	2018.52			
% of natural MAR	19.2			

Table 4.5 EWR O3: Assurance rules for PES: C

Desktop Version 2, Printed on 2010/11/04
Summary of EWR rule curves for: EWR O3 Natural Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type: Vaal PES = C

Data are given in m^3/s mean monthly flow

Reserve flows

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.557	31.178	30.480	29.242	27.155	23.841	18.990	12.651	5.723	0.000
Nov	65.933	60.925	56.132	50.999	42.292	36.002	27.841	18.899	11.195	6.982
Dec	68.900	62.971	57.368	51.403	42.074	35.325	27.632	20.516	15.497	13.222
Jan	76.372	69.112	62.097	54.413	43.272	34.906	26.535	19.904	15.927	14.331
Feb	159.208	134.641	113.429	93.237	66.395	51.557	38.472	29.439	24.667	22.895
Mar	184.526	177.511	162.886	139.020	108.533	78.046	54.180	39.555	32.540	30.055
Apr	51.049	49.491	46.254	40.754	33.170	24.759	17.341	12.220	9.515	8.510
May	39.997	39.086	37.217	33.943	29.104	23.159	17.211	12.499	9.673	8.539
Jun	33.355	32.813	31.727	29.787	26.745	22.627	17.932	13.590	10.527	9.138
Jul	28.504	28.148	27.459	26.223	24.194	21.196	17.307	13.045	9.374	7.366
Aug	28.089	27.831	27.356	26.514	25.094	22.840	19.539	15.227	10.513	7.115
Sep	23.717	23.529	23.203	22.645	21.700	20.127	17.579	13.631	7.996	1.988

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.557	31.178	30.480	29.242	27.155	23.841	18.990	12.651	5.723	0.000
Nov	38.256	37.703	36.635	34.718	31.573	26.926	20.896	14.289	8.597	5.484
Dec	40.268	39.631	38.355	36.076	32.502	27.663	22.148	17.046	13.447	11.816
Jan	45.989	45.032	43.069	39.630	34.547	28.303	22.056	17.107	14.138	12.948
Feb	58.295	56.840	53.818	48.682	41.601	33.747	26.821	22.040	19.514	18.576
Mar	56.174	54.453	50.864	45.008	37.528	30.047	24.192	20.603	18.882	18.272
Apr	51.049	49.491	46.254	40.754	33.170	24.759	17.341	12.220	9.515	8.510
May	39.997	39.086	37.217	33.943	29.104	23.159	17.211	12.499	9.673	8.539
Jun	33.355	32.813	31.727	29.787	26.745	22.627	17.932	13.590	10.527	9.138
Jul	28.504	28.148	27.459	26.223	24.194	21.196	17.307	13.045	9.374	7.366
Aug	28.089	27.831	27.356	26.514	25.094	22.840	19.539	15.227	10.513	7.115
Sep	23.717	23.529	23.203	22.645	21.700	20.127	17.579	13.631	7.996	1.988

Natural Duration curves

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	625.022	339.729	238.616	164.643	103.756	76.240	57.239	34.909	18.821	0.000
Nov	914.267	664.780	492.404	364.016	246.127	219.066	162.211	129.147	50.710	8.954
Dec	1012.929	715.192	532.706	406.933	331.291	290.737	204.794	105.802	74.175	24.985
Jan	1262.321	923.439	638.792	513.740	386.914	298.574	219.079	163.956	87.623	34.476
Feb	2068.130	1297.202	903.282	548.251	432.614	313.600	268.556	222.359	128.001	38.447
Mar	1579.234	1029.312	705.279	602.210	475.821	337.481	248.693	196.181	122.525	38.041
Apr	909.772	633.503	413.584	324.093	285.313	244.904	175.428	122.145	72.234	25.667
May	355.152	262.418	195.744	130.589	107.056	81.851	69.739	45.669	32.053	8.793
Jun	190.698	138.897	89.664	74.742	60.035	54.333	41.539	33.013	20.652	11.323
Jul	147.345	99.836	89.595	65.315	45.613	36.989	31.127	24.709	17.085	12.851
Aug	149.029	112.541	83.065	62.724	48.092	34.629	25.291	20.535	14.938	11.137
Sep	224.877	120.988	81.709	60.116	44.159	34.688	26.505	16.725	8.252	3.221

Table 4.6 EWR O3: Assurance rules for REC: B

Desktop Version 2, Printed on 2010/11/04
Summary of EWR rule curves for:EWRO3 Natural Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type: Vaal REC = B

Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	45.572	45.145	44.182	42.204	38.529	32.471	23.869	13.822	4.967	0.000
Nov	98.751	93.748	88.716	82.693	71.750	61.056	45.959	28.578	13.718	6.808
Dec	112.793	106.347	99.404	90.547	76.024	61.632	44.979	29.944	20.193	16.890
Jan	131.804	124.946	117.059	106.342	88.710	70.025	48.667	29.796	18.015	14.571
Feb	239.908	216.227	192.258	164.745	125.280	94.919	66.705	46.745	36.637	34.307
Mar	269.643	262.286	246.887	219.882	180.747	134.750	92.006	61.765	46.452	38.041
Apr	121.675	118.015	110.355	96.921	77.453	54.571	33.308	18.264	10.647	8.890
May	79.624	78.350	75.503	69.947	60.639	47.550	32.588	19.369	11.116	8.703
Jun	52.356	51.609	49.950	46.724	41.316	33.667	24.818	16.828	11.646	9.891
Jul	33.211	32.985	32.471	31.410	29.431	26.171	21.571	16.274	11.745	9.639
Aug	30.269	30.071	29.624	28.707	27.003	24.195	20.207	15.549	11.443	9.272
Sep	30.834	30.741	30.397	29.686	28.290	25.729	21.438	15.107	7.476	1.735
Reserve flows without High Flows										
Oct	45.572	45.145	44.182	42.204	38.529	32.471	23.869	13.822	4.967	0.000
Nov	70.979	70.350	68.922	65.968	60.464	51.397	38.599	23.865	11.267	5.409
Dec	84.098	82.892	80.214	75.005	66.273	53.924	39.637	26.736	18.370	15.536
Jan	103.110	101.496	97.887	90.845	79.047	62.456	43.491	26.736	16.275	13.217
Feb	144.274	140.567	132.809	119.202	99.485	76.310	54.774	39.537	31.822	30.044
Mar	146.201	142.472	134.667	120.979	101.143	77.829	56.164	40.836	33.074	31.285
Apr	121.675	118.015	110.355	96.921	77.453	54.571	33.308	18.264	10.647	8.890
May	79.624	78.350	75.503	69.947	60.639	47.550	32.588	19.369	11.116	8.703
Jun	52.356	51.609	49.950	46.724	41.316	33.667	24.818	16.828	11.646	9.891
Jul	33.211	32.985	32.471	31.410	29.431	26.171	21.571	16.274	11.745	9.639
Aug	30.269	30.071	29.624	28.707	27.003	24.195	20.207	15.549	11.443	9.272
Sep	30.834	30.741	30.397	29.686	28.290	25.729	21.438	15.107	7.476	1.735
Natural Duration curves										
Oct	625.022	339.729	238.616	164.643	103.756	76.240	57.239	34.909	18.821	0.000
Nov	914.267	664.780	492.404	364.016	246.127	219.066	162.211	129.147	50.710	8.954
Dec	1012.929	715.192	532.706	406.933	331.291	290.737	204.794	105.802	74.175	24.985
Jan	1262.321	923.439	638.792	513.740	386.914	298.574	219.079	163.956	87.623	34.476
Feb	2068.130	1297.202	903.282	548.251	432.614	313.600	268.556	222.359	128.001	38.447
Mar	1579.234	1029.312	705.279	602.210	475.821	337.481	248.693	196.181	122.525	38.041
Apr	909.772	633.503	413.584	324.093	285.313	244.904	175.428	122.145	72.234	25.667
May	355.152	262.418	195.744	130.589	107.056	81.851	69.739	45.669	32.053	8.793
Jun	190.698	138.897	89.664	74.742	60.035	54.333	41.539	33.013	20.652	11.323
Jul	147.345	99.836	89.595	65.315	45.613	36.989	31.127	24.709	17.085	12.851
Aug	149.029	112.541	83.065	62.724	48.092	34.629	25.291	20.535	14.938	11.137
Sep	224.877	120.988	81.709	60.116	44.159	34.688	26.505	16.725	8.252	3.221

4.2.3 EWR O4 (Vioolsdrift): EWR results

After combining low- and high flows, the final flow requirements for each EC consist of:

- An EWR table, which shows the results for each month for high flows and low flows separately (Table 4.7 – 4.7). Modelled results exclude high frequency floods, as they are unmanageable.
- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). Supplied EWR rules are for total flows as well as for low flows only (Table 4.9 – 4.10).

The low flow EWR rule table is used for the operation of low flows, whereas the EWR table is used for the operation of high flows.

Table 4.7 EWR O4: EWR table for PES: C

Desktop version:		2	Virgin MAR (Mm^3)	103351.1
BFI	0.312	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
October	12.783	0		
November	18.34	0	170	6
December	20.708	2.233	60 170	5 6
January	25.928	2.319	170	6
February	35.255	7.875	340	8
March	35.235	7.856	500	12
April	30.393	3.854		
May	21.409	4.829		
June	15.308	3.498		
July	11.408	2.639		
August	10.311	2.356		
September	10.034	0		
Total Mm^3	651.11	35.16	434.07	
% of natural MAR	6.3	0.9	4.2	
Total EWR	919.82			
% of natural MAR	8.9			

Table 4.8 EWR O4: EWR table for REC: B/C

Desktop version:		2	Virgin MAR (Mm^3)	103351.1
BFI	0.312	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
October	22.199	0		
November	30.049	0	170	6
December	33.18	2.233	60 170	5 6
January	40.414	2.319	170	6
February	53.819	12.333	340	8
March	53.311	12.303	500	12
April	46.751	3.854		
May	34.152	5.081		
June	25.848	5.478		
July	20.294	4.133		
August	18.773	2.356		
September	18.54	0		
Total Mm^3	1043.85	134.36	434.07	
% of natural MAR	10.1	1.3	4.2	
Total EWR	1260.88			
% of natural MAR	12.2			

Table 4.9 EWR O4: Assurance rules for PES: C

Desktop Version 2, Printed on 2010/11/05
Summary of EWR rule curves for: EWRO4 Natural Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type: Vaal PES = C

Data are given in m^3/s mean monthly flow

Reserve flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	18.927	18.675	18.198	17.333	15.852	13.492	10.084	5.827	1.688	0.000
Nov	57.741	52.179	46.926	41.387	31.962	25.570	17.583	9.487	3.514	0.000
Dec	72.078	63.462	55.516	47.320	34.552	26.293	17.409	9.971	5.545	4.425
Jan	70.583	62.303	54.184	45.173	32.261	22.852	14.108	7.922	4.790	4.068
Feb	146.798	122.512	100.934	79.747	51.969	36.569	24.104	16.465	13.024	12.277
Mar	143.662	138.431	127.394	108.778	83.896	57.826	36.723	23.790	17.966	16.700
Apr	42.016	40.453	37.157	31.597	24.165	16.379	10.077	6.214	4.475	4.096
May	29.914	29.105	27.412	24.443	20.141	15.084	10.384	7.060	5.376	4.988
Jun	21.732	21.280	20.353	18.682	16.081	12.663	8.987	5.908	4.077	3.613
Jul	16.449	16.194	15.686	14.760	13.236	11.012	8.233	5.417	3.339	2.726
Aug	15.297	15.125	14.799	14.207	13.195	11.581	9.251	6.340	3.510	2.438
Sep	12.402	12.289	12.088	11.734	11.119	10.076	8.364	5.720	2.113	0.000

