APPENDIX C: WATER QUALITY

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C1 CALEDON KRAAI AND MOLOPO RIVERS

C1.1 INTRODUCTION

The information below covers the following steps per EFR site for the Caledon, Kraai and Molopo systems:

- Catchment context, particularly as it pertains to water quality.
- Available data / data confidence.
- Data assessment and PAI (Physico-chemical driver Assessment Index) table.

The methods and approach are not detailed in this document, but followed that outlined in DWAF (2008).

C1.2 DELINEATION AND EFR SITES

Information per EFR site in the Caledon, Kraai and Molopo study area is shown on Table C.1 below.

Table C1 Map of the Caledon, Kraai and Molopo study area showing EFR sites, gauging weirs and Level II EcoRegions

EFR site number	EFR site name	River	EcoRegion (Level II)	Geomorphic zone	Altitude (m)	MRU	Quat	Gauge
EFR C5	Upper Caledon	Caledon	15.03	Lower Foothills	1640	MRU Caledon A/B	D21A	
EFR C6	Lower Caledon	Caledon	26.03	Lowland	1270	MRU Caledon D	D24J	
EFR K7	Lower Kraai	Kraai	26.03	Lowland	1327	MRU Kraai C	D31M	D1H011
EFR M8	Molopo Wetland	Molopo	11.01	Lower Foothills	1459	MRU UM C	D41A	D4H030 D4H014

Information regarding delineation and selected EFR sites is taken from the July 2010 Resource Unit report produced for the study (i.e. Louw, 2010).

Figure C1 below shows the position of gauging weirs and EFR sites at an EcoRegional level. This is most relevant to the water quality study as monitoring points representing sites should preferentially be in the same Level II EcoRegion.

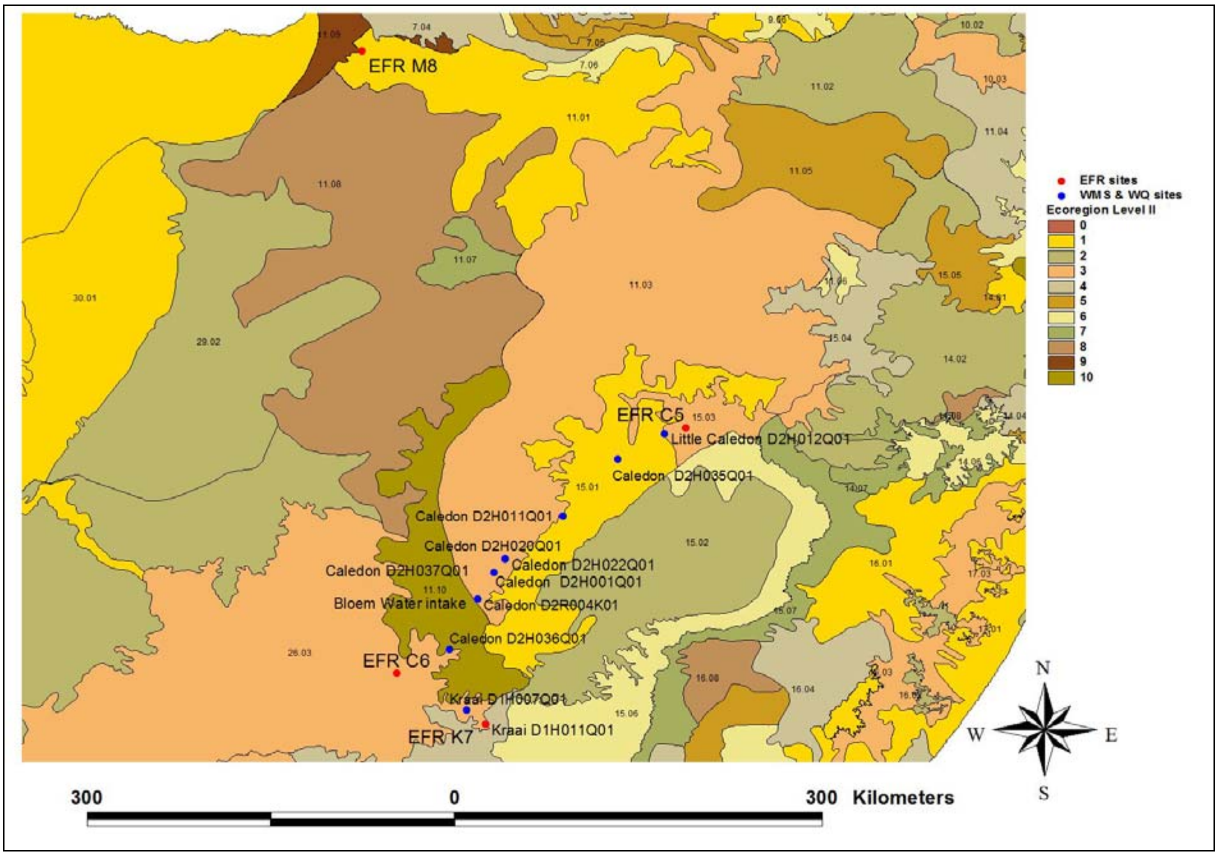

Figure C1 **Map of the Caledon, Kraai and Molopo study area showing EFR sites, gauging weirs and Level II EcoRegions**

C2 CALEDON RIVER

C2.1 CATCHMENT CONTEXT

The runoff from the Lesotho Lowlands drains to the west to the Caledon River while the highlands drain to the south via the Senqu River to the Orange River. The lowlands area is susceptible to erosion and the Caledon River transports large sediment loads causing extensive sedimentation of dams such as the Welbedacht Dam. Lesotho is a source of significant quantities of good quality water.

Bloem Water is the main supplier of bulk potable water to urban centres in the Modder/Riet sub-catchment, involving water from the Caledon River. In order to meet current water requirements, water is transferred from the Orange and Caledon River Systems. Transfer water supply schemes include the following: (1) The Caledon–Bloemfontein transfer which supplies Bloemfontein, Dewetsdorp, and small users from Welbedacht Dam, (2) the Maselspoort Scheme, and (3) the Caledon–Modder (or Novo) Transfer Scheme which supplies water via the Rustfontein Treatment Works to Bloemfontein, Botshabelo, and Thaba Nchu (DWA, 2010).

A brief overview of the water quality status in the main stem of the Vaal and Orange rivers was undertaken for ORASECOM (ORASECOM, 2007). The approach used was to collect water quality data at key stations on the Vaal, Caledon, Fish (Namibia) and the Orange Rivers. The water quality data was accessed from the South African Department of Water Affairs, Windhoek Consulting Engineers and the Lesotho government databases. Data used for the Caledon system was from DWA gauging weir D2H036Q01 on the lower Caledon River.

The Caledon system appears to be generally degraded, with a range of perceived water quality issues. Despite water of the Caledon River being naturally highly turbid (Heath and Brown, 2007), it also carries a considerable additional sediment load from poor land use management. Rooseboom (1992) stated that some of the highest sediment yields in RSA are to be found within the Caledon River catchment.

Results of “fitness for use” maps prepared by ORASECOM member states are shown in Table 3.1 for various users of the Caledon River (ORASECOM, 2009). As data were provided by Lesotho and South Africa for .the Caledon/Mokahare River, both sets of data are provided. Results were also provided for the Lesotho Lowlands by Lesotho. Suitability for use was designated according to the following categories, and using the domestic water quality guidelines available per member state, and the South African water quality guidelines for other users:

- No problems detected from the data
- Tolerable
- Poor
- Not suitable

Assessments were based on a worst case basis, i.e. the overall assessment of suitability for use was based on the variable(s) that showed the poorest quality water.

Table C2 Fitness for use for selected surface water areas of the Orange-Senqu River system

User category	Caledon/Mokahare River		Lesotho Lowlands
	SA data	Lesotho data	
Agriculture/Irrigation (crops)	No problems detected	Tolerable	Poor
Agriculture Livestock	No problems detected	No problems detected	No problems detected
Domestic	No problems detected	Tolerable	Poor
Industrial	Tolerable	Poor	Poor
Recreational	No problems detected	No problems detected	No problems detected

C2.2 UPPER CALEDON RIVER

C2.2.1 Background

The upper Caledon River can be defined as the area from the source of the river to Welbedacht Dam. Most of the area has Lesotho on the left bank (LB) with associated sedimentation problems due to land-use activities. Considerable irrigation development opportunity has been planned for previously disadvantaged farmers in the Lesotho Lowlands area (Heath and Brown, 2007), which might exacerbate existing erosion problems depending on land management practices.

On the right bank (RB) formal irrigation and dry land farming takes place. Many farm dams occur in the tributaries. The Little Caledon is situation within Golden Gate National Park and a section of the Caledon borders the Park.

The analysis of the water quality of the South Phuthiatsana River, which enters the Caledon River in quaternary catchment D22F and therefore drains the upper Caledon catchment area, showed that the Electrical Conductivity (EC) of the river is low with a maximum value of 25 mS/m. However, the orthophosphate concentrations were high with 43% exceeding 0.25 mg/L i.e. falling in the hypertrophic range. The source of the ortho-phosphate is from the runoff from the settlements scattered throughout the Lesotho lowlands catchment (ORASECOM, 2007).

C2.2.2 Available data/data confidence

The PES for *geomorphology* is a C category (70%), which is primarily attributed to the high sediment loads (sands and fines) being introduced from the upstream hillslopes and associated drainage lines (Rountree, 2010).

Data for *physico-chemical variables* registered on DWA's Water Management System (WMS) are shown in Table C3.

Table C3 WMS data available for the upper Caledon River system

Monitoring point name	River	Latitude	Longitude	Quat	No. Of samples	First sample date	Last sample date
D2H012Q01 Caledonspoort	Little Caledon River D21D	-28.69485	28.23487	D21C	587	1971/09/24	2010/03/23
D2H035Q01 Caledon River at Ficksburg/Ficksburg bridge	Caledon	-28.88333	27.89	D22C	354	1994/08/09	2010/03/23
D2H011Q01 Caledon River at Maseru (Lesotho G22)	Caledon	-29.29778	27.485278	D22H	489	1981/03/0	1994/02/09
D2H020Q01 Caledon River at pleasant view/Maseru	Caledon	29.30167	27.487778	D22H	89	1982/09/21	1991/03/05

Monitoring point name	River	Latitude	Longitude	Quat	No. Of samples	First sample date	Last sample date
Tributary of Caledon at Riverside lodge	Tributary of Caledon at Riverside	29.29367	27.4625	D22H	218	2003/02/05	2010/05/27
D2H022Q01 Caledon River at Wilgedraai/Hobhouse	Caledon	-29.61556	27.065278	D23E	51	1988/11/06	2008/05/06
D2H037Q01 Caledon river at Wilgedraai/Hobhouse	Caledon	-29.60917	27.065556	D23E	631	1995/10/31	2010/03/30
D2H001Q01 Caledon River at Jammerdrift	Caledon	-29.71528	26.98333	D23G	331	1955/02/04	1984/10/02

Diatom data indicated a change along the length of the upper section of the river. MRU A‘s diatom assessment shows a B category, indicating Good quality water with low pollution. However, there are indications that organics are elevated. The stretch of river in MRU B above the Little Caledon confluence, i.e. containing EFR C5, is in a B category. Diatom data for the Little Caledon River itself also shows an overall B category, although elevated nutrient and turbidity levels were indicated during all sampling occasions. Diatom data within the mainstem of the Caledon River shows levels ranging from a B to D category during various sampling events, probably due to changing flow conditions. Results again indicate organic pollution. Conditions around towns, i.e. Ficksburg and Maseru, deteriorate as expected, due to pollution events. Tributaries (e.g. Little Caledon and Grootfontein) appear to carry better quality water, with deteriorating conditions indicated for the main stem. Data are taken from the diatom report for the study (Koekemoer, 2010).

C2.2.3 Data assessment tables

Data are presented for various stretches of river stretching from EFR C5 through to Welbedacht Dam. The area is divided into (1) MRU A/B, containing EFR site C5; (2) the upper stretch of MRU B, i.e. downstream of EFR C5 up to and including Ficksburg; (3) below Ficksburg and including Maseru; and (4) below Maseru to the top of Welbedacht Dam. All these stretches are found within MRU B, with only the first reach being MRU A/B. Data assessment tables are listed per site, followed by PAI tables per site in Section C2.2.4.

Data assessment results for MRU B are shown as Table C4 - C7, with Table C4 being for the river reach containing EFR C5. As the closest gauging weir to the EFR site on the mainstem is at Ficksburg, data for the Little Caledon River were considered more representative of conditions at the EFR site. SASS and fish data for the present state are from this study (Palmer, 2010 and Kotzé, 2010 respectively).

Note that average salt ion and other concentration values were taken from Koekemoer (2010) where data not available from WMS. These data are indicated as averages of two sampling surveys held during 2008 and 2009.

Table C4 Water quality data assessment for reach containing EFR C5, MRU A/B

<table>
<tr><td rowspan="2">RIVER</td><td rowspan="2">Caledon River</td><td colspan="2">WATER QUALITY MONITORING POINTS</td></tr>
<tr><td>RC</td><td>Little Caledon River @ Caledonspoort (D21C; EcoRegion II: 15.03)
D2H012Q01 (1975 – 1977; n=84)</td></tr>
<tr><td>EFR SITE</td><td>C5 (D21A;
EcoRegion II: 15.03)</td><td>PES</td><td>1) Little Caledon River @ Caledonspoort (D21C; EcoRegion II: 15.03).
D2H012Q01 (2002 – 2010; n=47/48)
2) Data from diatom sample collection in 2008 + 2009</td></tr>
<tr><td colspan="2">Confidence assessment</td><td colspan="2">Moderate confidence. Although sufficient data, data gaps exist. Data for PES also below 60 records, and on the Little Caledon River.</td></tr>
</table>