Reserve flows without High Flows

Oct	18.927	18.675	18.198	17.333	15.852	13.492	10.084	5.827	1.688	0.000
Nov	26.382	25.894	24.924	23.156	20.243	15.995	10.687	5.307	1.337	0.000
Dec	29.357	28.684	27.304	24.819	20.951	15.867	10.397	5.819	3.094	2.405
Jan	36.161	35.070	32.786	28.781	22.976	16.154	9.814	5.328	3.057	2.533
Feb	48.810	47.134	43.598	37.634	29.663	21.311	14.550	10.406	8.541	8.135
Mar	48.782	47.107	43.571	37.609	29.639	21.289	14.529	10.387	8.521	8.116
Apr	42.016	40.453	37.157	31.597	24.165	16.379	10.077	6.214	4.475	4.096
May	29.914	29.105	27.412	24.443	20.141	15.084	10.384	7.060	5.376	4.988
Jun	21.732	21.280	20.353	18.682	16.081	12.663	8.987	5.908	4.077	3.613
Jul	16.449	16.194	15.686	14.760	13.236	11.012	8.233	5.417	3.339	2.726
Aug	15.297	15.125	14.799	14.207	13.195	11.581	9.251	6.340	3.510	2.438
Sep	12.402	12.289	12.088	11.734	11.119	10.076	8.364	5.720	2.113	0.000

Natural Duration curves

Oct	617.290	332.064	230.880	156.915	96.778	68.504	49.507	27.274	11.092	0.000
Nov	905.096	654.931	482.554	354.171	236.273	209.336	152.365	119.425	40.860	0.000
Dec	1002.860	704.824	522.461	396.565	321.263	280.369	194.437	95.456	63.937	4.734
Jan	1252.087	913.206	628.491	503.655	376.613	288.986	208.748	153.655	77.326	24.190
Feb	2063.864	1293.461	898.313	539.790	424.611	305.035	260.007	213.802	119.444	29.882
Mar	1577.203	1023.167	701.430	596.027	472.200	331.343	242.742	190.181	116.629	31.851
Apr	906.879	629.217	411.092	322.631	281.034	241.238	171.188	117.909	67.948	21.323
May	352.830	259.244	192.753	127.412	104.600	78.995	66.577	42.641	28.902	5.619
Jun	188.345	136.535	87.346	72.380	58.627	51.979	39.182	30.687	18.326	9.340
Jul	144.710	97.420	86.962	63.045	43.037	34.353	28.491	22.073	14.490	10.215
Aug	145.128	108.639	79.648	58.830	44.194	30.727	21.408	16.637	11.036	5.238
Sep	218.835	114.934	75.656	54.063	38.171	28.546	20.455	10.683	2.218	0.000

Table 4.10 EWR O4: Assurance rules for REC: B/C

Desktop Version 2, Printed on 2010/11/05
Summary of EWR rule curves for: EWRO4 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal REC = B/C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.766	31.447	30.704	29.141	26.200	21.373	14.701	7.399	1.800	0.000
Nov	74.473	69.078	63.966	58.310	48.043	39.468	27.617	14.645	4.699	0.000
Dec	86.512	77.922	69.818	60.962	46.615	35.624	23.222	12.514	6.096	4.514
Jan	85.724	78.848	71.898	63.615	50.112	38.119	24.586	12.902	5.899	4.173
Feb	163.354	142.077	122.406	102.019	72.867	54.170	36.795	24.502	18.278	16.843
Mar	161.737	157.177	147.634	130.898	106.645	78.140	51.650	32.909	23.419	21.231
Apr	61.069	59.224	55.363	48.591	38.778	27.243	16.525	8.942	5.102	4.217
May	44.994	44.266	42.629	39.424	34.059	26.559	18.097	10.790	6.411	5.332
Jun	34.071	33.550	32.377	30.081	26.237	20.865	14.802	9.568	6.431	5.658
Jul	29.066	28.816	28.233	27.005	24.697	20.908	15.672	9.940	5.546	4.289
Aug	26.878	26.632	26.059	24.852	22.582	18.855	13.705	8.068	3.746	2.509
Sep	26.715	26.506	26.061	25.162	23.454	20.449	15.694	9.267	2.218	0.000

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.766	31.447	30.704	29.141	26.200	21.373	14.701	7.399	1.800	0.000
Nov	42.999	42.567	41.562	39.445	35.465	28.930	19.900	10.015	2.437	0.000
Dec	43.684	42.929	41.228	37.900	32.328	24.540	15.750	8.162	3.614	2.493
Jan	53.204	52.277	50.189	46.103	39.263	29.702	18.913	9.597	4.015	2.639
Feb	70.452	68.578	64.656	57.777	47.808	36.092	25.204	17.501	13.601	12.701
Mar	69.789	67.935	64.055	57.251	47.392	35.803	25.034	17.415	13.557	12.667
Apr	61.069	59.224	55.363	48.591	38.778	27.243	16.525	8.942	5.102	4.217
May	44.994	44.266	42.629	39.424	34.059	26.559	18.097	10.790	6.411	5.332
Jun	34.071	33.550	32.377	30.081	26.237	20.865	14.802	9.568	6.431	5.658
Jul	29.066	28.816	28.233	27.005	24.697	20.908	15.672	9.940	5.546	4.289
Aug	26.878	26.632	26.059	24.852	22.582	18.855	13.705	8.068	3.746	2.509
Sep	26.715	26.506	26.061	25.162	23.454	20.449	15.694	9.267	2.218	0.000

Natural Duration curves

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	617.290	332.064	230.880	156.915	96.778	68.504	49.507	27.274	11.092	0.000
Nov	905.096	654.931	482.554	354.171	236.273	209.336	152.365	119.425	40.860	0.000
Dec	1002.860	704.824	522.461	396.565	321.263	280.369	194.437	95.456	63.937	4.734
Jan	1252.087	913.206	628.491	503.655	376.613	288.986	208.748	153.655	77.326	24.190
Feb	2063.864	1293.461	898.313	539.790	424.611	305.035	260.007	213.802	119.444	29.882
Mar	1577.203	1023.167	701.430	596.027	472.200	331.343	242.742	190.181	116.629	31.851
Apr	906.879	629.217	411.092	322.631	281.034	241.238	171.188	117.909	67.948	21.323
May	352.830	259.244	192.753	127.412	104.600	78.995	66.577	42.641	28.902	5.619
Jun	188.345	136.535	87.346	72.380	58.627	51.979	39.182	30.687	18.326	9.340
Jul	144.710	97.420	86.962	63.045	43.037	34.353	28.491	22.073	14.490	10.215
Aug	145.128	108.639	79.648	58.830	44.194	30.727	21.408	16.637	11.036	5.238
Sep	218.835	114.934	75.656	54.063	38.171	28.546	20.455	10.683	2.218	0.000

4.2.4 EWR O5 (Sendelingsdrift): EWR results

After combining low and high flows, the final flow requirements for each EC consist of:

- An EWR table, which shows the results for each month for high flows and low flows separately (Table 4.11 – 4.12). Modelled results exclude high frequency floods, as they are unmanageable.
- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). Supplied EWR rules are for total flows as well as for low flows only (Table 4.13 – 4.14).

The low flow EWR rule table is used for the operation of low flows, whereas the EWR table is used for the operation of high flows.

Table 4.11 EWR O5: EWR table for PES: B/C

Desktop version:		2	Virgin MAR (Mm^3)	11 373
BFI	**0.301**	**Distribution type**		**Vaal**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
October	13.1	2.1		
November	18.4	2.9	190	7
December	21.5	3.4	60 190	5 7
January	29.4	4.6	60 190	5 7
February	43.0	6.7	60 300	5 10
March	40.4	6.3	60 500	5 12
April	35.8	5.6		
May	25.08	3.9		
June	16.8	2.7		
July	12.1	1.9		
August	10.6	1.7		
September	10.1	0		
Total Mm^3	721.63	109.42	512.85	
% of natural MAR	6.35	0.96	4.51	
Total EWR	1234.48			
% of natural MAR	10.85			

Table 4.12 EWR O5: EWR table for REC: B

Desktop version:		2	Virgin MAR (Mm^3)	11373
BFI	**0.301**	**Distribution type**	**Vaal**	
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
October	22.9	2.6		
November	30.5	3.3	190	7
December	34.5	4.5	60 190	5 7
January	45.7	5.9	60 190	5 7
February	65.1	10.0	60 300	5 10
March	61.0	9.4	60 500	5 12
April	54.6	6.2		
May	39.5	5.9		
June	28.2	4.0		
July	21.4	2.9		
August	19.3	2.6		
September	18.8	0		
Total Mm^3	1154.46	149.64	512.85	

Desktop version:		2	Virgin MAR (Mm^3)	11373
BFI	0.301	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
% of natural MAR	10.15	1.32	4.51	
Total EWR	1667.32			
% of natural MAR	14.66			

Table 4.13 EWR O5: Assurance rules for PES: B/C

Desktop Version 2, Printed on 2013/02/05 Regional Type: Vaal PES = B/C

Data are given in m3/s mean monthly flow

Reserve flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	19.455	19.247	18.863	18.183	17.035	15.214	12.547	9.063	5.254	2.508
Nov	65.21	58.599	52.641	46.787	36.789	31.191	23.927	15.97	9.113	3.306
Dec	80.362	70.539	61.798	53.229	39.833	31.95	22.964	14.652	8.788	6.131
Jan	94.095	82.061	71.105	59.937	43.81	33.27	22.723	14.369	9.357	7.347
Feb	178.144	149.066	123.701	99.227	66.656	48.078	31.695	20.386	14.41	12.192
Mar	156.519	150.135	136.824	115.102	87.354	59.606	37.884	24.573	18.189	15.927
Apr	49.497	47.902	44.586	38.953	31.184	22.568	14.97	9.725	6.954	5.924
May	34.954	34.064	32.237	29.037	24.307	18.497	12.683	8.078	5.316	4.208
Jun	23.824	23.355	22.416	20.741	18.113	14.555	10.5	6.749	4.102	2.903
Jul	17.399	17.143	16.646	15.756	14.295	12.136	9.334	6.265	3.621	2.175
Aug	15.684	15.516	15.207	14.659	13.735	12.269	10.123	7.317	4.251	2.041
Sep	12.512	12.409	12.23	11.922	11.402	10.536	9.134	5.883	2.188	0.555

Reserve flows without High Flows

Oct	19.455	19.247	18.863	18.183	17.035	15.214	12.547	9.063	5.254	2.508
Nov	26.58	26.188	25.428	24.065	21.828	18.522	14.234	9.536	5.487	3.273
Dec	30.461	29.861	28.659	26.515	23.151	18.597	13.405	8.603	5.216	3.68
Jan	41.14	40.092	37.941	34.172	28.603	21.761	14.916	9.493	6.24	4.935
Feb	59.566	57.645	53.654	46.873	37.522	27.15	18.004	11.691	8.355	7.116
Mar	55.434	53.218	48.599	41.062	31.433	21.804	14.267	9.648	7.432	6.648
Apr	49.497	47.902	44.586	38.953	31.184	22.568	14.97	9.725	6.954	5.924
May	34.954	34.064	32.237	29.037	24.307	18.497	12.683	8.078	5.316	4.208
Jun	23.824	23.355	22.416	20.741	18.113	14.555	10.5	6.749	4.102	2.903
Jul	17.399	17.143	16.646	15.756	14.295	12.136	9.334	6.265	3.621	2.175
Aug	15.684	15.516	15.207	14.659	13.735	12.269	10.123	7.317	4.251	2.041
Sep	12.512	12.409	12.23	11.922	11.402	10.536	9.134	5.883	2.188	0.555

Natural Duration curves

Oct	706.187	309.569	217.611	156.519	98.212	64.191	44.605	22.252	10.749	2.595
Nov	805.208	601.728	474.263	354.198	245.224	191.331	158.225	114.363	37.176	3.306
Dec	994.388	659.939	506.724	396.744	317.003	284.468	223.029	87.582	49.231	21.001
Jan	1403.872	1016.473	786.376	510.682	382.09	257.68	208.964	130.974	72.405	28.129
Feb	2300.566	1709.974	1229.638	824.417	482.684	362.913	285.189	211.959	132.593	25.765
Mar	1869.067	1069.474	744.004	656.25	538.777	350.317	277.666	203.409	148.309	42.832
Apr	962.813	876.034	474.672	353.646	302.431	247.5	193.769	146.231	100.536	26.424
May	367.182	276.96	220.154	157.672	118.492	107.116	79.025	48.596	30.597	6.803
Jun	186.485	141.049	92.886	72.184	57.681	54.414	45.71	30.077	17.662	7.928
Jul	147.991	100.553	80.276	59.054	41.237	33.819	28.342	21.39	14.639	10.055
Aug	158.065	112.351	82.131	53.566	34.476	24.739	20.845	17.365	12.227	7.781
Sep	213.492	130.305	73.453	52.558	37.681	24.41	14.892	5.883	2.188	2.033

Table 4.14 EWR O5: Assurance rules for REC: B

Desktop Version 2, Printed on 2013/02/05   Regional Type: Vaal   REC = B
Data are given in m3/s mean monthly flow

%Points

Reserve flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	35.029	34.703	33.945	32.348	29.346	24.417	17.605	10.149	4.433	2.595
Nov	82.375	75.887	69.985	63.895	52.943	45.132	34.106	21.411	10.558	3.306
Dec	98.92	89.011	79.852	70.14	54.426	42.912	29.59	17.562	9.761	7.119
Jan	110.193	100.083	90.458	79.82	62.561	48.939	33.367	19.61	11.021	8.511
Feb	197.552	171.659	147.54	122.307	86.217	62.628	40.706	25.197	17.344	15.534
Mar	161.171	153.882	138.537	113.892	83.701	55.485	35.368	24.428	19.891	18.947
Apr	71.412	69.309	64.908	57.189	46.005	32.858	20.642	11.999	7.622	6.613
May	52.044	51.22	49.379	45.787	39.768	31.305	21.63	13.082	7.746	6.186
Jun	39.877	39.25	37.858	35.15	30.611	24.191	16.764	10.058	5.709	4.235
Jul	30.665	30.401	29.8	28.559	26.244	22.432	17.051	10.856	5.559	3.096
Aug	29.593	29.322	28.69	27.36	24.859	20.754	15.08	8.87	4.109	2.747
Sep	30.715	30.575	29.966	28.505	25.455	20.092	12.551	4.848	0.192	0.192

Reserve flows without High Flows

Oct	35.029	34.703	33.945	32.348	29.346	24.417	17.605	10.149	4.433	2.595
Nov	43.614	43.229	42.357	40.553	37.19	31.651	23.833	14.832	7.137	3.306
Dec	48.908	48.131	46.407	43.053	37.43	29.478	20.278	11.972	6.584	4.759
Jan	60.182	59.212	57.043	52.81	45.719	35.746	24.347	14.276	7.988	6.151
Feb	85.176	82.754	77.684	68.791	55.906	40.76	26.686	16.729	11.687	10.524
Mar	69.877	66.8	60.319	49.912	37.162	25.247	16.752	12.132	10.216	9.817
Apr	71.412	69.309	64.908	57.189	46.005	32.858	20.642	11.999	7.622	6.613
May	52.044	51.22	49.379	45.787	39.768	31.305	21.63	13.082	7.746	6.186
Jun	39.877	39.25	37.858	35.15	30.611	24.191	16.764	10.058	5.709	4.235
Jul	30.665	30.401	29.8	28.559	26.244	22.432	17.051	10.856	5.559	3.096
Aug	29.593	29.322	28.69	27.36	24.859	20.754	15.08	8.87	4.109	2.747
Sep	30.715	30.575	29.966	28.505	25.455	20.092	12.551	4.848	0.192	0.192

Natural Duration curves

Oct	706.187	309.569	217.611	156.519	98.212	64.191	44.605	22.252	10.749	2.595
Nov	805.208	601.728	474.263	354.198	245.224	191.331	158.225	114.363	37.176	3.306
Dec	994.388	659.939	506.724	396.744	317.003	284.468	223.029	87.582	49.231	21.001
Jan	403.872	16.473	786.376	510.682	382.09	257.68	208.964	130.974	72.405	28.129
Feb	300.566	709.974	229.638	824.417	482.684	362.913	285.189	211.959	132.593	25.765
Mar	869.067	69.474	744.004	656.25	538.777	350.317	277.666	203.409	148.309	42.832
Apr	962.813	876.034	474.672	353.646	302.431	247.5	193.769	146.231	100.536	26.424
May	367.182	276.96	220.154	157.672	118.492	107.116	79.025	48.596	30.597	6.803
Jun	186.485	141.049	92.886	72.184	57.681	54.414	45.71	30.077	17.662	7.928
Jul	147.991	100.553	80.276	59.054	41.237	33.819	28.342	21.39	14.639	10.055
Aug	158.065	112.351	82.131	53.566	34.476	24.739	20.845	17.365	12.227	7.781
Sep	213.492	130.305	73.453	52.558	37.681	24.41	14.892	5.883	2.188	2.033

4.3 EWR RESULT SUMMARY

Table 4.15 provides the final flow requirements, expressed as a percentage of the natural MAR (nMAR).

Table 4.15 Summary of EWR results as a percentage of the natural MAR

Site	EC	Maintenance low flows		Drought low flows		High flows		Long-term mean	
		(%nMAR)	Mm^3	(%nMAR)	Mm^3	(%nMAR)	Mm^3	(% nMAR)	Mm^3
EWR O2	PES/REC	11.6	1226.55	4.4	465.24	5.4	570.98	15.2	1607.20
EWR O3	PES: C	8.4	883.10	2.6	273.34	4.7	494.12	11.9	1251.06
	REC: B	17.6	1850.31	3.4	157.37	4.7	494.12	19.2	2018.52
EWR O4	PES: C	6.3	651.11	0.9	35.16	4.2	434.07	8.9	919.82
	REC: B/C	10.1	1043.85	1.3	134.36	4.2	434.07	12.2	1260.88
EWR O5	PES: B/C	6.35	721.63	0.96	109.42	4.51	512.85	10.85	1234.48
	REC: B	10.15	1154.46	1.32	149.64	4.51	512.85	14.66	1667.32

4.4 CONFIDENCE IN THE EWR RESULTS

The overall confidence in the results is 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 is applied when determining the overall confidence:

- If the hydraulics confidence is lower than the biological responses column, the hydraulics confidence becomes the overall confidence. Hydrology confidence is considered, especially if used to guide the requirements.
- If the biological confidence is lower than the hydraulics confidence, the biological confidence becomes the overall confidence. Hydrology confidence is also considered. If the hydrology guided requirements, then this confidence will be overriding.

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

Table 4.16 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
EWR O2	3.5	2.7	2.5	**2.5**	Hydraulic confidence is not high as the measured flows were all higher than the flows required.	3.3	5	**3.3**	Even though the hydraulics confidence was high, the biophysical response was moderate and that became the overall confidence.
EWR O3	2	3	2	**2**	See above for hydraulic confidence. As the hydraulic confidence was lower than the biological responses, this became the overall confidence.	3.5	5	**3.5**	Even though the hydraulics confidence was high, the biophysical response was lower (although still high) and that became the overall confidence.
EWR O4	2.6	3	2.5	**2.5**	See above.	2.8	5	**2.8**	Even though the hydraulics confidence was high, the biophysical responses were moderate and that became the overall confidence.

Site	**Hydrology**	**Biological responses: Low flows**	**Hydraulic: Low flows**	**OVERALL: LOW FLOWS**	**Comment**	**Biophysical responses: High flows**	**Hydraulics: High flows**	**OVERALL: HIGH FLOWS**	**Comment**
EWR O5	2.8	3.5	3	**3**	The hydraulic and biological confidences are both high.	3.5	3	**3**	The hydraulic and biophysical confidences are both moderate.

5 DESKTOP BIOPHYSICAL NODES: RESOURCE UNITS, LOCALITY AND ECOCLASSIFICATION

5.1 SCALE

The SQs river reaches as indicated in http://www.dwa.gov.za/iwqs/gis_data/river/rivs500k.html and http://www.dwa.gov.za/iwqs/gis_data/river/River_Report_01.pdf, forms the basis of the national PESEIS study (DWS, 2014b). A SQ changes when a significant tributary joins it. This means that a SQ may potentially be subdivided into various EcoRegions, geomorphic zones (slope zones) resource units (natural or management), etc. Such subdivisions are not addressed at desktop level, and may be required when higher confidence assessments are done. The version of the 1:500 000 coverage that was used for the PESEIS 2012 study (DWS, 2014a), was a version used by the National Freshwater Ecosystem Priority Areas (NFEPA) project in 2009 (Nel *et al*., 2011).

Desktop EWRs are usually assessed at SQ scale and for purposes of the Reserve study, the EWRs are assessed at the end of the quaternary catchment in the main river of the quaternary catchment. The reason for this is the following:

- During the PESEIS 2012 study (DWS, 2014a), many SQs were not assessed.
- Due to these gaps, reliance was placed on the 2010 EWR study (Louw and Koekemoer, 2010) that was undertaken at a quaternary catchment scale.
- The SQs other than the main river in the quaternary catchment are even more likely to be ephemeral in nature and results in the increasing problematic application of the EWR desktop models.

The node names correspond to the SQ in which they occur (See Table 5.1).

5.2 DESKTOP BIOPHYSICAL NODES

A desktop biophysical node represents a point at the end of the SQ or in this case, the SQ in the main river at the end of the quaternary catchment. These desktop biophysical nodes are represented in Figures 5.1 to 5.3and also include the PES results. Note that the names of the desktop biophysical nodes relate to the SQ name in which they are situated. The EWRs provided are for the node and represents all the SQsin the main river of the quaternary catchment.

5.3 DESKTOP ECOCLASSIFICATION

The PES of the 2010 EWR study (Louw and Koekemoer, 2010) was used as a starting point for the quaternary catchments and compared to the PESEIS 2012 study (DWS, 2014a) (specifically the SQ in the main river at the end of the quaternary catchment). Where there were differences, a Google Earth assessment was undertaken, and the PES of SQs located upstream of the biophysical node in the main river considered and motivated decision made. Results for the nodes within the F primary catchment were only available from the PESEIS 2012 study (DWS, 2014a). As these results were at SQ level, all SQ results of the main river in the quaternary catchments were considered during the determination of the PES.

The EI component of the national PESEIS study (DWS, 2014b) was used[5] to assess whether the REC should be improved. In cases where the importance (EI) is high or very high, an improved REC is recommended. The estimated EWR is linked to the REC and these results are provided in the following chapter. It must, however, be noted that if the REC is not based on an improved flow regime, the EWR for the PES is used. Information on the requirements needed to achieve the REC and the attainability there-of is supplied in Table 5.1.

Table 5.1 summarises the EcoClassification results used in this study, based on both the 2010 EWR (Louw and Koekemoer, 2010) and the PESEIS 2012 (DWS, 2014a) assessment and forms the basis for the EWR estimation (see Chapter 6). Table 5.2 lists the nodes that require improvement and the associated issues that will have to be addressed. For additional information, please refer to Appendix A, which provides the same information as Table 5.1. However, it includes the coordinates of the nodes and a comment on the summary comparison between the results of the 2010 EWR study (Louw and Koekemoer, 2010) and the national PESEIS study (DWS, 2014b).

The columns of Table 5.1 refer to:

- Column 1: SQ number (Biophysical node name).
- Column 2: 2010 node name (quaternary catchment). Note these names are not included for the F catchments as this did not form part of the PESEIS 2010 assessment. The associated quats can be seen in Appendix A.
- Column 3: River name where available.
- Column 4: PES according to the results of the 2010 EWR study (Louw and Koekemoer, 2010) compared to the national PESEIS study (DWS, 2014b). As the 2010 EWR study excluded the F catchment, results were taken from the PESEIS 2012 study (DWS, 2014a).
- Column 5: Ecological Importance according to the results of the national PESEIS study (DWS, 2014b). Only High or Very High evaluation is indicated as it is immaterial whether it is Low or Moderate.
- Column 6: REC generated during this study and documented in this report. If the RDRM (Hughes *et al*., 2012; Hughes *et al*., 2014) results are different from the REC (i.e. improvements required to achieve the REC other than increased flows), the RDRM EC is provided in brackets.