<table>
<tr><th colspan="2">Water Quality Constituents</th><th>RC Value</th><th>PES Value</th><th>Category/Comment</th></tr>
<tr><td>Inorganic salts (mg/L)</td><td colspan="4">TEACHA was not used for data assessment, as salinity levels not elevated.</td></tr>
<tr><td rowspan="6">Salt ions (mg/L)</td><td>Ca</td><td>50.97</td><td>44.88</td><td rowspan="6">Concentrations similar for the PES.
RC values indicate naturally elevated salinity levels for the Caledon River system.</td></tr>
<tr><td>Cl</td><td>7.27</td><td>10.26</td></tr>
<tr><td>K</td><td>2.91</td><td>2.93</td></tr>
<tr><td>Mg</td><td>22.49</td><td>21.77</td></tr>
<tr><td>Na</td><td>21.16</td><td>16.09</td></tr>
<tr><td>SO_4</td><td>19.24</td><td>23.15</td></tr>
<tr><td rowspan="2">Nutrients (mg/L)</td><td>SRP</td><td>0.018 *</td><td>0.039</td><td>B/C category</td></tr>
<tr><td>TIN</td><td>0.060</td><td>0.134</td><td>A category</td></tr>
<tr><td rowspan="5">Physical Variables</td><td>pH (5^{th} + 95^{th} %ile)</td><td>7.06 + 8.09</td><td>7.8 + 8.5</td><td>A/B category</td></tr>
<tr><td>Temperature</td><td>-</td><td>-</td><td rowspan="2">No data but no impacts expected.</td></tr>
<tr><td>Dissolved oxygen</td><td>-</td><td>-</td></tr>
<tr><td>Turbidity (NTU)</td><td>-</td><td>Avg: 11.31
Median: 3.34
95^{th} %ile: 30.34</td><td>No RC data. Turbid system that naturally carries sediments.</td></tr>
<tr><td>Electrical conductivity (mS/m)</td><td>47.5 *</td><td>45.8</td><td>A category</td></tr>
<tr><td rowspan="5">Response variables</td><td>Chl a: periphyton (mg/m^2)</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Chl a: phytoplankton (µg/L)</td><td>-</td><td>Avg: 1.67 (n=3)</td><td>A category</td></tr>
<tr><td>Macroinvertebrates</td><td>ASPT: 6.4
SASS: 174</td><td>ASPT: 5.7
SASS: 97
MIRAI: 63%</td><td>C category</td></tr>
<tr><td>Fish community score</td><td>-</td><td>FRAI: 43%</td><td>D category</td></tr>
<tr><td>Diatoms</td><td>-</td><td>SPI - tribs: B (avg: 14.2)</td><td>B category</td></tr>
<tr><td rowspan="4">Toxics</td><td>Fluoride (mg/L)</td><td>1.5 **</td><td>0.083</td><td>A category</td></tr>
<tr><td>Aluminium (mg/L)</td><td>0.02 **</td><td>0.100 (n=3)</td><td>C category</td></tr>
<tr><td>Iron (mg/L)</td><td>-</td><td>0.155 (n=3)</td><td>No guideline + insufficient data</td></tr>
<tr><td>Other</td><td>-</td><td>-</td><td>Impacts expected due to farming-related pesticides and fertilizer use.</td></tr>
<tr><td colspan="2">OVERALL SITE CLASSIFICATION</td><td colspan="3">B/C: 80.8% (from PAI model)</td></tr>
</table>

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

Table C5 Water quality data assessment: Reach below EFR C5 to Ficksburg, MRU B

RIVER	Caledon River	**WATER QUALITY MONITORING POINTS**		
		RC	Little Caledon River @ Caledonspoort (D21C; EcoRegion II: 15.03) D2H012Q01 (1975 – 1977; n=84)	
EFR SITE	None	**PES**	1) Caledon River @ Ficksburg (D22C; EcoRegion II: 15.01) D2H035Q01 (2000 – 2010; n=58) 2) Data from diatom sample collection in 2008 + 2009	
Confidence assessment	Moderate confidence. Although sufficient data, data gaps exist. Data for PES also below 60 records.			

Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	50.97	32.73	Concentrations similar or lower for the PES. Results may suggest a slightly different geology and salinity profile between EcoRegions 15.03 (RC data) and 15.01 (PES data). However, RC values indicate naturally elevated salinity levels for the Caledon River system.
	Cl	7.27	7.54	
	K	2.91	1.75	
	Mg	22.49	14.78	
	Na	21.16	10.41	
	SO_4	19.24	15.93	
Nutrients (mg/L)	SRP	0.018 *	0.033	B category
	TIN	0.060	0.252	A/B category
Physical Variables	pH (5^{th} + 95^{th} %ile)	7.06 + 8.09	7.5 + 8.4	A/B category
	Temperature	-	-	No data but no impacts expected.
	Dissolved oxygen	-	-	
	Turbidity (NTU)	Avg: 15 over whole data record, i.e. 1971-2010 (n=68)	Avg: 228.17 Median: 14 95^{th} %ile: 298	No RC data. Highly turbid system although naturally carries sediments.
	Electrical conductivity (mS/m)	47.5 *	38.17	A category
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 6 (n=2)	A category
	Diatoms	-	SPI - tribs: B (avg: 14.2) SPI – mainstem: D (6.1)	C/D category for Caledon
Toxics	Fluoride (mg/L)	1.5 **	Avg: 0.075 (n=2)	A category
	Aluminium (mg/L)	0.02 **	Avg: 0.096 (n=2)	B/C category
	Iron (mg/L)	-	Avg: 0.135 (n=2)	No guideline + insufficient data
	Lead (mg/L)	0.001 **	Avg: 0.0075 (n=2)	D category
	Other	-	-	Impacts expected due to farming-related pesticides and fertilizer use and industrial discharges.
OVERALL SITE CLASSIFICATION		**C: 68.0%** (from PAI model)		

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

Table C6 Water quality data assessment for reach below Ficksburg to Maseru, MRU B

RIVER	Caledon River	**WATER QUALITY MONITORING POINTS**	
		RC	Little Caledon River @ Caledonspoort (D21C; EcoRegion II: 15.03) D2H012Q01 (1975 – 1977; n=84)
EFR SITE	None	**PES**	1) Caledon River @ Maseru (D22H; EcoRegion II: 15.01) D2H011Q01 (1990 – 1994; n=70) 2) Data from diatom sample collection in 2008 + 2009
Confidence assessment	Moderate confidence. Although sufficient data for RC and PES, data gaps exist and no recent record for PES.		

Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	50.97	Avg: 28.95 (n=2)	Limited data, but concentrations similar for the PES other than Cl which has shown a significant increase. However, note that RC data is from WMS (so long-term although only until 1994), while PES data is for two sampling occasions.
	Cl	7.27	Avg: 17.82 (n=2)	
	K	2.91	2.73	
	Mg	22.49	Avg: 11.15 (n=2)	
	Na	21.16	Avg: 29.87 (n=2)	
	SO_4	19.24	16.91	
Nutrients (mg/L)	SRP	0.018 *	0.023	B category
	TIN	0.060	0.364	B category
Physical Variables	pH (5th + 95th %ile)	7.06 + 8.09	7.3 + 8.5	A/B category
	Temperature	-	Avg: 19.65 (n=13)	Little data but no impacts expected.
	Dissolved oxygen	-	-	
	Turbidity (NTU)	Avg: 15 over whole data record, i.e. 1971-2010 (n=68)	Avg: 30.5 (n=2)	Turbidities appear lower than upstream, although poor data record
	Electrical conductivity (mS/m)	47.5 *	35.0 (n=128)	A category
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 10 (n=2)	B category
	Diatoms	-	SPI: avg=7.1	D category
Toxics	Fluoride (mg/L)	1.5 **	0.494	A category
	Ammonia (mg/L)	0.015 **	0.008	A category
	Aluminium (mg/L)	0.02 **	Avg: 0.076 (n=2)	B category
	Iron (mg/L)	-	Avg: 0.0885 (n=2)	No guideline + insufficient data
	Other	-	-	No other data, but impact expected due to farming-related pesticides and fertilizer use + industrial discharges in the Maseru area.
OVERALL SITE CLASSIFICATION		**C: 66.40%** (from PAI model)		

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

Table C7 Water quality data assessment for reach below Maseru to upstream Welbedacht Dam, MRU B

<table>
<tr><td rowspan="2">RIVER</td><td rowspan="2" colspan="2">Caledon River</td><td colspan="3">WATER QUALITY MONITORING POINTS</td></tr>
<tr><td>RC</td><td colspan="2">Caledon River @ Jammerdrift (D23G; EcoRegion II: 11.03)
D2H001Q01 (1976 – 1979; n=92)</td></tr>
<tr><td>EFR SITE</td><td colspan="2">None</td><td>PES</td><td colspan="2">Caledon River @ Hobhouse (D23E; EcoRegion II: 11.03)
D2H037Q01 (2005 – 2010; n=148/149)</td></tr>
<tr><td>Confidence assessment</td><td colspan="5">Moderate - high confidence. Although sufficient data for RC and PES, data gaps exist.</td></tr>
<tr><td colspan="2">Water Quality Constituents</td><td>RC Value</td><td>PES Value</td><td colspan="2">Category/Comment</td></tr>
<tr><td>Inorganic salts (mg/L)</td><td colspan="5">TEACHA was not used for data assessment, as salinity levels not elevated.</td></tr>
<tr><td rowspan="6">Salt ions (mg/L)</td><td>Ca</td><td>34.3</td><td>40.48</td><td rowspan="6" colspan="2">Limited data, but concentrations similar for the PES other than Na, Cl and sulphate which have shown significant increases. Ions may be attached to high suspended sediment loads.</td></tr>
<tr><td>Cl</td><td>6.85</td><td>33.15</td></tr>
<tr><td>K</td><td>7.59</td><td>5.16</td></tr>
<tr><td>Mg</td><td>16.00</td><td>19.51</td></tr>
<tr><td>Na</td><td>15.74</td><td>49.57 (n=140)</td></tr>
<tr><td>SO_4</td><td>21.63</td><td>48.58</td></tr>
<tr><td rowspan="2">Nutrients (mg/L)</td><td>SRP</td><td>0.018 *</td><td>0.037</td><td colspan="2">B category</td></tr>
<tr><td>TIN</td><td>0.45 *</td><td>0.174 (n=140)</td><td colspan="2">B category</td></tr>
<tr><td rowspan="6">Physical Variables</td><td>pH (5^{th} + 95^{th} %ile)</td><td>6.67 + 7.58</td><td>7.17 + 8.59</td><td colspan="2">A/B category</td></tr>
<tr><td>Temperature</td><td>-</td><td>-</td><td rowspan="2" colspan="2">No data but no impacts expected.</td></tr>
<tr><td>Dissolved oxygen</td><td>-</td><td>-</td></tr>
<tr><td>Turbidity (NTU)</td><td>-</td><td>Avg: 382.5 over whole data record, i.e. 1995-2010 (n=130)</td><td colspan="2"></td></tr>
<tr><td>Suspended solids (mg/L)</td><td>Avg: 4 186
50^{th} %ile: 3066
95^{th} %ile: 10862.3</td><td>-</td><td colspan="2">Very high levels recorded in the 1970s</td></tr>
<tr><td>Electrical conductivity (mS/m)</td><td>35.3 *</td><td>59.1</td><td colspan="2">A category</td></tr>
<tr><td rowspan="3">Response variables</td><td>Chl a: periphyton (mg/m^2)</td><td>-</td><td>-</td><td colspan="2">-</td></tr>
<tr><td>Chl a: phytoplankton (µg/L)</td><td>-</td><td>-</td><td colspan="2">-</td></tr>
<tr><td>Diatoms</td><td>-</td><td>SPI - tribs: B
SPI – mainstem: B-D</td><td colspan="2">C/D category for Caledon</td></tr>
<tr><td rowspan="2">Toxics</td><td>Ammonia (mg/L)</td><td>0.015 **</td><td>0.016</td><td colspan="2">A category</td></tr>
<tr><td>Other</td><td>-</td><td>-</td><td colspan="2">No other data, but impact expected due to farming-related pesticides and fertilizer use.</td></tr>
<tr><td colspan="2">OVERALL SITE CLASSIFICATION</td><td colspan="4">C: 74.0% (from PAI model)</td></tr>
</table>

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

C2.2.4 PAI tables

PAI tables for the upper Caledon River catchment are shown as Tables C8, with Table C8 being for the river reach containing EFR C5 and Table C9 being the Alternative Ecological Category (AEC) for this site. The flow requirement for the AEC represents a drop in category with reduced flows.

Table C8 PAI table for reach containing EFR C5, MRU A/B

PERENNIAL (Y/N)	y
GEOMORPH ZONE	FOOTHILL
WIDTH (m)	2-15

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	50.0		50.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	1.5	NONE SPECIFIED	5.0	65.0		65.0
Water Temperature	0.0	N	5.0	55.0		55.0
Water clarity	2.0	NONE SPECIFIED	3.0	55.0		55.0
Oxygen	0.0	N	4.0	75.0		75.0
Toxics	2.0	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	0.96	MEAN CONF →	4.14			
FINAL PC MODIFICATION RATING	0.96					
P-C RATING BASED ON DEFAULT WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
80.80	B/C					
P-C RATING BASED ON ADJUSTED WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
80.78	B/C					

Suspected toxics and suspended solids from upstream farming activities dominate the water quality assessment.

Table C9 PAI table for the AEC for EFR C5

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	50.0		50.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	2.0	NONE SPECIFIED	3.0	65.0		65.0
Water Temperature	1.0	N	3.0	55.0		55.0
Water clarity	2.5	NONE SPECIFIED	3.0	55.0		55.0
Oxygen	1.0	N	3.0	75.0		75.0
Toxics	2.5	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	1.49	MEAN CONF →	3.43			
FINAL PC MODIFICATION RATING	1.49					
P-C RATING BASED ON DEFAULT WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
70.20	C					
P-C RATING BASED ON ADJUSTED WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
70.11	C					

Lower flows will result in a lower dilution capacity for toxicant and nutrient levels, as well as changes in temperature and oxygen conditions.

Table C10 PAI table for reach below EFR C5 to Ficksburg, MRU B

PERENNIAL (Y/N)	y
GEOMORPH ZONE	LOWLAND
WIDTH (m)	2-15

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	2.5	NONE SPECIFIED	4.0	75.0		75.0
Water Temperature	0.5	N	3.0	55.0		55.0
Water clarity	3.0	NONE SPECIFIED	3.0	50.0		50.0
Oxygen	0.5	N	3.0	65.0		65.0
Toxics	3.0	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	1.60	MEAN CONF →	3.57			
FINAL PC MODIFICATION RATING	1.60					

P-C RATING BASED ON DEFAULT WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
68.00	C
P-C RATING BASED ON ADJUSTED WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
68.02	C

Water quality conditions in the Ficksburg area expected to impact on water quality state, particularly in terms of toxics, nutrients and turbidity levels.

Table C11 PAI table for reach below Ficksburg to Maseru, MRU B

PERENNIAL (Y/N)	y
GEOMORPH ZONE	LOWLAND
WIDTH (m)	2-15

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	3.0	NONE SPECIFIED	4.0	75.0		75.0
Water Temperature	0.5	N	3.0	55.0		55.0
Water clarity	2.0	NONE SPECIFIED	3.0	50.0		50.0
Oxygen	0.5	N	3.0	65.0		65.0
Toxics	3.5	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	1.68	MEAN CONF →	3.57			
FINAL PC MODIFICATION RATING	1.68					

P-C RATING BASED ON DEFAULT WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
66.40	C
P-C RATING BASED ON ADJUSTED WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
66.37	C

Conditions seem similar to the upstream reach, although turbidities are lower and nutrient and toxic levels slightly elevated.

Table C12 PAI table for reach below Maseru to upstream Welbedacht Dam, MRU B

PERENNIAL (Y/N)	y
GEOMORPH ZONE	LOWLAND
WIDTH (m)	2-15

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	2.0	NONE SPECIFIED	4.0	75.0		75.0
Water Temperature	0.5	N	3.0	55.0		55.0
Water clarity	2.0	NONE SPECIFIED	3.0	50.0		50.0
Oxygen	0.5	N	3.0	65.0		65.0
Toxics	2.5	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	1.30	MEAN CONF →	3.57			
FINAL PC MODIFICATION RATING	1.30					

P-C RATING BASED ON DEFAULT WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
74.00	C

P-C RATING BASED ON ADJUSTED WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
74.07	C

Conditions seem to improve slightly downstream, with toxics and nutrient levels lower.

C2.3 LOWER CALEDON RIVER

3.3.1 Background

The lower Caledon River can be defined as the area from Welbedacht Dam to the Orange River (Gariep Dam). The only water flowing down the river are spills from the dam, inflows from tributaries and compensation water releases. The irrigators downstream of Welbedacht Dam have no claim to any water in Welbedacht Dam and no irrigation flows are released.

One of the main transfer water supply schemes in the area is the Caledon–Bloemfontein transfer which supplies Bloemfontein, Dewetsdorp, and small users from Welbedacht Dam. Due to the decreasing yield of the Welbedacht Dam as a result of siltation (gross storage capacity has reduced from the original 115 million m^3 to approximately 30 million m^3 in nine years) and the increasing demand on the Caledon-Bloemfontein Regional Water Supply Scheme (RWSS), the DWA supplemented the yield of the Welbedacht Dam through the construction of the Knellpoort off-channel storage dam on the Rietspruit (29º 45' 47" S; 26º 52' 29" E), a tributary of the Caledon River. Knellpoort Dam (storage capacity 137 Mm^3) is supplied with water from the Caledon River by the Tienfontein Pump Station. Water diverted from the Caledon River into Knellpoort Dam is then released back into the Caledon River to allow abstraction at Welbedacht Dam by Bloem Water all year round. Downstream of Welbedacht Dam is the Welbedacht Water Treatment Works (WTW) (DWA, 2010).

Tienfontein Pump Station is seen as the most critical component of the water supply infrastructure supplying Bloem Water with raw water, as Bloem Water receives approximately 70% of its water supply from Welbedacht Dam (via Tienfontein Pump Station and Knellpoort Dam) (DWA, 2010).

C2.3.1 Available data/data confidence

As the site is in the backup zone of Gariep Dam, it is strongly influenced by silt deposits in this zone. The PES for geomorphology is a C/D category, mostly due to the extremely high sediment loads (sands and fines) being introduced from the upstream hillslopes and associated drainage lines, and from bottom releases from Welbedacht Dam.

Data for physico-chemical variables registered on DWA's Water Management System (WMS) are shown in Table C13. Data were also sourced from Bloem Water's intake point, which is at the outlet of Welbedacht Dam – details are shown in Figure C2 and Table C14.

Table C13 WMS data available for the lower Caledon River system

Monitoring point name	River	Latitude	Longitude	Quaternary catchment	Number of samples	First sample date	Last sample date
D2R004K01 CALEDON RIVER: RIVER OUTLET	WELBEDACHT DAM-OUTLET (D2)	-29.90889	26.860556	D24C	125	1981/09/14	2007/05/01
D2H036Q01 CALEDONRIVER AT KOMMISSIEDRIFT	CALEDON	-30.27917	26.654167	D24G	434	1993/05/12	2010/03/10

Table C14 Water quality data for Bloem Water's intake point on the Caledon system

Monitoring point name	River	Latitude	Longitude	Quaternary catchment	Number of samples	First sample date	Last sample date
WELDAM RAW: BLOEM WATER RAW WATER INTAKE	CALEDON	-29.91	26.86	D23J	236	2001/01/08	2010/06/28

Water quality data has been sourced from Slabbert (2007), where monthly samples were taken from March 2000 to May 2001 at the abstraction point at the Tienfontein Pump Station in the Caledon River (29º 46' 00" S; 26 º 55' 44" E) (Figure C2), for the following selected variables: Nutrients [total phosphates (TP), dissolved reactive ortho-phosphates (PO_4-P), nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N) and silica-silicon (SiO_2-Si)], chlorophyll- *a*, TDS, pH and turbidity.

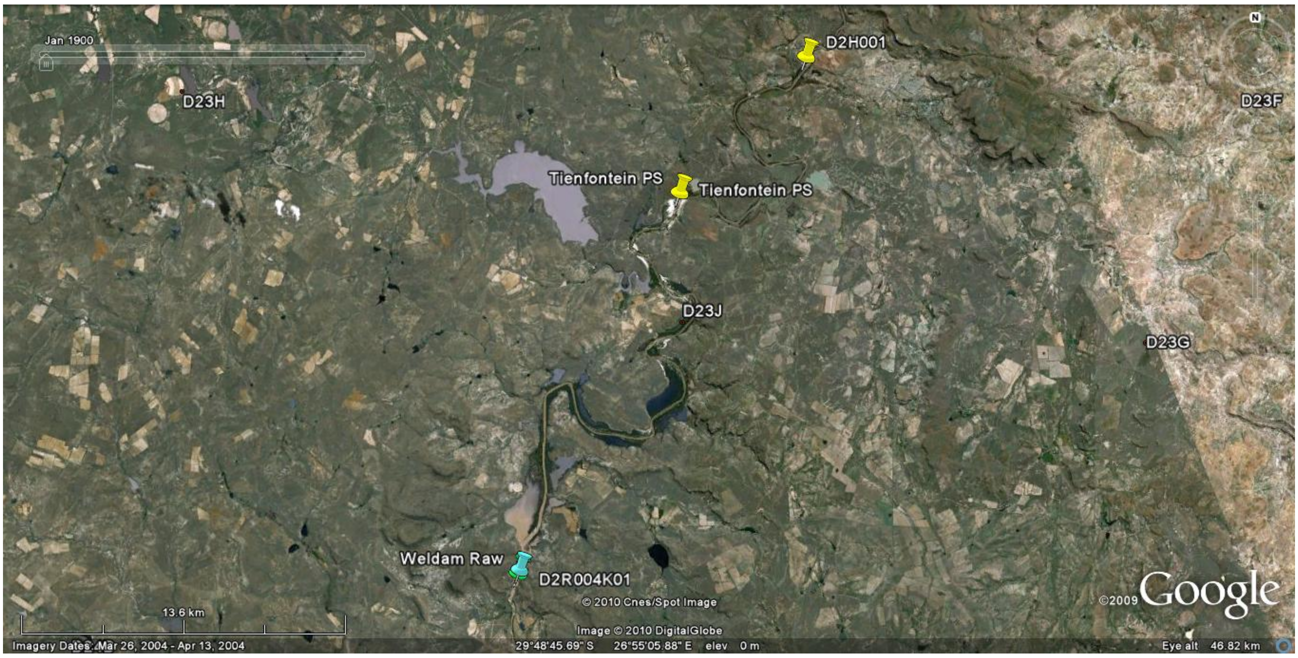

Figure C2 Position of Welbedacht Dam, Bloem Water intake point (Weldam Raw) and the Tienfontein Pump Station on the Caledon River

Slabbert's (2007) turbidity data for the Caledon River are shown in Table C15, with results for other physico-chemical variables shown in Table C16.

Table C15 Turbidity data for the Caledon River for March 2000 – May 2001

River	Avg turbidity (NTU)	Min. + max. values	Std. deviation	Variance	Median
Caledon	4 460	20 + 22 250	6 745	22 230	990

Since there was such a large variance in the turbidity data for the Caledon River, it is difficult to make conclusions from the averages, and the median values may be a better indication. However, it was confirmed during the study period that the turbidity in the Caledon River was consistently high with values increasing after the rains in September to October, and decreasing during the dry season (winter) from June to September (Slabbert, 2007).

Table C16 Water quality data (average values) for the Caledon River for March 2000 – May 2001

Variable	Unit	Average concentration or value	Notes
pH		7.95	Small change over study period so well-buffered
Alkalinity	mg/L	97	
Dissolved oxygen	mg/L	All values near saturation, so no problems expected	
Total Dissolved Solids (TDS)	mg/L	108.8	
EC	mS/m	16.7	A category
PO_4-P	µg/L	26.5	Above average levels
Summer concentrations of P	µg/L	35	Eutrophic (DWAF, 1996)
NO_3-N	µg/L	322.1*	100 µg/L NO_3-N = levels for unpolluted world rivers (Webb & Walling, 1992)
NH_4-N	µg/L	12.15	
SiO_2-Si	mg/L	12.8	Avg for river systems: 13.0 mg/L
Chlorophyll-*a* (phytoplankton)	µg/L	6.7	Low values

* Potential contaminating sources could be agricultural run-off from Lesotho, the geological formations underlying the river, as well as sewage and industrial pollution from Maseru (Slabbert, 2007).

Generally the nutrient status of the two river systems is oligotrophic to mesotrophic. There are indications that pollution of the Caledon River occurs. Note that the method for determining the water quality component of the Reserve uses percentile values rather than averages, due to the fluctuating levels of these variables with flow (DWAF, 2008). Nutrients are measured as 50th percentiles, and other ions and salts as 95th percentiles.

Table C17 Macroinvertebrate data for the Caledon River sampled March 2000 to May 2001

Sampling site	Habitats sampled	Habitat score	SASS5 score	No of taxa	ASPT score
Caledon River	Sand + marginal vegetation	50	32	5	6.4

The Caledon River was classified as Poor by Slabbert (2007) in terms of the macroinvertebrate assessment. Although the ASPT was between 5 and 7, both the habitat and SASS5 scores were low. *Diatom data* for EFR C6 appear not to be a true reflection of conditions at the site, as the 2010 result indicates an A category. Long-term monitoring will provide more accurate results. Data are taken from the diatom report for the study (Koekemoer, 2010). It is recommended that the high salinity levels indicated by few diatom samples be treated with caution, as this is not shown by physico-chemical data. Salinity levels in the Caledon system seem to be naturally elevated. Diatoms indicating salinity would therefore be expected.

C2.3.2 Data assessment tables

Only one data assessment table (Table C18) is provided for the lower Caledon, due to a dearth in data. This assessment therefore represents conditions in the stretch of river containing EFR C6. Data from Bloem Water has been used with caution as the intake point is just downstream of Welbedacht Dam. SASS data for the present state is from this study (Palmer, 2010).

Table C18 Water quality data assessment for the lower Caledon, MRUs C and D

RIVER	Caledon River	**WATER QUALITY MONITORING POINTS**	
		RC	Caledon River @ Jammerdrift (D23G; EcoRegion II: 11.03) D2H001Q01 (1976 – 1979; n=92)
EFR SITE	C6 (D24J; EcoRegion II: 26.03)	**PES**	1) Caledon River @ Kommissiedrift (D24G; EcoRegion II: 11.10) D2H036Q01 (2000 – 2010; n=90-96) 2) Weldam Raw (Bloem Water intake: **labelled BW**) (D23J; EcoRegion II: 11.03) (2001 – 2010; n=230. 3) Data from Slabbert (2007)
Confidence assessment		Moderate – High confidence.	

Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	34.3	40.96; BW: 34.3	Limited data, but concentrations similar for the PES.
	Cl	6.85	16.15; BW: 18.61	
	K	7.59	3.67; BW: 3.45	
	Mg	16.00	22.5; BW: 14.37	
	Na	15.74	24.9; BW: 25.66	
	SO_4	21.63	25.79; BW: 24.18	
Nutrients (mg/L)	SRP	0.018 *	0.037; BW: 0.05	B/C category
	TIN	0.45 *	0.188 (n=89); BW: 0.74	B category, C category
Physical Variables	pH (5th + 95th %ile)	6.67 + 7.58	7.44 + 8.40 BW: 6.68 + 8.11	A/B category
	Temperature	-	-	No data but some impacts expected downstream Welbedacht Dam.
	Dissolved oxygen	-	-	
	Turbidity (NTU) [WMS: n=90] [BW: n=60]	-	(WMS / BW) Avg: 249 / 429 Median: 45.75 / 332 95th%ile: 1 027 / 987	No RC data. Highly turbid system although naturally carries sediments.
	Suspended solids (mg/L)	Avg: 4 186 50th %ile: 3066 95th %ile: 10862.3	-	Very high levels recorded in the 1970s.
	Electrical conductivity (mS/m)	35.3 *	37.94	A category
Response variables	Chl a: phytoplankton (µg/L)	-	6.7	A category (Slabbert, 2007)
	Macroinvertebrates	ASPT: 5.9 SASS: 113	ASPT: 5.2 SASS: 52 MIRAI: 57%	D category
	Fish community score	-	FRAI: 55%	D category
	Diatoms	-	SPI - tribs: B (avg: 14.05) SPI – site: A	C category (as high flows responsible for high category at site)
Toxics	Fluoride (mg/L)	1.5 **	0.318 (n=90); BW: 0.230	A category
	Ammonia (mg/L)	0.015 **	0.016	A category
	Aluminium (mg/L)	0.02 **	BW: 0.46	E category, but low confidence as no RC value
	Copper (mg/L)	0.001 5**	BW: 0.02	E category, but low confidence as no RC value
	Iron (mg/L)		BW: 0.24	No RC data + no guidelines
	Other	-	-	No other data, but impact expected due to farming-related pesticides and fertilizer use + upstream industrial inputs.
OVERALL SITE CLASSIFICATION		**C: 62.8%** (from PAI model)		

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

C2.3.3 PAI tables

The PAI table for EFR C6 is shown as Table C19, with that for the Alternative Ecological Category (AEC) shown as Table C20. The following improved flow conditions can be expected for the AEC: Improvement of low flows, no zero flows and bottom releases during the high flow season.

Changes in parameters are indicated in red text on Table C20.

Table C19 PAI table for EFR C6

PERENNIAL (Y/N)	Y
GEOMORPH ZONE	LOWLAND
WIDTH (m)	>15

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.00	60.00		60.00
Salts	0.0	NONE SPECIFIED	5.00	50.00		50.00
Nutrients	2.0	NONE SPECIFIED	3.00	70.00		70.00
Water Temperature	1.0	N	3.00	60.00		60.00
Water clarity	4.0	NONE SPECIFIED	3.00	50.00		50.00
Oxygen	1.0	N	3.00	65.00		65.00
Toxics	3.5	N	3.00	100.00		100.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	1.86	MEAN CONF →	3.43			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	1.86					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	1.86					
FINAL PC MODIFICATION RATING	1.86					
P-C CATEGORY %	P-C CATEGORY					
62.80	C					

Turbidities are particularly high in this stretch of the river, with the impact of the dam shown in changing temperature and oxygen levels. Bloem Water intake data also indicates high toxics. The most likely source of aluminium in the surface water is due to alum or aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids.

Table C20 PAI table for the AEC for EFR C6

[redacted]

C2.4 GENERAL NOTES

There is extensive irrigation practised in the Vaal and Orange River system where herbicides and pesticides are used (ORASECOM, 2007). These could be present in the return flows and conveyed in the surface runoff to the river systems. The current water quality database does not support the identification of pesticides and herbicides in the rivers. It is recommended that a pesticide and herbicide monitoring program should be initiated to determine the extent of the problem, or toxicity testing should be undertaken at hot spots.

A nutrient management strategy needs to be developed for areas where high levels of eutrophication can be seen from point sources such as sewage works as well as diffuse sources associated with runoff from urban areas and agriculture. Modelling tools for nutrients have also not developed adequately and nutrient pathways are not sufficiently understood.

It is recommended that the high salinity levels indicated by few diatom samples be treated with caution, as this is not shown by physico-chemical data. Salinity levels in the Caledon system seem to be naturally elevated. Diatoms indicating salinity would therefore be expected.

The following general comments can be made about the water quality state of the tributaries of the system (taken from an update on the water quality status of the Orange River system prepared in 2009):

- The water quality in the Caledon River is highly variable but in general is in a Fair condition, however, pollution levels (nutrients and faecal contamination) at Ficksburg and Maseru are a matter of concern.
- The Caledon River is characterized by extreme seasonal fluctuations in turbidity (min. 0.5; max. 10 000 NTU) and with a mean value of 400 NTU (at Kommissiedrift) is probably the most turbid river in South Africa.
- The Little Caledon at Golden Gate is in a very good water quality condition, but shows signs of deterioration (higher salts and nutrients) downstream at the confluence with the Caledon River.
- The water quality in Meulspruit was Good and Moderate in the Leeu River, with relatively high nitrogen concentrations, but low SAR values – ideal for irrigation use.
- Grootspruit (close to Fouriesburg) showed signs of sewage pollution with faecal contamination, nutrient enrichment and high periphyton growth on rocks, associated with high pH and dissolved oxygen concentrations. Relatively high dissolved salts and metals were recorded, however, a high diatom score (SPI) indicate good water quality.