Table 5.1 Desktop biophysical nodes: EcoClassification summary results (PESEIS 2012 - DWS, 2014a)

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
Molopo River					
D42A-01082	D42A (910)	Nossob	**B**	**High**	**B**
D42D-02283	D42D	Molopo River	**B/C**		**B/C**
D42E-03047	D42D	Molopo River	**C**		**C**
Vis, Sak and Hartbees Rivers					
D51B-07208	D51B	Renoster RIver: Onderplaas to Sterkfontein	**B/C**		**B/C**
D51B-06782	D51C	Renoster River	**B/C**		**B/C**
D51C-06594	D51C	Renoster River	**B/C**		**B/C**

[5] The ES component was not used as it is only an indication of sensitivity to biota to flow and water quality changes. Sensitivity to flow changes may not require improved flows. Furthermore, species sensitive to flow cannot be a motivation for non-flow related changes. Discussion with RQIS, DWS, supported this approach.

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
D52A-07274	D52A	Vis	D		D
D52C-06920	D52C	Vis	C/D		C/D
D52E-06758	D52C/E	Vis	C/D		C/D
D52D-06761	D52D	Muiskraal	C		C
D52F-06591	D52E	Vis	D		D
D52F-06306	D52F	Vis	C		C
D53A-04197	D53A	Hartbees[6]	B		B
D53B-04104	D53B	Hartbees	D		D
D53C-03807	D53C	Hartbees: Kenhardt to Tuins River confluence	B		B
D53D-03879	D53D	Tuins	A/B		A/B
D53E-03557	D53E	Hartbees: Tuins to Sout River confluence	A/B		A/B
D53H-03564	D53H	Sout	A		A
D53J-03408	D53J	Hartbees	B		B
D54B-05160	D54A	Holsloot	B		B
D54D-04896	D54B	Carnaveronleegte	C		C
D54D-04630	D54D	Carnaveronleegte	C		C
D54F-05004	D54E	Botterslaagte	B		B
D54F-04645	D54F	Verneukpan	B		B
D54G-04407	D54G	Hartbeespoort	B		B
D55B-06707	D55A	Sak River	C		C
D55B-06615	D55B	Sak River	C		C
D55D-06429	D55C	Brak River	B		B
D55D-06524	D55D	Brak River	B		B
D55E-06496	D55E	Brak River	B/C		B/C
D55F-06209	D55F	Gansvlei River	C		C
D55G-06308	D55G	Gansvlei River	C		C
D55J-06243	D55H	Sak River	B		B
D55J-06180	D55J	Sak River	B/C		B/C
D55K-06347	D55K	Klein Sak	B		B
D55L-06115	D55L	Sak River	C		C
D55M-05697	D55M	Sak River	B/C		B/C
D56A-07453	D56A	Portugals R	B/C		B/C
D56B-07428	D56B	Riet River	B		B
D56D-07091	D56C	Portugals R	B		B
D56D-06822	D56D	Portugals R	B		B
D56F-07144	D56E	Klein Riet	B		
D56G-06932	D56F	Klein Riet	B		B
D56G-06753	D56G	Klein Riet	B		B
D56J-06649	D56H	Riet	B		B
D56J-06522	D56J	Riet	B/C		B/C
D57A-05387	D57A	Sak River	C		C
D57B-05325	D57B	Soutloot	B/C		B/C

[6]No EWR to be estimated for this node as it is situated immediately DS of a large dam with no outlet capacities.

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
D57C-05254	D57C	Sak	C		C
D57E-04534	D57D	Sak	B		B
D57E-04374	D57E	Sak	B		B
D58A-06302	D58A	Vis	C		C
D58C-05932	D58B	Vis	C		C
D58C-05390	D58C	Vis	C		C
Brak Ongers River					
D61A-06062	D61A	Laken	C		C
D61B-05841	D61B	Laken tributary	C		C
D61C-05866	D61C	Laken	C		C
D61D-06156	D61D	Brakpoort	B		B
D61E-06164	D61E	Brak	C		C
D61G-06223	D61F	Klein Brak	C		C
D61H-05960	D61G	Klein Brak	C		C
D61H-05865	D61H	Brak	B/C		B/C
D61J-05654	D61J	Groen	B		B
D61K-05388	D61K	Groen	B		B
D61L-05453	D61L	Perdepoortsleegte	B		B
D61M-05343	D61M	Ongers	C		C
D62A-05078	D62A	Ongers	C		C
D62B-04701	D62B	Ongers	B/C		B/C
D62C-05303	D62C	Elandsfontein	B/C		B/C
D62D-05183	D62D	Brak	B/C		B/C
D62G-04755	D62E	Brak	B		B
D62G-04703	D62G	Brak	A/B		A/B
D62J-04231	D62J	Ongers	B/C	High	B (B/C)
D71B-03620	D71B	Orange tributary	B		B
Small West coast rivers					
F10B-03391		Holgat	B	High	B
F20E-04290		Kwaganap	C	High	B (C)
F30A-04782		Buffels	B		B
F30B-04742		Brak	B		B
F30C-04823		Buffels	B		B
F30D-04598		Buffels	B		B
F30E-04444		Skaap	B		B
F30G-04539		Buffles	B/C		B/C
F40B-04917		WildeperdehoekseBrak	B		B
F40C-05007		Swartlintjies	B		B
F40D-04789		Swartlintjies	B		B
F40F-05159		Spoeg	B		B
F40G-05320		Bitter	C	High	B (C)
F40H-05480		Bitter	D		D
F50A-05626		Hartbees	C		C

1	2	3	4	5	6
Biophysical Node name	**2010 place name**	**River**	**PES**	**EI**	**REC (RDRM)**
F50B-05636		Swart-Doring	B		B
F50C-05764		Swart-Doring	B		B
F50D-05726		Swart-Doring	B		B
F50F-05560		Groen	B/C		B/C
F50G-05620		Groen	B		B
F60A-05886		Brak	B		B
F60C-06147		Sout	B		B
F60D-06231		Sout	B		B

Table 5.2 Aspects to be addressed to achieve the REC improvement

Biophysical Node name	River	PES	EI	REC	Improvements
D42A-01082	Nossob	B	High	B	None required as the PES already a B state.
D62J-04231	Ongers	B/C	High	B	Livestock, roads and crossings, irrigation in lower reach - from Orange River.
F10B-03391	Holgat	B	High	B	None required as the PES already a B state.
F20E-04290	Kwaganap	B/C	High	B	Roads and crossings, livestock, lower reach rivers do not exist due to mining activities, estuary.
F40G-05320	Bitter	C	**High**	B	Roads and crossings, dryland agriculture.

Desktop EcoClassification results are presented in Figures 5.1 to 5.3.

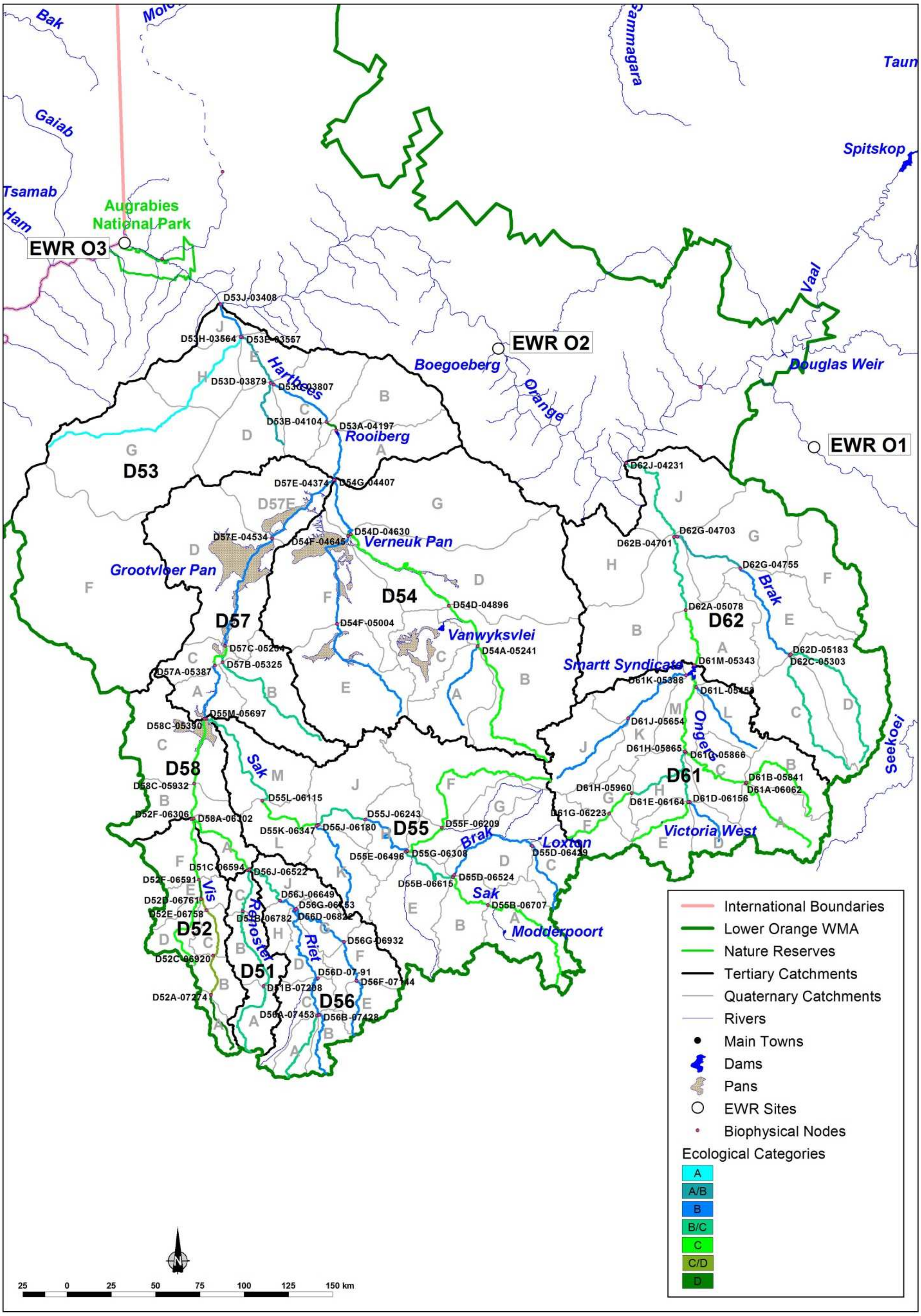

Figure 5.1 The location of the desktop biophysical nodes located in tertiary catchments D5 and D6, and the associated EcoClassification results