C3 EFR K7: UPPER KRAAI RIVER

C3.1 CATCHMENT CONTEXT

The Kraai River is a tributary of the Orange River which flows near Barkley East in the Eastern Cape. The river originates to the south of Lesotho and flows westward, where it joins the Orange near Aliwal North. Agricultural intensity in the area has declined since the 1980's, with many of the slopes previously cultivated now being abandoned to pasture or grassland (Rountree, 2010).

The Kraai system includes much of the area consisting of the farmlands of the Eastern Cape and subsistence farming areas of some of the former homelands. The degraded nature of the area means that the utilisation of the area, from a socio-cultural perspective, is not as high as it may have been historically. Impacts are primarily associated with agriculture, abstraction and farm dams as well as exotic vegetation, particularly in MRU C where EFR site K7 is situated. However, the presence of rare and unique riparian vegetation as well as the sensitivity of the habitat associated with a small and steep (gradient) river in the upper reaches, increases the ecological importance of this system. The river is also widely used for recreational activities such as river rafting and fly-fishing in the Rhodes area.

The general water quality state of the Kraai River was reported to be Good in a water quality status report of 2009.

C3.2 AVAILABLE DATA/DATA CONFIDENCE

The PES for geomorphology is an A/B category (90.6%), with the site considered to be close to its natural state. No embeddedness was evident at the site.

Data for physico-chemical variables registered on DWA's Water Management System (WMS) are shown in Table C21.

Table C21 WMS data available for the Kraai River system

Monitoring point name	River	Latitude	Longitude	Quaternary catchment	Number of samples	First sample date	Last sample date
D1H011Q01 KRAAI RIVER AT ROODEWAL	KRAAI	-30.83056	26.921389	D13L	1146	1967/02/13	2010/03/11
D1H007Q01 KRAAI RIVER AT BUFFELS VALLEI/SUNNYSIDE	KRAAI	-30.72694	26.782778	D13M	267	1974/06/04	1975/07/25

Diatom data show evidence of organic pollution and elevated nutrient levels, with fluctuating turbidity levels. The overall category for the reach based on diatoms is a C category (Koekemoer, 2010).

C3.3 DATA ASSESSMENT TABLE

The data assessment results for EFR K7 are shown in Table C22.

Table C22 Water quality data assessment for EFR K7

<table>
<tr><td rowspan="2">RIVER</td><td rowspan="2">Kraai River</td><td colspan="2">WATER QUALITY MONITORING POINTS</td></tr>
<tr><td>RC</td><td>Kraai River @ Roodewal (D13L; EcoRegion II: 26.03)
D1H011Q01 (1974 – 1977; n=80)</td></tr>
<tr><td>EFR SITE</td><td>K7 (D13M; EcoRegion II: 26.03)</td><td>PES</td><td>1) Kraai River @ Roodewal (D13L; EcoRegion II: 26.03)
D1H011Q01 (2000 – 2010; n=64-66)
2) Data from diatom sample collection in 2008 + 2009</td></tr>
<tr><td>Confidence assessment</td><td colspan="3">Moderate confidence. Although sufficient data for most variables, data gaps exist.</td></tr>
</table>

<table>
<tr><th colspan="2">Water Quality Constituents</th><th>RC Value</th><th>PES Value</th><th>Category/Comment</th></tr>
<tr><td>Inorganic salts (mg/L)</td><td colspan="4">TEACHA was not used for data assessment, as salinity levels not elevated.</td></tr>
<tr><td rowspan="6">Salt ions (mg/L)</td><td>Ca</td><td>37.12</td><td>35.74</td><td rowspan="6">Concentrations similar or lower for the PES.</td></tr>
<tr><td>Cl</td><td>8.22</td><td>7.92</td></tr>
<tr><td>K</td><td>2.32</td><td>1.50</td></tr>
<tr><td>Mg</td><td>17.53</td><td>15.81</td></tr>
<tr><td>Na</td><td>13.84</td><td>8.70</td></tr>
<tr><td>SO_4</td><td>12.61</td><td>13.92</td></tr>
<tr><td rowspan="2">Nutrients (mg/L)</td><td>SRP</td><td>0.031 *</td><td>0.033</td><td>A category</td></tr>
<tr><td>TIN</td><td>0.08</td><td>0.083</td><td>A category</td></tr>
<tr><td rowspan="5">Physical Variables</td><td>pH (5^{th} + 95^{th} %ile)</td><td>7.03 + 8.17</td><td>7.5 + 8.4</td><td>A/B category</td></tr>
<tr><td>Temperature</td><td>-</td><td>-</td><td rowspan="2">No data but no impacts expected.</td></tr>
<tr><td>Dissolved oxygen</td><td>-</td><td>-</td></tr>
<tr><td>Turbidity (NTU)</td><td>Avg: 45 over whole data record, i.e. 1993-2010 (n=214)</td><td>Avg: 28.72
Median: 5.3
95^{th} %ile: 192.6</td><td></td></tr>
<tr><td>Electrical conductivity (mS/m)</td><td>36.2 *</td><td>34.48</td><td>A category. RC shows slightly elevated natural salt levels.</td></tr>
<tr><td rowspan="5">Response variables</td><td>Chl a: periphyton (mg/m^2)</td><td>-</td><td>-</td><td>Benthic algal growth seen on rocks.</td></tr>
<tr><td>Chl a: phytoplankton (µg/L)</td><td>-</td><td>3 (n=1)</td><td>A category</td></tr>
<tr><td>Macroinvertebrates</td><td>ASPT: 6.5
SASS: 123</td><td>ASPT: 81
SASS: 6.2
MIRAI: 77%</td><td>C category</td></tr>
<tr><td>Fish community score</td><td>-</td><td>FRAI: 73%</td><td>C category</td></tr>
<tr><td>Diatoms</td><td>-</td><td>SPI – 11.5 (n=3)</td><td>C category</td></tr>
<tr><td rowspan="5">Toxics</td><td>Fluoride (mg/L)</td><td>0.281</td><td>0.195 (n=63)</td><td>A category</td></tr>
<tr><td>Ammonia (mg/L)</td><td>0.015 **</td><td>0.009</td><td>A category</td></tr>
<tr><td>Aluminium (mg/L)</td><td>0.02 **</td><td>0.159 (n=1)</td><td>D category</td></tr>
<tr><td>Iron (mg/L)</td><td>-</td><td>0.116 (n=1)</td><td>No guideline + insufficient data</td></tr>
<tr><td>Other</td><td>-</td><td>-</td><td>Some impacts expected due to farming-related pesticides and fertilizer use. Diatoms + macroinvertebrates indicate intermittent polluting events.</td></tr>
<tr><td colspan="2">OVERALL SITE CLASSIFICATION</td><td colspan="3">B/C: 81.54% (from PAI model)</td></tr>
</table>

* boundary value for the A category recalibrated - no data
** benchmark value, as no data

C3.4 PAI TABLES

The PAI table for EFR K7 is shown as Table C23. PAI tables for Alternative Ecological Categories are shown as C24 for an improved state, and Table C25 for a degraded state.

Table C23 PAI table for EFR K7

PERENNIAL (Y/N)	y
GEOMORPH ZONE	LOWLAND
WIDTH (m)	>15

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	2.0	NONE SPECIFIED	4.0	70.0		70.0
Water Temperature	0.0	N	3.0	60.0		60.0
Water clarity	1.0	NONE SPECIFIED	3.0	50.0		50.0
Oxygen	0.0	N	3.0	65.0		65.0
Toxics	2.0	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	0.92	MEAN CONF →	3.57			
FINAL PC MODIFICATION RATING	0.92					

P-C RATING BASED ON DEFAULT WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
81.60	B/C
P-C RATING BASED ON ADJUSTED WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
81.54	B/C

Table C24 PAI table for the AEC (IMPROVED) for EFR K7

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	1.0	NONE SPECIFIED	4.0	70.0		70.0
Water Temperature	0.0	N	3.0	60.0		60.0
Water clarity	1.0	NONE SPECIFIED	3.0	50.0		50.0
Oxygen	0.0	N	3.0	65.0		65.0
Toxics	1.0	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	0.55	MEAN CONF →	3.57			
FINAL PC MODIFICATION RATING	0.55					

P-C RATING BASED ON DEFAULT WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
89.00	A/B
P-C RATING BASED ON ADJUSTED WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
89.01	A/B

The following conditions result in an improved state of the river:

- No zero flows
- Improved base flows
- Clear alien vegetation
- Improved land-use management, resulting in improved pesticide and fertilizer use

Table C25 PAI table for the AEC (DEGRADED) for EFR K7

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	5.0	50.0		50.0
Nutrients	3.0	NONE SPECIFIED	4.0	70.0		70.0
Water Temperature	1.5	N	3.0	60.0		60.0
Water clarity	1.5	NONE SPECIFIED	3.0	50.0		50.0
Oxygen	1.5	N	3.0	65.0		65.0
Toxics	3.0	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	1.76	MEAN CONF →	3.57			
FINAL PC MODIFICATION RATING	1.76					

P-C RATING BASED ON DEFAULT WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
64.80	C

P-C RATING BASED ON ADJUSTED WEIGHTS	
P-C CATEGORY %	P-C CATEGORY
64.73	C

The following conditions would result in a more degraded system:

- Higher abstractions for farming and more zero flows
- Increased farming resulting in higher fertilizer and pesticide use, more erosion and potentially more sedimentation.
- More dams in small tributaries, so fewer small floods

C3.5 NOTES

Although nutrient data appear to be low, diatoms indicate some nutrients in the system, probably related to farming activities.

The source of the aluminium shown in the Kraai data (and Caledon River) is also unclear. Aluminium can be mobilised from soils and sediments by both natural weathering and accelerated acidification processes, resulting in detectable, though normally unavailable concentrations in surface waters. Aluminium may also be present due to other sources, such as the following:

- acid mine drainage waters and natural waters affected by acid rain.
- the principal particulate emitted from the combustion of coal, and aluminium fluoride is emitted from aluminium smelters.
- Industries using aluminium in their processes or in their products, e.g. the paper industry, the metal construction industry, the leather industry, and the textile industry.

However, the more likely source of aluminium in the surface water is due to alum or aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids (DWAF, 1996).

C4 EFR M8: UPPER MOLOPO RIVER

C4.1 CATCHMENT CONTEXT

C4.1.1 General

The Molopo River Basin (Nossop River Basin included), which forms part of the northern portion of the Orange-Senqu River Basin, is located in the southern part of Botswana with an area of approximately 71 000 km^2. Molopo and Nossop are the major rivers in the Basin and they form part of the international boundary with the Republic of South Africa. These rivers are ephemeral, flowing occasionally after heavy rainfall events (Heath and Brown, 2007).

The Molopo River was once a tributary of the Orange River system, but has become blocked by high dunes and no longer reaches the Orange River (Midgley *et al*., 1994). It is currently non-perennial as its water is heavily abstracted at source. This river has a number of tributaries which fall within the Province, namely the Ramatlabamaspruit, Setlagolespruit, Ganyesaspruit and Pepanespruit, all of which are non-perennial. The Mathlaawaringspruit, a tributary of the Kuruman River is the most south-westerly drainage line in the Province (NWDACE, 2002).

The Upper Molopo sub-management area is part of the Crocodile (West) Marico WMA. The Molopo River originates at the Molopo Eye (from the Grootfontein dolomitic compartments) and flows westwards towards the border with Botswana. It ceases as a surface water flow and discharges into pans in Botswana before it turns south and emerges again as a surface flow just before it reaches the Orange River.

Water is abstracted directly for Mafikeng, with flow released to the river being used primarily for intensive agriculture. Within Mafikeng, the sewage systems are not functioning properly and the river (which usually does not flow at this stage) receives sewage discharges of poor quality. The desktop PES classification of the system around Mafikeng is an E category (Louw *et al*., 2010). The Kuruman River is also in a poor state due to over-abstraction and canalisation.

Further eyes occur further down the system, with water diverted into canal systems for supplying Slurry and agricultural activities. Various small dams occur with the Modimole Dam just downstream of Mafikeng and the Dinoseng Dam further down. The river seldom flows in these reaches. Tributaries from Botswana are in a much better state as there is limited development due to their ephemeral nature.

C4.1.2 Molopo wetland

The Molopo wetland lies in a dolomite-driven system on the Highveld and plays a significant role in improving water quality, partly due to the presence of deep peat deposits. Peat enhances the ability of wetlands to remove toxicants, improve water quality and store water. The Molopo wetland is threatened by the following activities which also impact on water quality state (WFW, 200?; RHP, 2005):

- Water diversion and abstraction. The wetland has been modified by drainage channels and canalisation, resulting in desiccation of a large section of the wetland.
- Desiccation has resulted in encroachment of terrestrial and invasive alien plant species.
- Overgrazing due to subsistence grazing.
- Sand mining, which contributes to severe soil erosion in the wetland area and its

catchment.

- High nutrient and toxicant loads due to agricultural activities in the catchment.
- Poor sanitation and sewage return flows in the catchment, including lack of solid waste management.
- Mining and cement industries in the catchment.
- Altered flow patterns of water entering the wetland due to an upstream dam and cultivated fields – the wetland now dries out during low flow periods.
- Dams have resulted in reduced sediment loads entering the wetland in the water, resulting in erosion of the wetland.

Note that most of the above-mentioned impacts are experienced below the reach being assessed during the EFR study. Impacts directly relevant to the EFR site, and the section of impacted reach it represents, are as follows (Roux, 2005; Kotzé, 2010):

- Historical spraying of toxic pesticides for control of *Quelea quelea* (last known spraying is 2006/2007 although reeds currently showing evidence of spraying).
- Septic tanks resulting in increased nutrients.
- Spillage of chemicals during construction activities and maintenance of properties around the eye.
- Farming activities in the area.

C4.1.3 Groundwater

The lowest groundwater level is found in the south-western part of South Africa, along the Molopo River's course as it moves out of the basin to the Orange River. In this part of the basin and also up in the southern part of Botswana, the groundwater gradient is less than 0.05%.

The source of the Molopo River is a unique dolomitic eye (springs) and associated wetland system. Dolomitic eyes are of great conservation significance as they are biologically unique. The groundwater linkages in the aquifer systems contribute to the sensitivity of the dolomitic eyes as groundwater abstraction kilometers away can reduce the water levels at the dolomitic eyes (Roux, 2005).

C4.2 AVAILABLE DATA/DATA CONFIDENCE

There are no gauging stations along the Molopo River. Although the focus of this study is on the wetland area in the upper Molopo catchment (MRU A), there is no physico-chemical data available for an assessment.

A single water quality data point has been reported for the unimpacted Boovensteoog spring on the Mooi River system in the North West Province, which is also a dolomitic eye similar to the Molopo (Table 5.1). As this, and EFR site M8, are located in geomorphologically similar dolomite-driven landscapes, Bovensteoog was considered to be a suitable proxy for Reference Condition for the Molopo wetland, which is underlain by groundwater emerging as springs from a dolomitic geology. The diatom SPI indicates Very good water quality.

Table C26 Water quality and diatom data for Bovensteoog (supplied by J. Taylor, NWU)

Sampling date M/D/Y	Temperature	Electrical conductivity	pH	Dissolved Oxygen	SPI
05/13/2008	20.37	44.4	7.37	7.2	18.3

The following data for selected variables were sourced from the 2002 State of Environment (SOE) Report for the North West Province for reservoirs in the area, i.e. Disaneng Dam downstream of Mafikeng and Cooke's Lake between EFR M8 and Mafikeng (see Figure C3), in the Mafikeng Game Reserve (NWDACE, 2002) (Table C27).

Table C27 Water quality data for reservoirs in the Mafikeng area (Source: DWAF HIS QualDB)

Variable (mg/L)	D4H026Q01: Cooke's Lake (Molopo)	D4R003Q01: Disaneng Dam
TDS	595	354.4
EC (calculated)	88.8	52.9
SO_4	38.8	16.4
F	0.16	0.33
Cl	52.5	25.8
TAL	304.2	184.4
Na	29.1	31.3
Mg	3.3	6.27
Ca	53.4	23.5
K	55	24.3

The data in Table C27 presents a summary for the period 1990 to 2000. Although this information provides an overview of quality in the reservoirs, the water within these impoundments will differ in quality from both upstream and downstream conditions, particularly in terms of temperature, dissolved oxygen, nutrients and sediments. As the site under investigation is a wetland upstream of Mafikeng, the data for Cooke's Lake may provide some representation of wetland conditions.

The calculated EC assumes standard organics levels, which is obviously not representative of a wetland, so EC values on Table C27 are merely an estimate.

Figure C3 The position of Cooke's Lake in relation to EFR M8 and Mafikeng

The major pollution sources to the Molopo system listed in the SOE report (NWDACE, 2002) for the Molopo River is treated and untreated domestic sewage, which would primarily result in elevated nutrient levels. The dominant salinisation source is listed as the geology of the area, i.e. natural salinisation. Although algal scums had not yet formed on Cooke's Lake as at 2002, the potential for toxic incidences in this dam has been acknowledged. Note that this information is provided as context, as the reach under consideration is some distance upstream of Cooke's Lake and Mafikeng.

The geomorphologist for the study has run a Wetland Index of Habitat Integrity (IHI) assessment, which includes a physico-chemical component (Rountree, 2010). The approach for water quality was to use this as a basis for the water quality assessment, and modify the water quality component of the wetland IHI as required. The modified and updated Wetland IHI indicates that the PES of this valley bottom wetland is a D category, with water quality being a **B category**. Disturbances on the wetland surface – thought to be from peat mining – and reduced flows have had an impact upon wetland condition.

The diatom assessment for the Molopo wetland was based on samples collected from EFR site M8 during April 2010 at three sampling sites. Data showed good high SPI scores indicating Very good water quality (i.e. an A/B category). Oxygen levels were high and nutrient and organic levels were low. However, confidence in the assessment is low as no seasonal data were available. The major impact in this river is Mafikeng and the river is critically impacted in MRU C, with diatom data indicating a D category. Although conditions seem to improve slightly below Modimole Dam, the overall diatom assessment remains a D category (Koekemoer, 2010).

C4.3 WATER QUALITY ASSESSMENT

The water quality assessment shown in the table extracted from the Wetland IHI in Table C28 is for the reach containing the wetland and EFR M8, i.e. MRU A. Mafikeng is in MRU C and Modimole Dam in MRU D.

Table C28 Water quality assessment for EFR M8, i.e. the Molopo wetland, from the Wetland IHI

CONSIDER THE IMPACT OF THESE ACTIVITIES ON WATER QUALITY:

Water Quality Components	Modified flow conditions	Inundation: Weirs	Inundation: Dams	Effluent: Urban areas	Effluent: Cultivation (agricultural activities; return flows)	Effluent: Industries	Effluent: Mining	Instream plants (macrophytes) & algae (incl. blue-green)	Forestry	Roads & crossings	Invasive riparian vegetation	Riparian vegetation removal	Bed disturbance: Bull dozing, sand mining, etc.	Bank disturbance: vegetation removal, artificial covering.	Solid waste disposal (rubbish disposal)	AVERAGE	MEDIAN	MODE	RATING (use avg, median or mode)
pH	X	X	X							X		X	X	X	X	#DIV/0!	#NUM!	#N/A	0.0
Salts								X	X	X	X	X	X	X	X	#DIV/0!	#NUM!	#N/A	0.0
Nutrients									X	X	X		X	X	X	#DIV/0!	#NUM!	#N/A	1.0
Water Temp.					X				X	X			X	X	X	#DIV/0!	#NUM!	#N/A	0.5
Turbidity															X	#DIV/0!	#NUM!	#N/A	1.0
Oxygen									X	X	X	X	X	X		#DIV/0!	#NUM!	#N/A	0.5
Toxics	X	X	X						X		X	X	X	X		#DIV/0!	#NUM!	#N/A	2.0

Water Quality	RATING		Weighting	Confidence (1-5)
pH	0.0	0	100	1
Salts	0.0	0	50	2
Nutrients	1.0	0.167	50	2
Water Temp.	1.0	0.033	10	2
Turbidity	0.0	0	10	2
Oxygen	0.5	0.017	10	1
Toxics	2.0	0.467	70	3

Water Quality: overall scores			
Rating:	0.7	*Confidence:*	*1.9*
Percentage:	86.3		
PES Category:	B		

Notes

Changed the weightings of salts from 70 to 50, and toxics from 50 to 70. Note that this assessment is evaluating the lower impacted end of the site.

The land-use impact sheet recently developed for use as a water quality tool for wetland Rapid Reserve assessments (Malan *et al*., 2010), was completed with the assistance of workshop participants during September 2010 (see Table C29). The PES category was defined as an A category according to this method. Cautions with the use of this spreadsheet in this instance is that it is designed to assess catchment-wide activities, while the current assessment for EFR M8 is restricted to the zone around the wetland. Impacting activities such as pesticide spraying should therefore score higher than shown in Table C29. The water quality component of the Wetland IHI, i.e. a B category, was therefore considered to be a more accurate assessment of the water quality state of the Molopo wetland, despite this PAI model approach (on which the water quality sheet of the Wetland IHI is based) being designed specifically for rivers.

Table C29 Assessment of water quality for EFR M8 using land-use impact sheet

ASSESSMENT OF PES WATER QUALITY USING LANDUSE																
WETLAND NAME:	**Molopo**															
DATE:	**08-Sep-10**															
ASSESSOR:	**P-A Scherman, D Louw, H Roux**															
			Contaminants default scores (change if data available)													
		pH	**SALTS**					**Sediments**		**TOXICS** (All toxins score equally. Max impact score = 5)						
	Landuse (in wetland and catchment)	**pH**	**SO4**	**K**	**NaCl**	**P**	**N**	**Clastic**	**Organic**		**SUM OF IMPACT RATING SCORES**	**Adjusted for weighting**	**Default ratings**	**% AREA (MAJOR LANDUSES ONLY)**	**AREA WEIGHTED SCORES**	**RATING**
Infrastructure	Housing (sewered)					2	2	2	1	1	8	14	2	5	10	0.1
	Housing (unsewered)					4	4	2	4	3	17	29	3	0	0	0
	Industrial (or mixed industrial/residential)		3	5	5	5	5	1	5	5	34	49	5	0	0	0
															0	0
Agriculture	Non-irrigated croplands					4	1	4		2	11	20	2	5	10	0.1
	Irrigated croplands				2	3	2	3		2	12	20	2	0	0	0
	Non-irrigated pasture			1	1	3	1	4		1	11	18	2	10	20	0.2
	Irrigated pasture			2	1	4	1	4		1	13	22	3	0	0	0
															0	0
Commercial plantations	Commercial plantations					3		3		1	7	13	2	0	0	0
	Dense alien trees/shrubs					3		2			5	11	2	0	0	0
Natural vegetation	Natural vegetation (and low-intensity grazing)					1		0			1	3	0	75	0	0
															0	0
Other	Sports fields					1	2	2			5	9	1	0	0	0
	Gardens					1	2	2			5	9	1	5	5	0.05
															0	0
																0.45
												TOTAL AREA (MUST EQUAL 100%)		**100**		**A**

TENTATIVE PES CATEGORY

ADJUSTMENT OF PES CATEGORY	YES/NO?	ALTERED RATING SCORE
1. Is the wetland well-buffered by natural vegetation? Then **improve** PES score by 1 category	YES	-0.55
2. Are there point-sources of pollutants discharging directly into the wetland or immediately upstream? Then **lower** PES score by 1 category	YES	0.45
3. If there is mining or power generation activity in the catchment, **lower** PES score by half a category	NO	0.45
3. Is there intensive agriculture within the wetland itself? Then **lower** PES score by 1 category	NO	0.45
4. Has flow been significantly altered from natural? Then **lower** PES score by half a category	YES	0.95
5. Is the areal extent of urban landuse > 50% of catchment? Then **lower** PES score by 1 category	NO	0.95
PES SCORE		0.95
PES CATEGORY		**A**

Lookup table

0.00	**A**
1.00	**B**
2.00	**C**
3.00	**D**
4.00	**E**
5.00	**F**
	YES
	NO

NOTES

NB: Vegetation, e.g. Typha, is very prolific around the wetland + serves to clear any nutrients due to cattle + horses in the area.
There is also damming related to the road crossing.
Water is overlain by reeds, but still 1-2m deep water below reeds.

C5 ORANGE RIVER

C5.1 INTRODUCTION

The information below covers the following steps per EFR site for the Orange River.

- Catchment context, particularly as it pertains to water quality.
- Available data / data confidence.
- Data assessment + PAI tables.

The methods and approach are not detailed in this document, but followed that outlined in DWAF (2008).

C5.2 DELINEATION AND EFR SITES

Information per EFR site in the Orange River study area is shown on Table C30 below.

Table C30 Details of EFR sites for the Orange River

EFR site number	EFR site name	River	EcoRegion (Level II)	Geomorphic zone	Altitude (m)	MRU	Quat	Gauge
EFR O1	Hopetown	Orange	26.01	Lowland	1060	MRU Orange B	D33G	
EFR O2	Boegoeberg	Orange	26.05	Lowland	871	MRU Orange D, RAU D.1	D73C	D7H008
EFR O3	Augrabies	Orange	28.01	Lowland		MRU Orange E	D81B	D7H014
EFR O4	Vioolsdrif	Orange	28.01	Lowland	167	MRU Orange F	D82F	D8H003 D8H013

Information regarding delineation and selected EFR sites is taken from the July 2010 Resource Unit report produced for the study (i.e. Louw, 2010). The study area is defined as that area stretching below Gariep Dam on the Orange River to the river mouth at the sea. The straight line distance from the Van der Kloof Dam to the Orange River Mouth is approximately 600 km, while the river length itself is 1 400 km. All EFR sites (Table C30) are situated in this 600 km stretch.

The following main areas have been defined for this report:

- Senqu River: information on the Senqu system is provided for context only.
- Upper Orange River (from the Lesotho border to the confluence with the Vaal River), i.e. containing the stretch of the Orange River between Gariep and Van der Kloof dams (and EFR 01 downstream of the Van der Kloof Dam).
- Vaal River system.
- Lower Orange River (from the Orange-Vaal confluence to the sea).

Figure C4 below shows the position of gauging weirs and EFR sites at an EcoRegional level. This is most relevant to the water quality study as monitoring points representing sites should preferentially be in the same Level II EcoRegion.

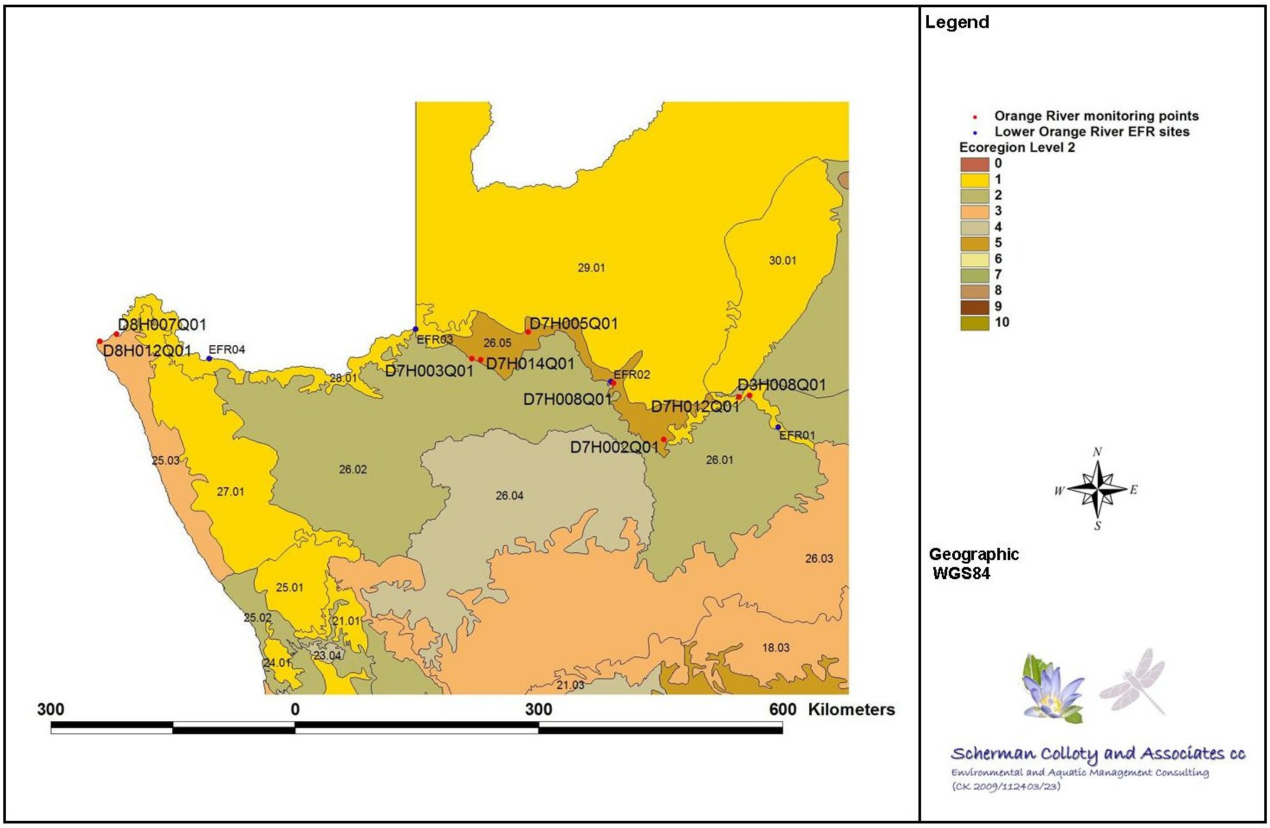

Figure C4 Map of the Orange River study area showing EFR sites, gauging weirs and Level II EcoRegions

C6 SENQU RIVER

This section provides contextual information for the Upper Orange River within the borders of Lesotho. The runoff from the Lesotho Lowlands drains to the west to the Caledon River while the highlands drain to the south via the Senqu River to the Orange River.