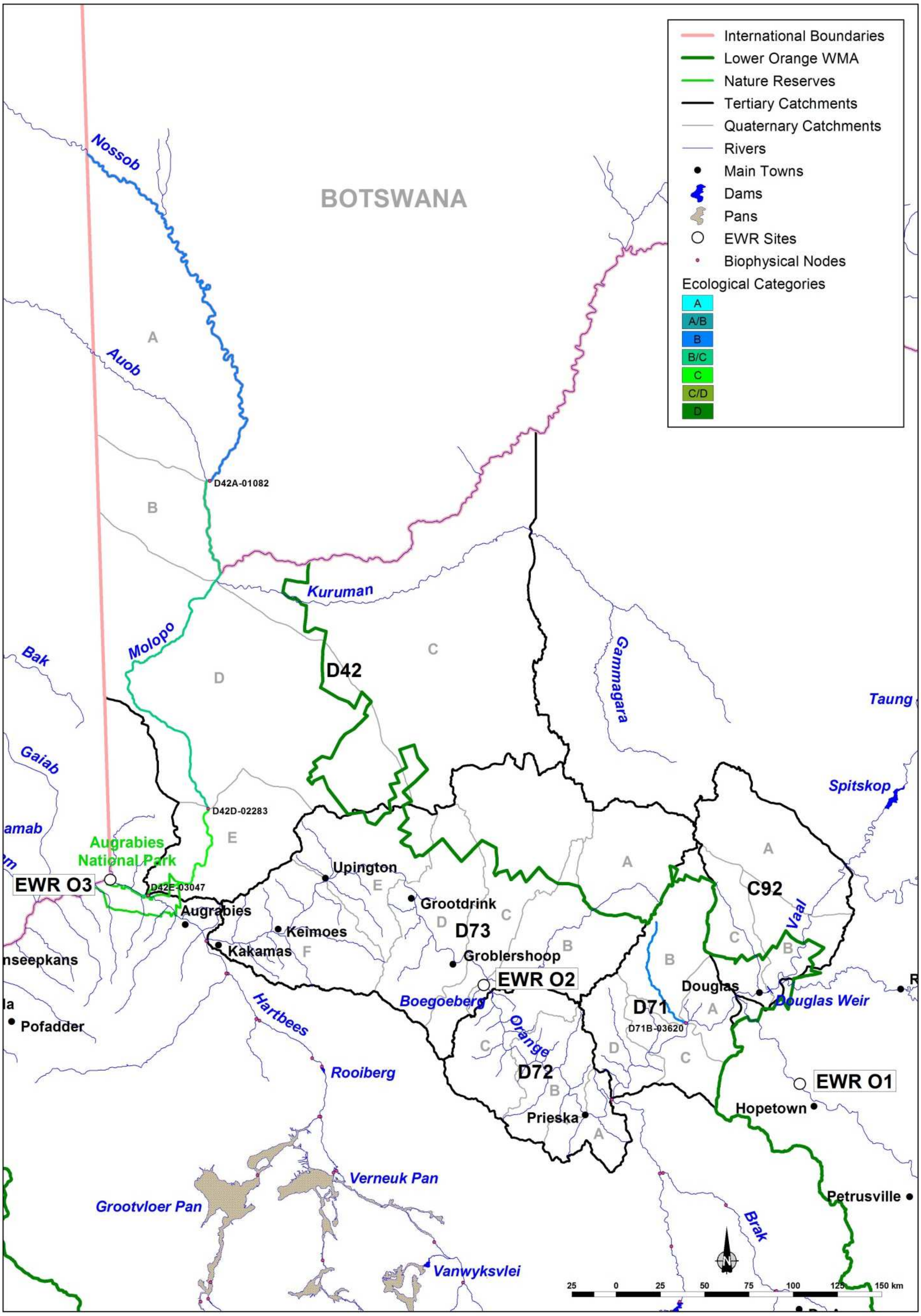

Figure 5.2 **The location of the desktop biophysical nodes located in tertiary catchments D7 and D42,and the associated EcoClassification results**

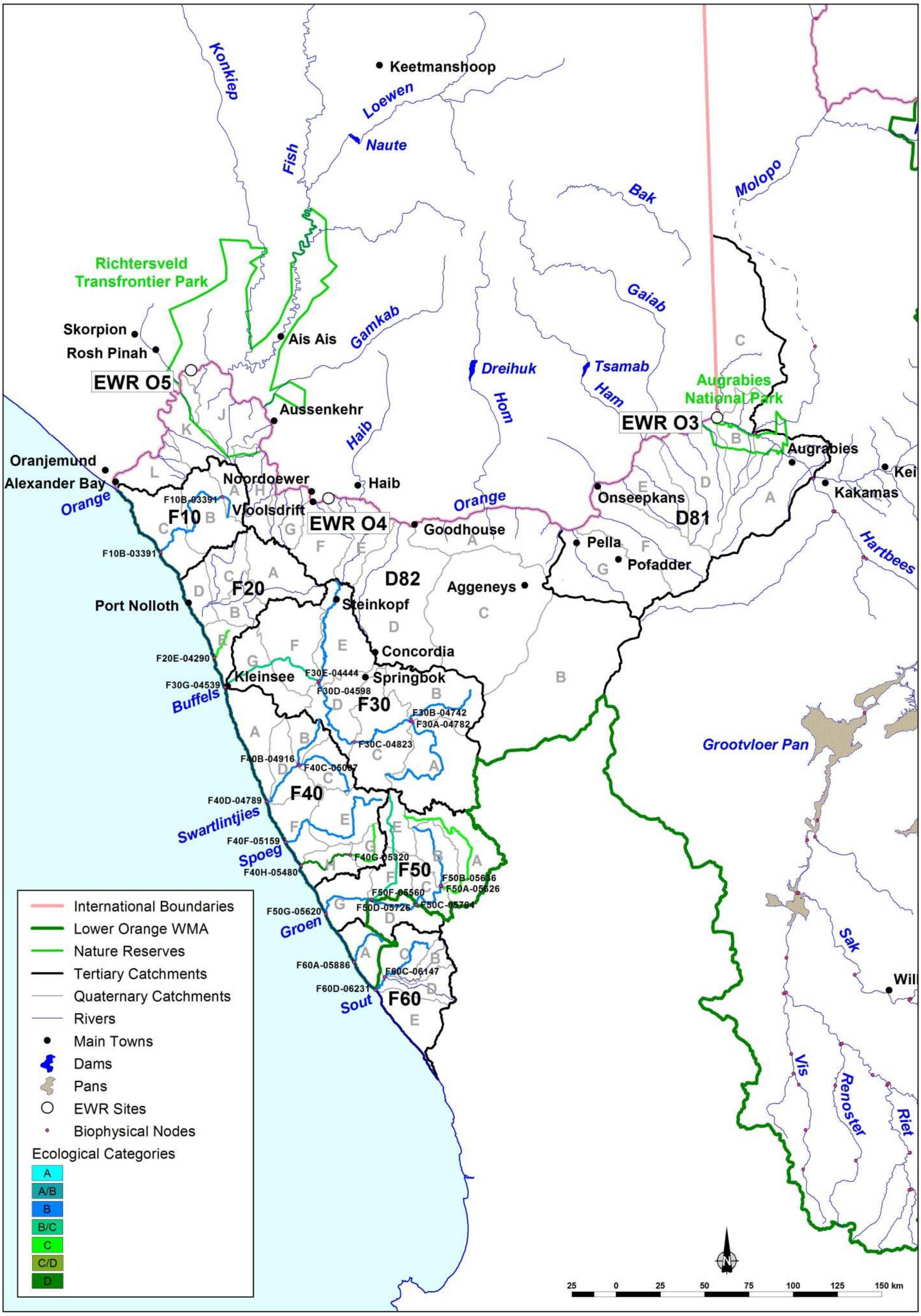

Figure 5.3 The location of the desktop biophysical nodes located in tertiary catchments F and D8, and the associated EcoClassification results

6 DESKTOP BIOPHYSICAL NODES: EWR ESTIMATION AND RESULTS

6.1 BACKGROUND

The Desktop Reserve Model (DRM) of Hughes and Hannart (2003) has been extensively used over the last decade for estimating Ecological Water Requirements (EWRs) in this and other countries. The DRM is used in this study, rather than the Revised Desktop Reserve Model (RDRM) version (refer to Hughes *et al*., 2012; Hughes *et al*., 2014) for the following reason: The “lower Orange” hydrology is largely characterised by high flows with very little base flow contribution. The RDRM’s high flow component is considered insufficiently developed and tested for these types of systems, as is its functionality when there is no ecologically-based low flow requirement. These, and other considerations, are being addressed in an existing Water Research Commission (WRC)/DWS project. Therefore, the stand-alone version of the DRM was used for this study.

6.2 APPROACH

The quaternary catchments requiring Desktop EWR assessments were provided by Rivers for Africa, together with the PES and REC. So-called 'nodes' were located at the quaternary catchment outlets and are labelled using SQ NFEPA[7] codes. WRP Consulting Engineers provided Naturalised and Present Day (PD) monthly hydrological time-series for the period 1920-2004.

Desktop EWRs are provided for 91 of the 99 desktop nodes identified. None of the desktop biophysical nodes have an improved REC relative to the PES, and thus requirements are constrained to PD flows (i.e. there is no improvement in the PES through hydrology).

6.3 RESULTS

The EWR results are provided in the following formats as text files named according to the biophysical node:

- Time-series of average monthly EWR flow requirements (in 10^6 m^3) for the period 1920 to 2004.
- Assurance rules for EWR total flows (in 10^6 m^3).

A summary of the total flow requirements, including naturalised and PD runoff is provided in Table 6.1. As mentioned previously, these catchments have highly variable temporal flow distributions, largely characterised by high flows with low baseflow contributions. Consequently, the use of Mean Annual Runoff (MAR) is somewhat misleading, as all flows contribute to MAR, but extreme floods occur infrequently and cannot be deemed to be part of an “average (or mean) year”. For this reason, the results are also presented in terms of median annual runoff, which is the annual runoff at the 50th percentile (i.e. half of the annual runoffs are less, and half are higher). Note that when considered in terms of median runoff, the EWR requirements can be substantially higher[8], reflecting the distribution of annual volumes. A further point worth mentioning is that the default DRM high flow rule curve does not increase substantially below the 10th percentile. For these systems, however, a substantial proportion of the high flow volume (naturalised and PD) may occur below at low percentiles[9]. Although these volumes may not be part of the EWR high flow requirement, in the

[7] National Freshwater Ecosystem Priority Areas Project (http://bgis.sanbi.org/nfepa/project.asp). The numerical NFEPA codes are unique to each SQ at a national level.
[8] Up to 40% for certain catchments.
[9] Infrequent high floods.

absence of very large storage reservoirs, these large floods are not essentially "manageable", and would occur anyway.

A few results in Table 6.1 require discussion:

- Requirements are not provided for the nodes in the Molopo River system, including the Nossob. The nodes in the Molopo (D42D-02283 and D42E-03047) essentially have no surface flow; the Nossob (D42A-01082) flows very infrequently under naturalised and PD conditions - only 3.7% of the months have (surface) flows under PD conditions.
- Five nodes (Ongers River: D61M-05343; D62A-05078; D62B-04701; Gansvlei: D55G-06308; and Vis: D58A-06302) have low EWR results. These are due to requirements being constrained to PD hydrology which indicates substantially reduced flows from naturalised conditions for these catchments. By comparison, the unconstrained requirements are: Ongers between 15.3 and 16.7%; Gansvlei 25.0%; and Vis 25.9%, of median naturalised runoffs. There are no justifications for increasing flows above PD conditions.
- Other nodes that have seemingly low requirements are:
  - F10B-03391, which has a very low runoff (mean of 0.064 million m^3 and median of zero) with 66% of the (85-year) volume occurring less than 10% of the time. This implies a strongly ephemeral hydrology, that in the absence of large storage reservoir/s, should remain essentially unchanged;
  - F40H-05480 (8.3% of median) and D53B-04104 Hartbees River, 9.5% of median) which both have a D Category REC.