A summary of the present status of water quality monitoring in the Orange-Senqu River Basin was recently carried out by the UNDP/GEF in their preliminary Transboundary Diagnostic Analysis. This information was cited in a draft document on monitoring resource quality in the Orange-Senqu River Basin (ORASECOM, November 2009, draft document), and states the following:

- Water in the main stem of the Senqu River in Lesotho is generally of good quality although increased turbidity is increasing due to agricultural activities, particularly in the Lesotho Lowlands which drains to the Caledon River.
- Water originating in the high rainfall area of Lesotho is generally of low salt concentration.
- Eutrophication and microbial pollution are the primary water quality issues, which have been caused by rapid demographic changes to the Lesotho Lowlands coupled with inadequate sewage infrastructure.

Results of “fitness for use” maps prepared by ORASECOM member states are shown in Table C31 for various users of the Senqu River or Lesotho Highlands (ORASECOM, 2009). Suitability for use was designated according to the following categories, and using the domestic water quality guidelines available per member state, and the South African water quality guidelines for other users:

- No problems detected from the data
- Tolerable
- Poor
- Not suitable

Assessments were based on a worst case basis, i.e. the overall assessment of suitability for use was based on the variable(s) that showed the poorest quality water. The assessment was not based on water quality at a single point, but that an overview of the suitability of the water in the whole sub-basin.

Table C31 Fitness for use for selected surface water areas of the Lesotho Highlands

User category	Lesotho Highlands
Agriculture/irrigation (crops)	Not suitable
Agriculture Livestock	Good
Domestic	Poor
Industrial	Poor
Recreational	Good

C7 UPPER ORANGE RIVER

C7.1 CATCHMENT CONTEXT

The Upper Orange River can be defined as that part of the system from the Lesotho border to above the Orange-Vaal confluence.

The two major river systems that drain the Upper Orange Water Management Area (WMA) are the Modder-Riet and the Orange River. Bloemfontein and Thaba 'Nchu are the main urban and industrial development areas in the Upper Orange WMA, with two large hydropower stations at Gariep and Vanderkloof dams (impounded during 1970 and 1976 respectively (Hart, 1985)). Mining activities have significantly declined and currently mainly relate to salt works and small diamond mining operations. The largest land use in the catchment is agriculture, with 80% of the water requirements in the Upper Orange WMA being for agriculture (ORASECOM, 2007).

The areas of the system particularly relevant to this study are below Gariep Dam to the confluence with the Vaal River.

C7.2 WATER QUALITY SUMMARY

In general, the salinity of the water in the Orange River has always been relatively low. The reason for this lies in the fact that most of the water originates in the high rainfall area of Lesotho, where the geology is such that the water is generally of low salt concentration. With the implementation of the Lesotho Highlands Water Project, substantial volumes of this low salinity water will be diverted to the Vaal River Catchment. This means that the dilution effect of water from Lesotho will be diminished, which will lead to increased salt levels in the Gariep and Vanderkloof dams.

The following comments regarding water quality of the Upper Orange River were made in a 2009 summary on *Orange River Water Quality Status* (Golder Associates, 2009).

- The water quality and quantity in the uppermost reaches of the Orange River, above Gariep Dam, is still in a fairly natural state and show minor changes over the past 35 years.
- The water in the uppermost reach is moderately soft, relatively low in salt concentrations, but generally high in suspended solids and turbidity.
- The water quality in the Upper Orange River is suitable for domestic use, recreational use and irrigation with low Total Dissolved Solids (TDS) and low Sodium Adsorption Ratio (SAR).
- The concentration of Total Suspended Solids (TSS) and turbidity in the Upper Orange River are high because of soil erosion, but fluctuate seasonally.

This assessment was supported by the analyses of diatom data (limited samples for 2005, 2009-2010) for the study (Koekemoer: diatom specialist), which indicated that the upper tributaries of the Orange River are in a good condition, although nutrient input from farming was elevated at times. Overall estimates for the diatoms of the Upper Orange above Gariep Dam, was a C category.

A study in 1985 by Hart showed that physico-chemistry stayed quite stable due to the influence of the two upstream impoundments, except for temperature, which still showed seasonal fluctuations. Seasonal fluctuations in other variables were severely depressed (Hart, 1985).

Results of “fitness for use” maps prepared by ORASECOM member states are shown in Table C32 for various users of the Upper Orange River (ORASECOM, 2009).

Table C32 Fitness for use for selected surface water areas of the Orange-Senqu River system

User category	Lesotho Highlands
Agriculture/irrigation (crops)	Good
Agriculture Livestock	Good
Domestic	Poor
Industrial	Poor
Recreational	Good

C7.3 EFR O1: HOPETOWN

C7.3.1 Data availability/confidence

The PES for geomorphology is a C/D category (Rountree, 2010). Although the flows are critically reduced at the site due the large upstream dams, this has been compensated for in some ways by the reduced sediment loads (since much is trapped in upstream dams). The increased expansion of bars and islands (rather than erosion) suggests that the decreased transport potential (due to reduced flows) has been more critical than the reduced sediment supply (due to trapping in upstream dams) in forming habitats.

Data for physico-chemical variables registered on DWA’s Water Management System (WMS) are shown in Table C33.

Table C33 WMS data available for the Upper Orange River, i.e. upstream Orange/Vaal confluence

Monitoring point name	River	Latitude	Longitude	Quaternary catchment	Number of samples	First sample date	Last sample date
D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER	ORANGE	-29.16167	23.696389	D33K	1 546	1966/03/29	2010/04/28

Diatom data indicate a B category for reach 3 of MRU B, which contains EFR O1, with primary impacts being elevated salts and nutrients due to farming activities. Fluctuating flows probably have an impact on diatom population structure. Data for the entire MRU is a C category, due to the influence of reach 4 where the Vaal River enters the system (Koekemoer, 2010).

C7.3.2 Data assessment

Table C34 shows the data assessment information for EFR O1, followed by the PAI table in Section C7.3.3. SASS data are from this study (Palmer, 2010). Note that average salt ion and other concentration values were taken from Koekemoer (2010) where data not available from WMS.

Table C34 Water quality data assessment for reach containing EFR O1, MRU B

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**	
		RC	Orange River @ Marksdrift (D33K; EcoRegion II: 26.01) D3H008Q01 (1966 – 1978; n=51)
EFR SITE	EFR O1 (D33G; EcoRegion II: 26.01)	**PES**	1) Orange River @ Marksdrift (D33K; EcoRegion II: 26.01) D3H008Q01 (2000 – 2010; n=414-427) 2) Data from diatom sample collection in 2008 (n=2)
Confidence assessment	Moderate - High confidence. Although sufficient data, particularly for the present state, data gaps exist, e.g. metal ions, pesticides, herbicides. Water quality and EFR site in the same EcoRegion level II.		

Water Quality Constituents		RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not significantly elevated.			
Salt ions (mg/L)	Ca	29.75	24.74	Concentrations similar for the PES, except for sulphate, sodium and chloride which show increases from the RC.
	Cl	9.96	12.98	
	K	1.80	1.79	
	Mg	11.00	10.24	
	Na	10.80	13.75	
	SO_4	11.00	19.94	
Nutrients (mg/L)	SRP	0.014 *	0.020	A category
	TIN	0.15	0.38	B category
Physical Variables	pH (5^{th} + 95^{th} %ile)	6.93 + 8.02	7.64 + 8.34	A/B category
	Temperature	-	Two upstream dams result in large fluctuations in temp + DO.	No data. C – D category (qualitative assessment)
	Dissolved oxygen	-		
	Turbidity (NTU)	-	**WMS data:** Avg: 17.62 95^{th} %ile: 51.2 **Koekemoer (2010):** 21.85 (avg)	No RC data. Turbidity from system that naturally carries sediments, although trapped in dams. A/B category (qualitative assessment).
	Electrical conductivity (mS/m)	28.36 (n=79)	28.88	A category
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 17.5 (n=2) (Koekemoer, 2010)	C category
	Macroinvertebrates	ASPT:6.6 SASS: 179	ASPT: 6.1 SASS: 128 MIRAI: 72.8%	C category (Palmer, 2010)
	Fish community score		FRAI: 57.6%	C/D category (Kotzé, 2010)
	Diatoms	-	EFR O1: 15.7. Marksdrift: 14.4 (avg SPI)	B category
Toxics	Fluoride (mg/L)	1.5 **	0.31	A category
	Aluminium (mg/L)	0.02 **	0.221 (n=2) (Koekemoer, 2010)	E category
	Iron (mg/L)	-	0.143 (n=2) (Koekemoer, 2010)	No guideline + insufficient data
	Ammonia (mg/L)	0.002	0.01	A category
	Other	-	-	Impacts expected due to farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION		**C: 67.25% - from PAI model, if override on temperature not in place E/F: 20% - from PAI model, if override on temperature in place D – final category based on expert judgement and hydrology (E)**		

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

C7.3.3 PAI table

The PAI table for the Upper Orange River at EFR 01 is shown as Table C35. Note that two final values are shown:

- Category C: 67.25% - from PAI model, if override on temperature not in place.
- Category E/F: 20% - from PAI model, if override on temperature in place.
- Category D – final category using judgement and hydrology rating (E category).

Although biotic indicators suggest that a category C situation exists, instream dams have large impacts on water quality in terms of changing conditions from the reference state, particularly for temperature. Seasonal fluctuations have been severely impacted on, so that although overall present state for water quality seems acceptable, changes from the natural state have been severe.

Table C35 PAI table for EFR 01, MRU B

PERENNIAL (Y/N)	y
GEOMORPH ZONE	LOWLAND
WIDTH (m)	>15

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	4.0	50.0		50.0
Nutrients	1.5	NONE SPECIFIED	3.0	70.0		70.0
Water Temperature	4.0	N	3.0	60.0		60.0
Water clarity	0.5	NONE SPECIFIED	4.0	50.0		50.0
Oxygen	3.0	N	3.0	65.0		65.0
Toxics	1.5	N	2.5	100.0		100.0
CALCULATED PC MODIFICATION RATING	4.00	MEAN CONF →	3.36			
FINAL PC MODIFICATION RATING	4.00					
P-C RATING BASED ON DEFAULT WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
20.00	E/F					
P-C RATING BASED ON ADJUSTED WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
67.25	C					

Elevated nutrients from farming impact on the water quality assessment. Aluminium levels are high, although this assessment is based on very limited data. The most likely source of aluminium in the surface water is due to alum or aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids, or aluminium loads carried in suspended solids. However, sediment loads are low due to the upstream dams. Temperature impacts due to the presence of instream dams are significant (Hart, 1985).

C8 VAAL RIVER

C8.1 CATCHMENT CONTEXT

The Vaal River system can be considered part of the upper section of the Orange River basin as it is above the Orange-Vaal confluence. Although information is drawn from a number of texts, data analyses and PAI tables for the lower section of the Vaal, i.e. just above the confluence, are taken from the Comprehensive Reserve Determination currently being completed for the Lower Vaal River by Golder Associates.

There are many large urban (e.g. Johannesburg) and industrial centres and gold tailings dams located on the east and west Rand. The water quality in these areas are impacted on by discharges from the gold mines, seepages from the tailings dams, discharges from industry directly to the river, urban runoff and discharges from the large number of sewage treatment plants located in the urban areas. The return flows from these sewage treatment plants have resulted in the flows in many of the river systems exceeding the natural flows. Coal mining is located in the Waterval and Grootdraai Dam catchments in the upper reaches of the Vaal River, along the banks of the Vaal Barrage below Vaal Dam (ORASECOM, 2007).

Although the Middle Vaal is less urbanized, discharges from mining operations and sewage treatment facilities still predominate. The predominant land use in the Lower Vaal is agriculture, with extensive irrigation schemes located on the Vaal River and along the Harts River (ORASECOM, 2007).

C8.2 WATER QUALITY SUMMARY

The following information was taken from a recent draft document on monitoring resource quality in the Orange-Senqu River Basin (ORASECOM, November 2009, draft document).

A summary of the present status of water quality monitoring in the Orange-Senqu River Basin was recently carried out by the UNDP/GEF in their preliminary Transboundary Diagnostic Analysis. The findings of this study are summarised below for water quality of the Vaal catchment.

- The usage of water in the Vaal River is impacted by high levels of salinity and related macro-ions, which has major implications for domestic, industrial and agricultural water use.
- Eutrophication is a key issue in the Vaal River resulting in algal blooms and growth of water hyacinth.
- Microbiological pollution is an emerging concern.
- While sections of the upper part of the Vaal catchment has water of a good quality, the areas of concern include the Vaal Barrage and Lower Vaal River downstream of Harts River confluence.
- Elevated TDS concentrations are a concern for users downstream of the Vaal Barrage.

The following additional points are found in the water quality report of ORASECOM (2007):

- Discharges from coal and gold mining, industrial discharges and decant from mines post closure, cause water quality problems in the Vaal system.
- The common water quality variables of concern are elevated salinities generally represented by EC, sulphate in the mining areas and nutrients as they relate to eutrophication. The algae resulting from eutrophication has led to odour and colour

problems in the intake water to water treatment plants which are not geared for dealing with eutrophic waters.

- Along the main stem of the Vaal organics has been raised as an issue by the water boards, with monitoring programmes identifying increases in Dissolved Organic Carbon (DOC) in raw intake water to the water treatment plants. This gives concerns regarding disinfection technologies used as the traditional chlorine disinfection can give rise to trihalomethanes if excessive organics are present in the intake water.

Results of "fitness for use" maps prepared by ORASECOM member states are shown in Table C36 for various users of the Lower Vaal River (ORASECOM, 2009).

Table C36 Fitness for use for selected surface water areas of the Lower Vaal River system

User category	Lower Vaal
Agriculture Livestock	Not suitable
Domestic	Poor
Industrial	Good
Recreational	Not suitable

C8.2.1 Available data/data confidence

Available information is considered of high confidence as it results from the Comprehensive Reserve study currently being completed. The two Ecological Water Requirements (EWR) sites considered here are EWR7 on the Lower Vaal River below Schmidtsdrift Weir, and EWR8 on the Riet River. Figure 5.1 shows the proximity of the two sites to the Orange-Vaal confluence. Table 5.2 provides information on the two EWR sites. All information is taken from Heath and Moodley (2009). Water quality state represented by these sites is then considered as input water to the Upper Orange River.

Figure C5 Google Earth image showing EWR 7 and 8 on the Lower Vaal system

Table C37 Information for EWR7 and 8 on the Lower Vaal and Riet rivers respectively

EWR site no., name + river	GPS co-ordinates	Quaternary catchment	Closest gauging weir	Comments
EWR 7: Schmidtsdrift; Vaal River	28°42'27.29" S 24°04'32.81" E	C92B	C9H024	High salinities; low nutrients
EWR 8: Lilydale Lodge; Riet River	29°02'18.3" S 24°30'10.2" E	C51L	C5H048	Extremely high salinities; moderate – high nutrients
Reference site: VS2 Vaal River at R29/N2 bridge at Camden; Vaal River	-	(Upper Vaal) C11B	-	WQSU 1: No upstream impacts

- information not available

C8.2.2 Data assessment

These tables, Table C38 for EWR 7 on the Vaal River, and Table C39 for EWR 8 on the Riet River, are taken direly from Heath and Moodley (2009).