Table 6.1 Summary of Desktop EWRs for the biophysical nodes in the lower Orange River

Node	River name	Annual Runoff ($10^6 m^3$)				REC	Long-term EWR requirements			
		Mean		Median			($10^6 m^3$)		% Natural	
		Natural	PD	Natural	PD		Mean	Median	Mean	Median
Small Orange River tributary										
D71B-03620		9.862	9.862	3.650	3.650	B	1.540	0.963	15.6	26.4
Brak/Ongers River systems										
D61A-06062	Laken	3.430	3.224	1.280	1.190	C	0.364	0.183	10.6	14.3
D61B-05841	Laken tributary	2.688	2.688	0.980	0.980	C	0.286	0.143	10.6	14.6
D61C-05866	Laken	7.634	7.145	2.800	2.610	C	0.811	0.408	10.6	14.6
D61D-06156	Brakpoort	0.920	0.920	0.310	0.310	B	0.138	0.068	15.0	21.9
D61E-06164	Brak	1.961	1.285	0.430	0.250	C	0.206	0.081	10.5	18.8
D61G-06223	Klein Brak	0.966	0.484	0.180	0.060	C	0.087	0.029	9.0	16.1
D61H-05865	Brak	6.829	5.483	1.670	1.310	B/C	0.893	0.371	13.1	22.2
D61H-05960	Klein Brak	1.996	1.326	0.400	0.220	C	0.208	0.077	10.4	19.3
D61J-05654	Groen	2.122	2.122	0.430	0.430	B	0.324	0.127	15.2	29.5
D61K-05388	Groen	4.826	4.826	1.010	1.010	B	0.736	0.290	15.3	28.7
D61L-05453	Perdepoortsleegte	0.474	0.474	0.170	0.170	B	0.070	0.033	14.8	19.4
D61M-05343	Ongers	22.124	5.015	6.690	0.000	C	0.297	0.000	1.3	na
D62A-05078	Ongers	22.904	5.795	7.180	0.310	C	0.810	0.260	3.5	3.6
D62B-04701	Ongers	23.529	6.420	7.690	0.520	B/C	1.249	0.494	5.3	6.4
D62C-05303	Elandsfontein	4.529	4.529	1.840	1.840	B/C	0.609	0.339	13.5	18.4
D62D-05183	Brak	7.544	7.399	3.190	2.920	B/C	1.013	0.569	13.4	17.8
D62G-04703	Brak	17.366	17.22	7.210	6.850	A/B	3.352	1.959	19.3	27.2
D62G-04755	Brak	16.132	15.98	6.660	6.300	B	2.579	1.452	16.0	21.8

Node	River name	Annual Runoff (10^6 m^3)				REC	Long-term EWR requirements			
		Mean		Median			(10^6 m^3)		% Natural	
		Natural	PD	Natural	PD		Mean	Median	Mean	Median
D62J-04231	Ongers	42.331	25.07	17.140	8.050	B	6.225	3.077	14.7	18.0
Vis River system										
D51B-06782	Renoster	13.403	12.62	2.690	2.520	B/C	1.384	0.826	10.3	30.7
D51B-07208	Renoster	6.397	6.025	1.284	1.203	B/C	0.661	0.395	10.3	30.8
D51C-06594	Renoster	14.033	13.25	2.820	2.650	B/C	1.447	0.865	10.3	30.7
D52A-07274	Vis	2.933	2.633	0.435	0.397	D	0.168	0.113	5.7	26.0
D52C-06920	Vis	8.054	7.312	1.195	1.092	C/D	0.547	0.362	6.8	30.3
D52D-06761	Muiskraal	2.655	2.356	0.393	0.343	C	0.195	0.130	7.3	33.1
D52E-06758	Vis	11.662	10.58	1.730	1.580	C/D	0.791	0.524	6.8	30.3
D52F-06306	Vis	17.337	15.60	2.661	2.409	C	1.387	0.909	8.0	34.2
D52F-06591	Vis	16.852	15.19	2.500	2.250	D	0.940	0.632	5.6	25.3
D56A-07453	Portugals	1.639	1.586	0.314	0.317	B/C	0.178	0.079	10.9	25.2
D56D-06822	Portugals	8.257	7.994	1.585	1.595	B	1.049	0.476	12.7	30.0
D56D-07091	Portugals	6.262	6.062	1.201	1.206	B	0.794	0.360	12.7	30.0
D56G-06753	Klein Riet	3.544	3.432	0.880	0.840	B	0.516	0.297	14.6	33.7
D56G-06932	Klein Riet	2.564	2.483	0.636	0.608	B	0.373	0.214	14.6	33.6
D56J-06522	Riet	13.932	13.33	3.130	3.030	B/C	1.597	0.865	11.5	27.6
D56J-06649	Riet	13.237	12.81	2.950	2.910	B	1.772	0.984	13.4	33.4
D58A-06302	Vis	28.190	21.52	6.450	0.640	C	1.893	0.382	6.7	5.9
D58C-05390	Vis	46.373	37.77	10.330	4.190	C	3.768	1.686	8.1	16.3
D58C-05932	Vis	45.943	37.32	10.278	4.051	C	3.699	1.628	8.1	15.8
Sak River system										
D55B-06615	Sak	4.498	3.357	1.570	1.170	C	0.479	0.235	10.6	15.0
D55B-06707	Sak	2.688	2.007	0.939	0.699	C	0.286	0.141	10.6	15.0
D55D-06429	Brak	1.542	1.317	0.304	0.192	B	0.233	0.095	15.1	31.3
D55D-06524	Brak	5.249	4.482	1.030	0.650	B	0.793	0.325	15.1	31.6
D55E-06496	Brak	11.352	8.892	3.320	2.220	B/C	1.507	0.674	13.3	20.3
D55F-06209	Gansvlei	3.135	3.134	0.552	0.553	C	0.341	0.139	10.9	25.2
D55G-06308	Gansvlei	4.661	3.427	0.820	0.190	C	0.421	0.063	9.0	7.7
D55J-06180	Sak	18.928	15.10	5.140	3.070	B/C	2.479	1.192	13.1	23.2
D55J-06243	Sak	17.079	13.33	4.350	2.637	B	2.621	1.204	15.3	27.7
D55K-06347	Klein Sak	1.100	1.100	0.240	0.240	B	0.159	0.057	14.5	23.7
D55L-06115	Sak	20.876	16.99	5.354	3.184	C	2.258	1.046	10.8	19.5
D55M-05697	Sak	22.115	18.14	5.420	3.410	B/C	2.874	1.300	13.0	24.0
D57A-05387	Sak	68.804	56.07	20.742	13.199	C	6.648	3.567	9.7	17.2
D57B-05325	Soutloot	0.886	0.456	0.174	0.093	B/C	0.101	0.037	11.3	21.3
D57C-05254	Sak	69.813	56.59	20.790	13.230	C	6.775	3.604	9.7	17.3
D57E-04374	Sak	72.377	47.13	21.850	16.440	B	9.793	6.069	13.5	27.8
D57E-04534	Sak	70.972	57.69	21.002	13.429	B	9.588	5.530	13.5	26.3
Hartbees River system										
D53B-04104	Hartbees	84.236	66.80	29.150	20.222	D	5.964	2.764	7.1	9.5
D53C-03807	Hartbees	86.535	68.62	29.648	20.297	B	12.591	6.346	14.6	21.4
D53D-03879	Tuins	2.008	1.906	0.204	0.193	A/B	0.253	0.079	12.6	38.7

Node	River name	Annual Runoff (10^6 m^3)				REC	Long-term EWR requirements			
		Mean		Median			(10^6 m^3)		% Natural	
		Natural	PD	Natural	PD		Mean	Median	Mean	Median
D53E-03557	Hartbees	89.543	71.48	30.300	20.879	A/B	15.648	7.803	17.5	25.8
D53H-03564	Sout	1.783	1.783	0.090	0.090	A	0.237	0.050	13.3	55.6
D53J-03408	Hartbees	91.687	69.19	30.660	16.665	B	11.959	5.492	13.0	17.9
D54B-05160	Holsloot	2.790	1.194	0.553	0.225	B	0.363	0.130	13.0	23.5
D54D-04630	Carnaveronleegte	10.060	5.250	1.981	0.992	C	1.020	0.454	10.1	22.9
D54D-04896	Carnaveronleegte	8.335	3.567	1.653	0.670	C	0.826	0.341	9.9	20.6
D54F-04645	Verneukpan	6.342	4.703	1.229	0.895	B	0.919	0.404	14.5	32.9
D54F-05004	Botterslaagte	2.713	1.161	0.538	0.218	B	0.353	0.126	13.0	23.4
D54G-04407	Hartbeespoort	21.295	14.72	4.141	2.798	B	3.061	1.346	14.4	32.5
Small West Coast Rivers										
F10B-03391		0.064	0.064	0.000	0.000	B	0.006	0.000	8.8	na
F20E-04290		0.738	0.738	0.140	0.140	B	0.090	0.057	12.2	40.7
F30A-04782		2.313	2.313	0.737	0.737	B	0.345	0.225	14.9	30.5
F30B-04742		1.731	1.731	0.553	0.553	B	0.258	0.168	14.9	30.4
F30C-04823		6.003	6.003	1.914	1.914	B	0.896	0.585	14.9	30.6
F30D-04598		7.158	7.158	2.282	2.282	B	1.068	0.697	14.9	30.5
F30E-04444		1.492	1.492	0.476	0.476	B	0.222	0.145	14.9	30.5
F30G-04539		11.199	11.19	3.570	3.570	B/C	1.407	0.909	12.6	25.5
F40B-04917		0.345	0.345	0.178	0.178	B	0.047	0.034	13.8	19.1
F40C-05007		0.519	0.519	0.268	0.268	B	0.072	0.052	14.0	19.4
F40D-04789		1.215	1.215	0.629	0.629	B	0.172	0.125	14.2	19.9
F40F-05159		1.282	1.282	0.664	0.664	B	0.181	0.132	14.2	19.9
F40G-05320		0.297	0.297	0.154	0.154	B	0.041	0.030	13.7	19.5
F40H-05480		0.630	0.630	0.326	0.326	D	0.041	0.027	6.5	8.3
F50A-05626		1.546	1.546	0.779	0.779	C	0.164	0.116	10.6	14.9
F50B-05636		0.715	0.715	0.360	0.360	B	0.107	0.077	15.0	21.4
F50C-05764		2.782	2.782	1.402	1.402	B	0.424	0.313	15.2	22.3
F50D-05726		3.597	3.597	1.813	1.813	B	0.550	0.405	15.3	22.3
F50F-05560		1.260	1.260	0.635	0.635	B/C	0.162	0.117	12.8	18.4
F50G-05620		5.458	5.458	2.750	2.750	B	0.835	0.615	15.3	22.4
F60A-05886		0.177	0.177	0.064	0.064	B	0.027	0.017	15.1	26.6
F60C-06147		0.450	0.450	0.161	0.161	B	0.068	0.042	15.2	26.1
F60D-06231		0.675	0.675	0.246	0.246	B	0.106	0.064	15.6	26.0

7 REFERENCES

Department of Water Affairs and Forestry, South Africa (DWAF). 1999. Resource directed measures for the protection of water resources. Volume 3: River ecosystems, version 1.0, Pretoria.

Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the water quality component of the Ecological Reserve. Report prepared for Department of Water Affairs and Forestry, Pretoria, South Africa by P-A Scherman of Scherman Consulting.

Department of Water and Sanitation (DWS). 2014a. A Desktop Assessment of the PresentEcological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Secondary: Lower Orange (D, F]. Compiled by RQIS-RDM.

Department of Water and Sanitation (DWS). 2014b. A Desktop Assessment of the PresentEcological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reachesfor Secondary Catchments in South Africa.
Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx.

Department of Water and Sanitation (DWS). 2015. Continuation and Maintenance of Reconciliation Strategies for All Towns in the Central Planning Region. Prepared by WorleyParsons in association with WRP Consulting Engineers, Muondli and Golder Associates on behalf of the Department of Water and Sanitation, Directorate: National Water Resource Planning.

Department of Water and Sanitation (DWS), South Africa, March 2016. Determination of Ecological Water Requirements for Surface water (river, estuaries and wetlands) and Groundwater in the Lower Orange WMA. Resource Unit report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Authored by Louw D, Mackenzie J, Sami K, Van Niekerk L. DWS Report No: RDM/WMA06/00/CON/COMP/0116.

Hughes, D.A. and Hannart, P. 2003. A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa. Journal of Hydrology 270(3-4), 167-181.

Hughes, D.A. and Forsyth, D.A. 2006. A generic database and spatial interface for the application of hydrological and water resource models. Comput. Geosci. 32 1389-1402.

Hughes, D.A., and Louw, D. 2010. Integrating hydrology, hydraulics and ecological response into a flexible approach to the determination of environmental water requirements for rivers. Environmental Modelling and Software 25: 910-918.

Hughes, D.A., Desai, Louw, D. and Birkhead, A.L. 2012. Development of a revised desktop model for the determination of the Ecological Reserve for rivers. Water Research Commission (WRC) Report no. 1856/1/12. WRC, Pretoria, South Africa. Available at http://www.wrc.org.za.