Table C38 Water quality data assessment for EWR 7 on the Lower Vaal River

River	Vaal		**DWA Water Quality Monitoring points**	
WQSU			**RC**	VS2 Vaal River at R29/N2 bridge at Camden (GDDC10)
EWR Site	7		**PES**	C9H024Q01 1995 – 2008 (*n* = 163)
Water Quality Constituents			**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		259	E
	Na_2SO_4		139	E
	$MgCl_2$		20.9	B
	$CaCl_2$		91.3	D
	NaCl		170	B
	$CaSO_4$		0.73	A
Electrical conductivity	EC (ms/m)		77.4	C
Nutrients (mg/L)	SRP		0.06	B
	TIN		0.007	A
Physical variables	pH (pH units)		7.80 -8.62	A
	Temperature (º C)		20	
	Dissolved oxygen (mg/L)		3.4	
	Turbidity (NTU)			
Response variable	Chl-a: (ug/L) Phaeophyte			
	Biotic community composition -macroinvertebrate (ASPT) score		4	D/E
	In-stream toxicity (Daphnia survival percentage)			A
	Diatoms		13.1	B
Toxics	Fluoride (mg/L)		0.54	A
	Ammonia (mg/L)		0.092	B/C
Overall site classification (estimate)			**C**	

Table C39 Water quality data assessment for EWR 8 on the Riet River

River	Vaal		**DWAF Water Quality Monitoring points**	
WQSU			**RC**	VS2 Vaal River at R29/N2 bridge at Camden (GDDC10)
EWR Site	8		**PES**	C5H048Q01 1990 – 2008 (*n* = 789)
Water Quality Constituents			**Value**	**Category / Comment**
Inorganic salts (mg/L)	$MgSO_4$		347	E
	Na_2SO_4		167	E
	$MgCl_2$		91.4	E
	$CaCl_2$		152	E
	NaCl		490	E

	$CaSO_4$	0.54	A
Electrical conductivity	EC (ms/m)	124	D
Nutrients (mg/L)	SRP	0.02	B
	TIN	0.95	B
Physical variables	pH (pH units)	8.00 – 8.61	A
	Temperature (° C)	19	
	Dissolved oxygen (mg/L)	5.4	
	Turbidity (NTU)		
Response variable	Chl-a: (ug/L) Phaeophyte (ug/L)		
	Biotic community composition -macroinvertebrate (ASPT) score	5.3	B/C
	In-stream toxicity (Daphnia survival %)		B/C
	Diatoms	SPI: 8.9	C/D (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.48	A
	Ammonia (mg/L)	0.12	C/D
Overall site classification (estimate)		**D**	

C8.3 PAI tables

Tables C40 and C41 show the PAI tables for EWR sites 7 and 8 respectively.

Table C40 PAI table for EWR 7

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**LOWLAND**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.50	N	2.00	60.00		60.00
Salts	3.50	NONE SPECIFIED	2.00	50.00		80.00
Nutrients	2.00	NONE SPECIFIED	2.00	70.00		80.00
Water Temperature	0.50	N	2.00	60.00		40.00
Water clarity	0.50	NONE SPECIFIED	2.00	50.00		40.00
Oxygen	0.50	N	2.00	65.00		40.00
Toxics	2.50	N	2.00	100.00		100.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	1.50	MEAN CONF →	2.00			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	1.50					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	1.77					
FINAL PC MODIFICATION RATING	1.20					
P-C CATEGORY %	P-C CATEGORY					
76.00	C					

Table C41 PAI table for EWR 8

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**LOWLAND**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.50	N	4.00	60.00		50.00
Salts	5.00	NONE SPECIFIED	4.00	50.00		90.00
Nutrients	4.00	NONE SPECIFIED	4.00	70.00		90.00
Water Temperature	1.00	N	4.00	60.00		35.00
Water clarity	0.50	NONE SPECIFIED	4.00	50.00		35.00
Oxygen	1.00	N	4.00	65.00		35.00
Toxics	2.50	N	4.00	100.00		100.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	2.11	MEAN CONF →	4.00			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	2.11					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	2.70					
FINAL PC MODIFICATION RATING	2.11					
P-C CATEGORY %	P-C CATEGORY					
57.80	D					

C9 LOWER ORANGE RIVER

C9.1 CATCHMENT CONTEXT

The Lower Orange River can be defined as that stretch of the Orange River between the Orange-Vaal confluence and Alexander Bay or Oranjemund where the river meets the ocean (Figure C6). The area is hot and dry with rainfall varying from 400mm in the east to 50mm on the west coast and large parts of the catchment considered desert with annual precipitation dropping to below 25mm in some areas. The major river systems that contribute to flows in the Orange River include the Ongers and Sak rivers from the northern Karoo; the Kuruman and Molopo rivers from the Northern Cape Province, north of the Orange and the southern part of Botswana; and the Fish River from Namibia (ORASECOM, 2007).

Land-use is primarily irrigation and mining, with the area highly dependent on water from the Orange River. Sheep and goat farming is practised over most of the area, with large parts falling within conservation areas. Cultivation is restricted to isolated patches where somewhat higher rainfall occurs, and extensive irrigation is practised in the fertile alluvial soils along the Orange River valley. This irrigation is supplied with releases from the Vanderkloof Dam. Large mining operations occur in various parts areas. The water quality in the Lower Orange WMA is affected by upstream activities in the Vaal and Orange River catchments. Given the arid nature of the Lower Orange River and the high potential evaporation, the evaporative losses result in an increase in concentrations along the length of the lower Orange River (ORASECOM, 2007).

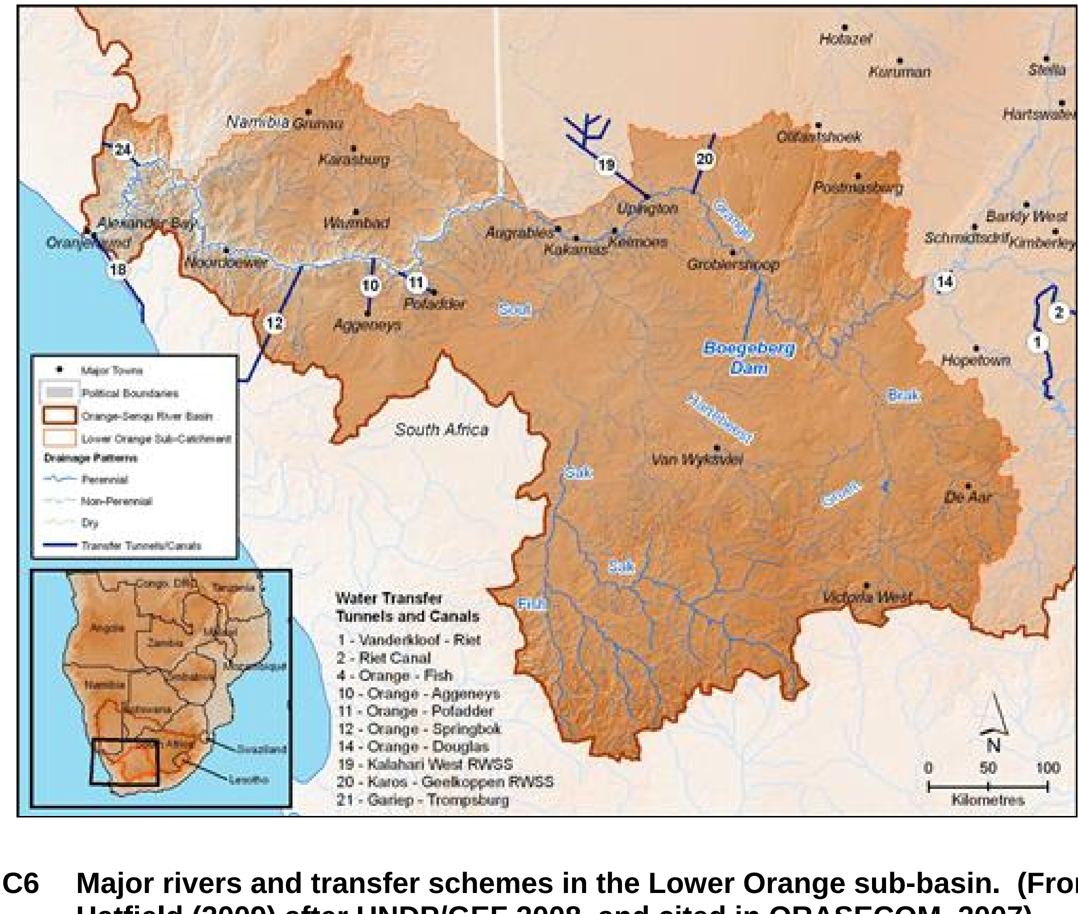

Figure C6 Major rivers and transfer schemes in the Lower Orange sub-basin. (From Hatfield (2009) after UNDP/GEF 2008, and cited in ORASECOM, 2007)

C9.2 WATER QUALITY SUMMARY

The following information was taken from a recent draft document on monitoring resource quality in the Orange-Senqu River Basin (ORASECOM, November 2009, draft document).

A summary of the present status of water quality monitoring in the Orange-Senqu River Basin was recently carried out by the UNDP/GEF in their preliminary Transboundary Diagnostic Analysis. The findings of this study for the water quality of the Lower Orange River are summarised below:

- Water quality between Boegoeberg and Onseepkans is generally good despite extensive irrigation and settlements in the Upington area.
- The salinity deteriorates downstream of the confluence of the Vaal and Orange rivers but still remains good. There is an increase in EC from Prieska to Vioolsdrift along the reaches of the lower Orange River. This is due to irrigation return flows and evaporative losses along the river.
- Eutrophication is evident in localised areas along the Lower Orange River. A DWAF study in 2000 noted high organic matter content in the Orange River, as indicated by the overwhelming abundance of filter-feeding invertebrates downstream of the Orange-Vaal confluence (Chutter *et al.*, 1995; cited in WCD, 2000). Major factors that would contribute organic matter to the system are likely to be decay of reeds, coupled to phyto- and zooplankton injection from the reservoirs.
- Water quality downstream of Onseepkans remains good although salinity increases are observed towards the mouth of the Orange River due to increasing aridity, evaporation and tidal influences.
- The flushing of salts that are built up in the soils may occur during high flows.
- The return flows from the irrigation areas contribute salinity and nutrients to the Orange River (ORASECOM, 2007).

It was noted with concern during the *Orange River Replanning Study* (ORRS) (DWAF, 1998) that there was a decrease in salt load down the river at the time. This indicated that salt was being retained in the system, a situation which could not continue indefinitely. There was also a marked annual cyclicity in the salt concentration of the water downstream of Vioolsdrift, with variations between 400 mg/L and 1 500 mg/L. Under these circumstances only salt-tolerant crops such as dates and wheat could be grown.

It was assumed that any increases in irrigation along the lower reaches of the Orange River would lead to higher return flows which would further increase the salinity of the water in the river. This effect will be most felt downstream of Vioolsdrift, where the last significant volume of water is abstracted and return flows will form the bulk of the flow in the river during dry periods (DWAF, 1998).

The following additional points regarding water quality of the Lower Orange River were made in a 2009 summary on *Orange River Water Quality Status* (Golder Associates, 2009) and ORASECOM (2009).

- The concentration of some metals, i.e. Al, Cd, Cu and Pb, were occasionally unacceptably high and potentially harmful for human health and for the aquatic environment. The reason for the high metal concentrations at Upington, Neusberg weir, Pella and Vioolsdrift were unclear and should be investigated further. Mining activities in the area could be a potential source of some of the metals observed.
- The water quality in the Lower Orange River was occasionally above the target water quality range (ideal) for irrigation, particularly due to high salts and high pH values.

- Some of the water withdrawn for irrigation is returned to the river environment for reuse, but its quality is seriously degraded with considerably higher salts and nutrient concentrations which contribute significantly to the salts load in the Orange River.
- The presence of toxic algae was reported for the Lower Orange River passing Upington in 2008. Reports of cyanobacterial blooms in Van der Kloof Dam were reported in DWAF (2000). Blooms of *Microcystis* sp. and *Anabaena* sp. in the dam were reported by Allanson and Jackson in 1983 (cited in WCD, 2000). Blooms appear to be a result of clearing of water due to sedimentation in dams. There is a major area of sediment contribution to the river from the upper catchment. Evidence suggests that algae growth in the Orange River is limited and that drops in turbidity are promoting algal blooms.
- Human health incidences and fish kills were reported in the Richtersveld (De Hoop camp and Grasdrif respectively) during April 2008, with a further fish kill incident in May 2008 (Bezuidenhout, SANParks, *pers. comm*., November 2010).

Results of “fitness for use” maps prepared by ORASECOM member states are shown in Table C42 for various users of the Middle and Lower Orange River. The Middle Orange is defined as the area from the Vaal-Orange confluence to the common border with Namibia, and the Lower Orange the length of the common border with Namibia (ORASECOM, 2009). EFR O2 and EFR O3 therefore fall into the Middle Orange, and EFR O4 into the Lower Orange for the purposes of this assessment.

Table C42 Fitness for use for selected surface water areas of the Middle and Lower Orange River system

User category	Middle Orange	Lower Orange
Agriculture/irrigation (crops)	Good	Poor
Agriculture Livestock	Good	Good
Domestic	Good	Good
Industrial	Good	Poor
Recreational	Good	Good

C9.3 WMS DATA

Data available for *physico-chemical* variables for the Lower Orange River registered on DWA’s WMS database are shown on Table C43 below.

Table C43 Data on WMS for the Lower Orange River area

Monitoring point name	River	Latitude	Longitude	Quaternary catchment	Number of samples	First sample date	Last sample date
D7H012Q01 AT IRENE ON ORANGE	ORANGE	-29.1825	23.575556	D71A	21	1989/02/27	1997/08/26
D7H002Q01 AT PRIESKA ON ORANGE	ORANGE	-29.65139	22.746389	D72B	1 428	1952/10/24	2003/03/28
D7H008Q01 ORANGE RIVER AT BOEGOEBERG RESERVE/ZEEKOEBAART	ORANGE	-29.02972	22.187778	D73B	1 106	1966/04/01	2009/06/22
D7H003Q01 ORANGE RIVER AT KAKAMAS	ORANGE	-28.75528	20.621111	D73F	202	1965/10/01	2003/03/28
D7H005Q01 ORANGE RIVER AT UPINGTON	ORANGE	-28.46083	21.248889	D73F	4 118	1952/10/03	2010/05/12
D7H014Q01 ORANGE RIVER AT KAKAMAS SOUTH/NEUSBERG LEFT SIDE	ORANGE	-28.76806	20.720556	D73F	416	1995/01/02	2010/05/17
D8H007Q01 ORANGE RIVER AT KORRIDOR BRAND KAROSS	ORANGE	-28.48611	16.695556	D82L	414	1971/08/08	2002/04/16
D8H012Q01 ORANGE RIVER AT ALEXANDER BAY @ SIR ERNEST OPPENHEIMER BRIDGE	ORANGE	-28.56611	16.508056	D82L	286	1995/05/16	2003/05/19

C9.4 EFR O2: BOEGOEBERG

C9.4.1 Available data/data confidence

The PES for *geomorphology* is a C category (73%), with flows critically reduced at the site due to large upstream dams. Sediment loads have also been trapped in these dams. The key issue for this site is the loss of large floods that scour and maintain the channels and beds. Stabilisation and increasing vegetation on the lower banks and bars will occur in the future (Rountree, 2010).

Although two DWA monitoring points (D7H002Q01 and D7H008Q01) were assessed for data for physico-chemical variables, D7H008Q01 was used as the site is closer to the EFR site.