Hughes, D.A., Desai, A.Y., Birkhead, A.L., and Louw, D. 2014. A new approach to rapid, desktop-level, environmental flow assessments for rivers in southern Africa. Special issue: Hydrological Science for Environmental Flows.

Iversen, T.M., Madsen, B.L., and Bøgestrand, J. 2000. River conservation in the European Community, including Scandinavia. In: "Global Perspectives on River Conservation: Science Policy and Practice", Edited by P.J. Boon, B.R. Davies and G.E. Petts, John Wiley & Sons Ltd.

King, J.M., and Louw, D. 1998. Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management 1: 109-124.

Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N.J., and Rowntree, K. 2005. River EcoClassification: Manual for EcoStatus determination (Version 1). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. KV 168/05.

Kleynhans, C.J. 2007. Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 330/08.

Kleynhans, C.J. and Louw, M.D. 2007. Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT329-08.

Kleynhans, C.J., Mackenzie, J. and Louw, M.D. 2007. Module F: Riparian Vegetation Response Index. In River EcoClassification: Manual for EcoStatus Determination (version 2) Water Research Commission Report No. TT 333/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Kleynhans, C.J., Louw, M.D., and Graham, M. 2009. Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity (Section 1, Technical manual) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

Louw M.D. and S Koekemoer (Eds). 2010. Deliverable 12: Volume 1: Environmental Flow Requirements Produced for WRP as part of Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan. 193 pp.

Louw, D., Kotze, P., and Mackenzie, J. 2010. Support to Phase 2 of the ORASECOM Basin-Wide Integrated Water Resources Management Plan. Work Package 5: Assessment of Environmental Flow Requirements - Scoping study to identify priority areas for detailed EFR and other assessments. Prepared for WRP Consulting Engineers. Report 016/2010.

Louw, M.D., Deacon, A., Koekemoer, S., Kotze, P., Mackenzie, J., Palmer, R., Rountree, M. and Scherman, P-A. 2013. Research project on environmental flow requirements of the Fish River and the Orange–Senqu River mouth: River EFR assessment, Volume 1: Determination of lower Orange River EFR. Prepared for the UNDP-GEF Orange-Senqu Strategic Action Programme (Atlas Project ID 71598). Technical Report 29.

Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L., and Nienaber, S. 2011. Technical Report for the National Freshwater Ecosystem Priority Areas Project. WRC Report No. 1801/2/11.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

Orange-Senqu River Commission (ORASECOM). 2009. Feasibility Study of the Potential for Sustainable Water Resources Development in the Molopo-Nossob Watercourse: Surface Water Hydrology. Prepared by Ninham Shand (Pty) Ltd for ORASECOM. January 2009. Report Number 002/2009.

Orange-Senqu River Commission (ORASECOM). 2014. Support to Phase 3 of the ORASECOM Basin-wide integrated Water Resources Management Plan Main report: Integrated Water Resource Management Plan for the Orange-Senqu River Basin December 2014 Compiled by S Crerar and B Weston. Report no. ORASECOM 019/2014.

Rowntree, K.M. and du Preez, L. 2006. Draft Report. Geomorphology Driver Assessment Index. Joint Water Research Commission and Department of Water Affairs and Forestry report. Water Research Commission, Pretoria, South Africa.

Thirion, C. 2007. Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

8 APPENDIX A: COMPARISON BETWEEN THE 2010 AND NATIONAL 2014 PESEIS RESULTS

Quaternary	Latitude	Longitude	Biophysical node name	River	PES	EI	REC(RDRM)	Notes on PES
Molopo River								
D42A	-26.43564	20.64088	D42A-01082	Nossob	B	High	B	
D42D	-28.08516	20.58034	D42D-02283	Molopo	B/C		B/C	
D42E	-28.51430	20.21567	D42E-03047	Molopo	C		C	PESEIS database gave a B. Reason probably as flow modification was scored a zero. It cannot be a zero due to all the impacts in the Nossob.
Vis, Sak and Hartbees Rivers								
D51A	-32.19609	20.69020	D51B-07208	Renoster: Onderplaas to Sterkfontein	B/C		B/C	PESEIS database gave a high C which relates to a B/C.
D51C	-31.81523	20.57795	D51B-06782	Renoster	B/C		B/C	PESEIS database gave a high C which relates to a B/C.
D51C	-31.60719	20.61626	D51C-06594	Renoster	B/C		B/C	PESEIS database gave a high C which relates to a B/C.
D52A	-32.23380	20.37130	D52A-07274	Vis	D		D	PESEIS database gives a D for most of this river upstream - selected a D for EWR estimate.
D52B	-32.03458	20.39268	D52C-06920	Vis	C/D		C/D	PESEIS database gives a high D. Flows to be provided for a C/D.
D52C	-31.80475	20.36033	D52E-06758	Vis	C/D		C/D	PESEIS database gives a high D. Flows to be provided for a C/D.
D52D	-31.74761	20.32960	D52D-06761	Muiskraal	C		C	PESEIS gave a high D. 2010 gave a B/C initially, but was rescored with updated Google.
D52E	-31.64769	20.32002	D52F-06591	Vis	D		D	PESEIS gives a high D due to riparian veg rating. As the quat is much larger than SQ, go with PESEIS.
D52F	-31.34212	20.28601	D52F-06306	Vis	C		C	Same result.
D53A	-29.39973	21.20478	D53A-04197	Hartbees	B		B	Coincides with PESEIS.
D53B	-29.35703	21.14860	D53B-04104	Hartbees	D		D	PESEIS gives a C, going with the quat as it reflects the upper SQ which is downstream of a dam.
D53C	-29.16175	20.84653	D53C-03807	Hartbees: Kenhardt to Tuins Riverconfluence	B		B	Same result.
D53D	-29.15301	20.82764	D53D-03879	Tuins	A/B		A/B	PESEIS gives a B due to riparian veg rating. The reasons are livestock and road crossings, which will have a minor impact in seasonalriver.
D53E	-28.92011	20.66884	D53E-03557	Hartbees: Tuins to Sout River confluence	A/B		A/B	PESEIS gives a B which could translate to an A/B as PESEIS did not deal with half categories. Keeping it an A/B therefore.
D53H	-28.91865	20.65892	D53H-03564	Sout	A		A	Same result.
D53J	-28.75228	20.54755	D53J-03408	Hartbees	B		B	PESEIS gives a C for DS SQ and a B for the US SW (longer). Going for the B which is more representative of the whole quat.
D54A	-30.50243	22.01418	D54A-05241	Holsloot	B		B	Upper catchment not assessed as part of PESEIS therefore used 2013.

Quaternary	Latitude	Longitude	Biophysical node name	River	PES	EI	REC(RDRM)	Notes on PES
D54B	-30.29660	21.84730	D54D-04896	Carnaveronleegte	C		C	PESEIS gives a C for two quats. Google Earth confirmed habitat continuity problems. Fish and inverts not completed in 2012 due to perceived episodic nature.
D54D	-29.92641	21.27680	D54D-04630	Carnaveronleegte	C		C	PESEIS gives a C as they evaluated the instream biota. As invertebrates may utilise the stream, have given the PESEIS score.
D54E	-30.37747	21.18407	D54F-05004	Botterslaagte	B		B	PESEIS gives a B due to riparian veg impacts. Due to possible alien impacts, use the PESEIS value.
D54F	-29.93643	21.26027	D54F-04645	Verneukpan	B		B	PESEIS did not assess this due to it being a pan.
D54G	-29.65312	21.18988	D54G-04407	Hartbeespoort	B		B	Same result.
D55A	-31.81091	22.05219	D55B-06707	Sak	C		C	PESEIS has an upstream C SQ and downstream D.
D55B	-31.66580	21.84276	D55B-06615	Sak	C		C	Use the 2012 as PESEIS is a B but only small section of wholequat. Other SQs are a C.
D55C	-31.51452	22.32161	D55D-06429	Brak	B		B	DS SQ a C and US a B. Used the 2012 as representative of quat.
D55D	-31.65441	21.85421	D55D-06524	Brak	B		B	Use a B as SQ small section of quat.
D55E	-31.53304	21.56503	D55E-06496	Brak	B/C		B/C	PESEIS gives a B. Used the B/C as this SQ only a small section of quat.
D55F	-31.41459	21.78317	D55F-06209	Gansvlei	C		C	PESEIS gives a DS of a B but US of a C.
D55G	-31.52921	21.57471	D55G-06308	Gansvlei	C		C	Same result.
D55H	-31.36585	21.32659	D55J-06243	Sak	B		B	SQ not relevant as most of DS SQ in next quat. US SQ also a B.
D55J	-31.38729	21.04388	D55J-06180	Sak	B/C		B/C	SQs a mixture of C and B, so used the 2012 B/C.
D55K	-31.39210	21.03468	D55K-06347	Klein Sak	B		B	Same result.
D55L	-31.25786	20.71239	D55L-06115	Sak	C		C	DS middle of SQ a C. All US SQ a C , therefore with better Google, assumed C.
D55M	-30.83767	20.39273	D55M-05697	Sak	B/C		B/C	Most of the SQs in a C, some in a B. Took average of B/C.
D56A	-32.35131	21.00809	D56A-07453	Portugals	B/C		B/C	DS SQ a C, US a B. Therefore assuming better quality Google, a B/C was selected.
D56B	-32.34862	21.02130	D56B-07428	Riet	B		B	PESEIS is a B. Improved Google, used the B.
D56C	-32.16351	21.01843	D56D-07091	Portugals	B		B	Same result.
D56D	-31.81654	20.89108	D56D-06822	Portugals	B		B	Same result.
D56E	-32.18088	21.25144	D56F-07144	Klein Riet	B			Same result.
D56F	-31.98243	21.18280	D56G-06932	Klein Riet	B		B	Same result.
D56G	-31.81039	20.90019	D56G-06753	Klein Riet	B		B	PESEIS SQ is a B in upper half of quat and C DS. To ensure that the B of quat is catered for, the flow requirements are set for a B.
D56H	-31.76611	20.80411	D56J-06649	Riet	B		B	Same result for US SQ which is actually main river in quat.

Quaternary	Latitude	Longitude	Biophysical node name	River	PES	EI	REC(RDRM)	Notes on PES
D56J	-31.60344	20.62585	D56J-06522	Riet	B/C		B/C	Small section of quat in a B, the rest a C, therefore the B/C for flow estimation.
D57A	-30.57032	20.45329	D57A-05387	Sak River	C		C	Same result.
D57B	-30.55522	20.49942	D57B-05325	Soutloot	B/C		B/C	Both SQs of main quat rated a C, but bulk of Main River in quat not evaluated as stated that it is episodic. Therefore, the B/C is more appropriate as whole quat was assessed.
D57C	-30.47333	20.51714	D57C-05254	Sak	C		C	As two SQs are rated C and this rating is .2 above a C, a C was selected.
D57D	-29.93926	20.81221	D57E-04534	Sak	B		B	Same result.
D57E	-29.65111	21.18345	D57E-04374	Sak	B		B	Same result.
D58A	-31.33839	20.30058	D58A-06302	Vis	C		C	PESEIS ratings a D. Felt that riparian zone modification and phys chem rated to high. If modified, it comes out a C which will be used for flow estimation.
D58B	-31.16235	20.30892	D58C-05932	Vis	C		C	PESEIS ratings a C and D. Felt that riparian zone modification and phys chem rated to high. If modified, it comes out a C which will be used for flow estimation.
D58C	-30.83714	20.38228	D58C-05390	Vis	C		C	PESEIS a D and a C. Google check confirmed that the A/B is not correct. However, riparian and phys chem rated to high and therefore selected the C.
Brak Ongers River								
D61A	-31.20947	23.60141	D61A-06062	Laken	C		C	PESEIS: C.
D61B	-31.20380	23.60679	D61B-05841	Laken tributary	C		C	PESEIS: C.
D61C	-31.05066	23.24582	D61C-05866	Laken	C		C	PESEIS: B, US a C which is the longer section.
D61D	-31.30007	23.26646	D61D-06156	Brakpoort	B		B	PESEIS: B.
D61E	-31.30064	23.25767	D61E-06164	Brak	C		C	PESEIS: C.
D61F	-31.35528	22.78456	D61G-06223	Klein Brak	C		C	PESEIS: C.
D61G	-31.25260	22.91949	D61H-05960	Klein Brak	C		C	Episodic.
D61H	-31.04479	23.24010	D61H-05865	Brak	B/C		B/C	PESEIS: C. US SQ a B and rest not evaluated - use the B/C as representative of quat.
D61J	-30.87568	22.90351	D61J-05654	Groen	B		B	PESEIS: B. US quat a B as well.
D61K	-30.66108	23.24828	D61K-05388	Groen	B		B	PESEIS: C, US SQ not assessed therefore using 2012.
D61L	-30.72082	23.30871	D61L-05453	Perdepoortsleegte	B		B	PESEIS: C, US SQ not assessed therefore using 2012.
D61M	-30.61084	23.29821	D61M-05343	Ongers	C		C	PESEIS: D, DS quat a D due to dam. US SQ a B or not evaluated. A/B due to dam should be lower so catering for a B which is representative of US of dam.
D62A	-30.33245	23.25014	D62A-05078	Ongers	C		C	PESEIS: C.
D62B	-29.96430	23.18373	D62B-04701	Ongers	B/C		B/C	PESEIS: C, riparian rated to high - if adjusted, a B/C would suffice.
D62C	-30.56393	23.86438	D62C-05303	Elandsfontein	B/C		B/C	PESEIS: C, US SQ not assessed therefore using 2012.

Quaternary	Latitude	Longitude	Biophysical node name	River	PES	EI	REC(RDRM)	Notes on PES
D62D	-30.55835	23.87186	D62D-05183	Brak	B/C		B/C	PESEIS: B, US SQs lower, therefore using B/C
D62E	-30.12453	23.57422	D62G-04755	Brak	B		B	PESEIS: B.
D62G	-29.96190	23.20277	D62G-04703	Brak	A/B		A/B	Episodic.
D62J	-29.58993	22.90620	D62J-04231	Ongers	B/C	High	B (B/C)	PESEIS: B.
D71B	-29.20724	23.34363	D71B-03620	Orange tributary	B		B	Ephemeral.
Small West coast rivers								
F10A	-28.71823	17.10232	F10B-03391	Holgat	B	High	B	PESEIS: B.
F20E	-29.52422	17.00079	F20E-04290	Kwaganap	C	High	B (C)	PESEIS: C.
F30A	-29.89982	18.14349	F30A-04782	Buffels	B		B	PESEIS: B.
F30B	-29.89061	18.13899	F30B-04742	Brak	B		B	PESEIS: B.
F30C	-29.98675	17.79761	F30C-04823	Buffels	B		B	PESEIS: B.
F30D	-29.67807	17.60292	F30D-04598	Buffels	B		B	PESEIS: B.
F30E	-29.66987	17.60944	F30E-04444	Skaap	B		B	PESEIS: B.
F30G	-29.67664	17.05329	F30G-04539	Buffels	B/C		B/C	PESEIS: C; SQs a mixture of B and Cs.
F40B	-30.08611	17.45965	F40B-04917	WildeperdehoekseBrak	B		B	PESEIS: B.
F40C	-30.09004	17.46775	F40C-05007	Swartlintjies	B		B	PESEIS: A, much longer US SQ in a B so this short DS SQ cannot be in an A.
F40D	-30.26400	17.26102	F40D-04789	Swartlintjies	B		B	PESEIS: B.
F40F	-30.47230	17.36051	F40F-05159	Spoeg	B		B	PESEIS: B.
F40G	-30.55411	17.73929	F40G-05320	Bitter	C	High	B (C)	PESEIS: C.
F40H	-30.59577	17.44355	F40H-05480	Bitter	D		D	PESEIS: D.
F50A	-30.73706	18.27257	F50A-05626	Hartbees	C		C	PESEIS: B, US quats a C - longer areas.
F50B	-30.73190	18.26622	F50B-05636	Swart-Doring	B		B	PESEIS: B.
F50C	-30.82303	18.11749	F50C-05764	Swart-Doring	B		B	PESEIS: B.
F50D	-30.78946	17.85192	F50D-05726	Swart-Doring	B		B	PESEIS: B.
F50F	-30.78446	17.85221	F50F-05560	Groen	B/C		B/C	PESEIS: B, longer section in C.
F50G	-30.84514	17.57622	F50G-05620	Groen	B		B	PESEIS: B.
F60A	-31.09686	17.72978	F60A-05886	Brak	B		B	PESEIS: B.

Quaternary	Latitude	Longitude	Biophysical node name	River	PES	EI	REC(RDRM)	Notes on PES
F60C	-31.17986	17.90619	F60C-06147	Sout	B		B	PESEIS: B.
F60D	-31.24218	17.84726	F60D-06231	Sout	B		B	PESEIS: B.

9 APPENDIX B: COMMENTS REGISTER

Section	Report statement	Comments	Changes made?	Author comment
	Do not include a biophysical node on the Aub	Why is the Aoub River not included? It forms part of the Stampriet Trans Boundary Aquifer. It does not flow but neither does the Nossob. The two rivers baseflow water quality are also completely different.	No	The Aoub was not assessed as part of the 2012 PESEIS assessment. It also did not form part of the PESEIS 2010 study (not being a main river in a quaternary catchment). Neither of the two rivers have baseflow.
		The Nossob River got a B grading while the Buffels River in quaternary F30G gets a B/C grading where there is AMD pollution and previously other diamond mining activities?	No	This is the result of a desktop study. Three SQs were assessed as part of the DWS study. Two received a B PES and one a C. The PES for the whole quat is set as a B/C.
Exec summary		The Executive summary is too long.	Yes	
Exec Summary		The Eco classification and EWR tables for each EWR site should not be in the executive summary. Rather consider concise 1 paragraph summaries per EWR for each site.	Yes	
Table 6.1		The summary of desktop for the biophysical node should be 1 row for each river system.	No	Uncertain regarding comment. Cannot provide one row per river system. It is currently one row per node. Is this reference to the Executive summary? Impossible to summarise per system. Does comment refer to merging Table 5.1 and 6.1?. This is not recommended as it is two separate issues that warrant separate discussion.
1.3		There is a need for a method/ process description ie for 1.3. for the not so informed reader to understand the process.		Uncertain what this means as 1.3 is introduction providing background and there are no methods or processes applicable.

Section	Report statement	Comments	Changes made?	Author comment
2.3.1	The report stated that this is natural flow.	The Natural flow volumes of 4 024 Mm^3/a from Vaal and 10 719 Mm^3/a from Orange should contextualized. Will these volumes be available with 98 % assurance? Are all the current transfers from upstream catchments accounted for and this is also present day flows? Is there any provision for climate change and what could the impact be? Do we only use a portion of this?	Yes No No	This is the mean annual runoff under natural conditions and will thus not be available at a 98% assurance. Due to the fact that this refers to natural flows current transfers from upstream catchments are not included. Natural flows do not include climate change. In the scenario analysis all upstream developments and transfers will be included and taken into account for present day development flows in the Main Orange at the given EWR sites.
2.3.1	Table 2.1 in the report provides the cumulative flows at each biophysical node.	The sum of Table 2.1 should tally with the total natural flow for the system mentioned in Section 2.3.1.	yes	The values were checked and included some additional description in Section 2.3.1 as well as updates in Figure 2.2 and Table 2.1. The word cumulative was added to the column heading.
2.3.1	Two table were provided in the report, one for natural flows and the other focussing on present day flows.	Table 2.1 and 2.2 should be combined to prevent confusing repetition of information.	Yes	
2.3.1	The difference between natural and presen tday flows were given in Table 2.2 (now Table 2.1)	There should be an explanation why the present day flow declined.	No	These differences are all due to demands and infrastructure developments such as dams of an extremely complex system. It is not possible to provide this in one column as all will refer to upstream development and operation of the system
3.2		In Section as 3.2 there could be more detail from A-Natural to F-critically modified as this is the essence of the investigation	Yes	
	Table 4.2 etc.	The use of Vaal River in the EWR results in Tables 4.2; 4.5; 4.6; 4.9 is confusing because the study is for the Orange Orange River not the Vaal River.	No	The Vaal in the table refers to the Regional Type that is used in the Desktop River. These are standard names and a standard output.

Section	Report statement	Comments	Changes made?	Author comment
		Tables 4.13 and 4.14 are not properly presented and thus cannot be easily interpreted. They should be orderly presented like the other tables.	No	No changes were required. The tables were corrupted once the document was opened in DWS. DWS is aware of this. The original tables were copied back into the document.
		There is a need for a map where the EWR's and Biophysical nodes are mapped with the PES and REC and visually represented to give a holistic view of the Orange river. See Fig 5.1 and 5.2 for the tributaries which gives this kind of view.	No	The map would be per MRU, i.e. 6 river reaches all basically the same colour. If any any stage a complete map is drawn for stakeholder purposes, then that will be included.
Table 5.1		In Table 5.1 the ES of the SQ has not been included. Since it influences the REC (just like the EI), it also needs to be incorporated into this table.	No	Reasons have been provided in the report why it was not provided. It is not a useful indicator for basing improvement on at desktop level as it only indicates a flow (and quality) sensitivity.
		Upon interrogation of the DWS (PESEIS) spreadsheet it has been noted that some SQ with High EI were not noted in Table 5.1 for example Hartbees in D54G	No	There are three Hartbees SQs in the quat of which one is High. There are no other high SQs in the whole quat. A comparison to the quat based 2010 EIS lead to the decision to keep the evaluation of the downstream SQ which was moderate.
		Karee in D56F	No	The Karee was not the main river in the quat.
		D62F not captured in Table 5.1	No	This quat as a whole not assessed in PESEIS due to endorheic state.
		F10A not captured in Table 5.1	No	It is addressed as the SQ F10B-03391. The associated quats are provided in Appendix A
		F30 catchment just to mention a few examples	No	Uncertain what is meant with F30 as they are all included apart from F30F. F30F left out as F30g more representative as no clear main river as

Section	Report statement	Comments	Changes made?	Author comment
		What is the justification of leaving them out?		well as uncertainty around quat borders.There are some additional quats left out which are all represented by the estuary and downstream quat due to uncertainty around borders and limited assessment in the quat itself due to endorheic nature of the rivers.
		The PSPs should link the EWR site number (e.g EWR04) to the REMP site number (D8ORAN-VIOOLS) where possible as it will make the eventual monitoring of the site easier.	No	This is an important comment for the monitoring report and it will be linked then.
		Perhaps the naming of the site EWR02 as Augrabies may be changed as it implies the site is within the National Park	No	It cannot be changed as it will confused the link to all the other reports. The name was specific and agreed on by stakeholders including DWS as this site represents Augrabies as it was impossible to select a site within the park. In reality, the site is between two sections of the park which is situated both upstream and downstream of the site.
		Since the same PSP is also working on the Noordoewer/Vioolsdrift Dam Feasibility Study, the PSP must qualify their findings *viz a viz* the findings of related study.	No	Vioolsdrift study did not re-assess EWRs or EcoClassification and used the results presented in this study.
		EWR O4. As the site is outside of the National Park, why does this play a role in the EIS evaluation	Yes	The evaluation of EIS is for the MRU in which the site is situated. This includes the Transfortier park.
Page 3-4		This refers to the previous version of the PES EIS, to newer version did not look at “rare and endangered” or unique” species.	No	The ‘newer version’ mentioned is the desktop application of EI and ES. There is no newer version of the detailed site based EIS assessment.
		Again, this refers to the original PES EIS, the latest version only gives EI and ES not EIS. Would you consider improvement if either EI or ES is “high or very high”, or only when both are “high or very high”?	Yes	See above. There seems to be some confusion that the desktop country wide approach of PESEIS replaces the detailed Level IV EcoClassification approach. Although the principles stay the same for all levels, the

Section	Report statement	Comments	Changes made?	Author comment
				heading has been changed to make it more explicit.