Diatom data at EFR O2, sampled during May 2008 and August 2009, classified as a B to B/C category. Data showed evidence of organic pollution and elevated nutrient levels, with fluctuating turbidity levels. The overall category for the reach based on diatoms is a C category (Koekemoer, 2010). Water quality data from diatom surveys of 2008 were used with low confidence, as all variables display much higher values than long-term records.

C9.4.2 Data assessment

Data assessment results for EFR O2 are shown in Table C44.

Table C44 Water quality data assessment for EFR O2

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**		
		RC	Orange River @ Boegoeberg Reserve (D73B; EcoRegion II: 26.05) D7H008Q01 (1966 – 1979; n=43 - 57)	
EFR SITE	O2 (D81B; EcoRegion II: 28.01)	**PES**	1) Orange River @ Boegoeberg Reserve (D73B; EcoRegion II: 26.05) D7H008Q01 (2000 – 2009; n=348) 2) Data from diatom sample collection in 2005, 2008, 2009, 2010	
Confidence assessment	Moderate confidence. Although sufficient data for most variables, data gaps exist, particularly in the case of herbicides, pesticides and metal ions. Note that water quality and EFR sites are not in the same EcoRegion level II.			
Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	37.40	34.06	Concentrations similar for the PES, except for sulphate, sodium and chloride which show increases from the RC, particularly sulphate and chloride.
	Cl	20.36	46.28	
	K	3.70	3.99	
	Mg	15.10	18.00	
	Na	23.70	35.36	
	SO_4	48.10	63.99	
Nutrients (mg/L)	SRP	0.014 *	0.022	A category
	TIN	0.14	0.22	A category
Physical Variables	pH (5^{th} + 95^{th} %ile)	7.05 + 7.91	7.71 + 8.60	A/B category
	Temperature	-	-	Site downstream of numerous dams upstream, with significant changes expected from natural.
	Dissolved oxygen	-	-	
	Turbidity (NTU)	-	Avg: 7.92 95^{th} %ile: 30.67	Levels not very significant. A/B category (qualitative assessment)
	Electrical conductivity (mS/m)	35.68 *	50.80	A/B category. RC shows slightly elevated natural salt levels.
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	46.5 (n=2; 2008) (Koekemoer, 2010)	E category

	Macroinvertebrates	ASPT: 6.6 SASS: 165	ASPT: 5.8 SASS: 116 MIRAI: 63.7%	C category (Palmer, 2010)
	Fish community score		FRAI: 66.9%	C category (Kotzé, 2010)
	Diatoms	-	SPI: avg – 12.9 (n=4; Boegoeberg + EFR O2)	B/C category (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.452	0.260	A category
	Ammonia (mg/L)	0.002	0.011	A category
	Aluminium (mg/L)	0.02 **	0.166 (n=2; 2008) (Koekemoer, 2010)	D category
	Iron (mg/L)	-	0.110 (n=2; 2008) (Koekemoer, 2010)	No guideline + insufficient data
	Arsenic (mg/L)	0.02 **	297 (n=2; 2008) (Koekemoer, 2010)	E category
	Cadmium (mg/L)	0.000 3 **	0.005 (n=2; 2008) (Koekemoer, 2010)	E category
	Lead (mg/L)	0.002 **	0.011 (n=2; 2008) (Koekemoer, 2010)	E category
	Other	-	-	Impacts expected due to farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION		**C: 69.34%** (from PAI model)		

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

C9.4.3 PAI table

The PAI table for EFR O2 is shown as Table C45. Note that the toxics are included as a D category based on the 2008 data of Koekemoer (2010) (n = 2), although the use of this information is low confidence.

Table C45 PAI table for EFR O2

PERENNIAL (Y/N)	**y**
GEOMORPH ZONE	**LOWLAND**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.5	NONE SPECIFIED	4.0	50.0		50.0
Nutrients	1.0	NONE SPECIFIED	3.0	70.0		70.0
Water Temperature	2.5	N	3.0	60.0		60.0
Water clarity	0.5	NONE SPECIFIED	4.0	50.0		50.0
Oxygen	1.5	N	3.0	65.0		65.0
Toxics	3.0	N	2.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	1.53	MEAN CONF →	3.29			
FINAL PC MODIFICATION RATING	1.53					
P-C RATING BASED ON DEFAULT WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
69.40	C					
P-C RATING BASED ON ADJUSTED WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
69.34	C					

C9.5 EFR 03: AUGRABIES

C9.5.1 Available data/data confidence

The PES for geomorphology is a C category (71%). Although sediment loads from the Upper Orange catchment are high - often elevated above natural conditions due to intensive settlement and poor land management - large dams along the mainstem trap sediments and reduce the sediment load. These reduced loads are being partially replenished by tributary inputs (Rountree, 2010).

Three DWA monitoring points (D7H003Q01 (Kakamas), D7H005Q01 (Upington) and D7H014Q01 (Neusberg)) were assessed for data for physico-chemical variables, with D7H003Q01 used to represent RC and D7H014Q01 PES. Data of D7H005Q01 was assessed against that of D7H014Q01 for the present state – results were very similar. Water quality data from diatom surveys of 2008 (n=7 for a range of sites: Kanoneiland, Neusberg, Blouputs, Khamkirri) were also used (Koekemoer, 2010).

Diatom data fluctuated between a B and C EC during 2005, 2008 – 2009, and 2010 surveys, with data indicating a gradual deterioration within the reach from Boegoeberg Dam to Augrabies. The EC for the reach is a B/C (Koekemoer, 2010).

C9.5.2 Data assessment

Data assessment results for EFR O3 are shown in Table C46.

Table C46 Water quality data assessment for EFR O3

<table>
<tr><td rowspan="2">RIVER</td><td rowspan="2">Orange River</td><td colspan="3">WATER QUALITY MONITORING POINTS</td></tr>
<tr><td>RC</td><td colspan="2">Orange River @ Kakamas (D73F; EcoRegion II: 26.05)
D7H003Q01 (1965 – 1980; n=68)</td></tr>
<tr><td>EFR SITE</td><td>EFR O3 (D81B; EcoRegion II: 28.01)</td><td>PES</td><td colspan="2">1) Orange River @ Neusberg (D73F; EcoRegion II: 26.05)
D7H014Q01 (1995 – 2010; n=94)
2) Data from diatom sample collection in 2008 (n=7)</td></tr>
<tr><td colspan="2">Confidence assessment</td><td colspan="3">Moderate confidence. Although sufficient data, particularly for the present state, data gaps exist, e.g. metal ions, pesticides, herbicides. Note that the EFR site and monitoring points are <u>not</u> in the same EcoRegion level II. Agricultural activities were also already in place in the 1960s.</td></tr>
<tr><th colspan="2">Water Quality Constituents</th><th>RC Value</th><th>PES Value</th><th>Category/Comment</th></tr>
<tr><td>Inorganic salts (mg/L)</td><td colspan="4">TEACHA was not used for data assessment, as salinity levels not significantly elevated.</td></tr>
<tr><td rowspan="6">Salt ions (mg/L)</td><td>Ca</td><td>46.4</td><td>32.2</td><td rowspan="6">Concentrations similar for the PES as compared to natural levels.</td></tr>
<tr><td>Cl</td><td>31.3</td><td>33.9</td></tr>
<tr><td>K</td><td>3.58</td><td>3.88</td></tr>
<tr><td>Mg</td><td>22.9</td><td>16.9</td></tr>
<tr><td>Na</td><td>34.2</td><td>33.5</td></tr>
<tr><td>SO_4</td><td>59.2</td><td>50.9</td></tr>
<tr><td rowspan="2">Nutrients (mg/L)</td><td>SRP</td><td>0.014 *</td><td>0.029</td><td>B category</td></tr>
<tr><td>TIN</td><td>0.11</td><td>0.09</td><td>A category</td></tr>
<tr><td rowspan="5">Physical Variables</td><td>pH (5th + 95th %ile)</td><td>6.93 + 8.01</td><td>7.81 + 8.46</td><td>A/B category</td></tr>
<tr><td>Temperature</td><td rowspan="2">-</td><td rowspan="2"></td><td rowspan="2">Little impact expected, although temperature less variable than natural (B category).</td></tr>
<tr><td>Dissolved oxygen</td></tr>
<tr><td>Turbidity (NTU)</td><td>-</td><td>WMS data (n=186):
Avg: 12.74
95th %ile: 52.43
Koekemoer (2010):
5.9 (avg)</td><td>No RC data. Turbidity from system trapped in dams.
A/B category (qualitative assessment).</td></tr>
<tr><td>Electrical conductivity (mS/m)</td><td>45.4 *
(n=118)</td><td>51.62 (n=129)</td><td>A category</td></tr>
<tr><td rowspan="4">Response variables</td><td>Chl a: periphyton (mg/m^2)</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Chl a: phytoplankton (µg/L)</td><td>-</td><td>Avg: 18.4 (n=7)
(Koekemoer, 2010)</td><td>C category</td></tr>
<tr><td>Macroinvertebrates</td><td>ASPT:6.6
SASS: 165</td><td>ASPT: 6.7
SASS: 133
MIRAI: 75.9%</td><td>C category (Palmer, 2010)</td></tr>
<tr><td>Fish community score</td><td></td><td>FRAI: 76.9%</td><td>C category (Kotzé, 2010)</td></tr>
</table>

	Diatoms	-	Avg SPI: 12.6 (n=5)	C category (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.44	0.51	A category
	Aluminium (mg/L)	0.02 **	0.08 (n=7) (Koekemoer, 2010)	B category
	Iron (mg/L)	-	0.073 (n=7) (Koekemoer, 2010)	No guideline + insufficient data
	Ammonia (mg/L)	0.002 (n=41)	0.006	A category
	Other	-	-	Impacts expected due to intensive farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION		**C: 72.40% (from PAI model)**		

* boundary value for the A category recalibrated - no data

** benchmark value, as no data

C9.5.3 PAI table

The PAI table for EFR O3 is shown as Table C47.

Table C47 PAI table for EFR O3

PERENNIAL (Y/N)	**y**
GEOMORPH ZONE	**LOWLAND**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	0.0	NONE SPECIFIED	4.0	50.0		50.0
Nutrients	2.0	NONE SPECIFIED	3.0	70.0		70.0
Water Temperature	1.0	N	3.0	60.0		60.0
Water clarity	1.0	NONE SPECIFIED	4.0	50.0		50.0
Oxygen	0.0	N	3.0	65.0		65.0
Toxics	3.5	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	1.38	MEAN CONF →	3.43			
FINAL PC MODIFICATION RATING	1.38					
P-C RATING BASED ON DEFAULT WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
72.40	C					
P-C RATING BASED ON ADJUSTED WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
72.31	C					

There is some indication of elevated nutrient levels throughout the reach; probably due to intensive agricultural activities in the area. The presence of toxic algae has been reported in the Lower Orange River passing Upington. Toxics from herbicide and pesticide use are also expected. Data collected from WMS and that collected by Koekemoer (2010) do not support the reported intermittent high concentrations of some metals, i.e. Al, Cd, Cu and Pb, in the Upington and Neusberg weir area. Temperature levels are probably less variable than under natural conditions, as the system was naturally more variable than at present (despite the system now being more manipulated).

Note that aerial photographs for the late 1960s indicated very low flows, with agricultural activities already in place at Blouputs.

C9.6 EFR 04: VIOOLSDRIFT

C9.6.1 Available data/data confidence

The PES for geomorphology is a C category (74%). The reduced floods and baseflows (MAR is about one third of the virgin flow volumes) decrease the ability of the river to flush out sediment, whilst the surrounding tributaries are adding increasing volumes of sediment to the main channel (Rountree, 2010).

Two DWA monitoring points (D8H007Q01 (Korridor Brand Kaross) and D8H012Q01 (Alexander Bay)) were assessed for data for *physico-chemical variables*. Note that neither data record was suitable for present state as data were only collected until 2003, resulting in a lower confidence for the assessment. An insufficient data record also exists for Reference Condition. Water quality data from diatom surveys of 2008 (n=9 for a range of sites: Pella, Vioolsdrift, Brandkaros, Sendelingsdrift, Alexander Bay) were also used (Koekemoer, 2010).

Diatom data showed a C category for the lower reaches of the river, with nutrients and salinity being the main contributing factors (Koekemoer, 2010).

C9.6.2 Data assessment

Data assessment results for EFR O4 are shown in Table C48.

Table C48 Water quality data assessment for EFR O4

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**	
		RC	Orange River @ Korridor Brand Kaross (D82L; EcoRegion II: 25.03) D8H007Q01 (1980; n=35)
EFR SITE	EFR O4 (D82F; EcoRegion II: 28.01)	**PES**	1) Orange River @ Oppenheimer Bridge, Alexander Bay (D82L; EcoRegion II: 25.03) D8H012Q01 (1995 – 2003; n=263) 2) Data from diatom sample collection in 2008 (n=9)
Confidence assessment	Low - moderate confidence. The data record for the present state is not recent and gaps exist for data such as metal ions, pesticides, herbicides. RC data also poor. Note that the EFR site and monitoring points are <u>not</u> in the same EcoRegion level II.		

Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for the data assessment.			
Salt ions (mg/L)	Ca	28.06	44.07	PES data show significant elevations for all ions as compared to the natural state.
	Cl	27.10	73.05	
	K	1.92	5.62	
	Mg	12.36	22.08	
	Na	32.34	76.97	
	SO_4	33.16	84.30	
Nutrients (mg/L)	SRP	0.006	0.026	C/D category
	TIN	0.060	0.076	A category
Physical Variables	pH (5th + 95th %ile)	6.77 + 7.53	8.10 + 8.60	A/B category
	Temperature	-		Impacts expected due to the extreme reductions of flow for large parts of the year, although now more similar to natural.
	Dissolved oxygen			
	Turbidity (NTU)	-	10.24 (avg; n=9) (Koekemoer, 2010)	No RC or DWA PES data. Turbidity from system trapped in dams. A/B category (qualitative assessment).
	Electrical conductivity (mS/m)	38.03 *	72.96	B category
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 25.2 (n=9) (Koekemoer, 2010)	D category
	Macroinvertebrates	ASPT:6.6 SASS: 165	ASPT: 6.0 SASS: 96 MIRAI: 63.3%	C category (Palmer, 2010)
	Fish community score		FRAI: 65.2%	C category (Kotzé, 2010)
	Diatoms	-	Avg SPI: 11.5 (n=8)	C category (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.38	0.50	A category
	Aluminium (mg/L)	0.02 **	0.042 (n=9) (Koekemoer, 2010)	A category

	Iron (mg/L)	-	0.035 (n=9) (Koekemoer, 2010)	No guideline + insufficient data
	Ammonia (mg/L)	0.001	0.010	A category
	Copper (mg/L)	0.003 **	0.013	E category
	Zinc (mg/L)	0.0002: TWQR 0.0036: CEV (DWAF, 1996)	0.0056	Both guidelines exceeded
	Other	-	-	Impacts expected due to farming activities and large abstractions. References suggest mining impacts
OVERALL SITE CLASSIFICATION		**C/D: 58.24% (from PAI model)**		

* boundary value for the A category recalibrated - no data
** benchmark value, as no data
TQWR: Target Water Quality Range CEV: Chronic Effects Value

C9.6.3 PAI table

The PAI table for EFR O4 is shown as Table C49.

Table C49 PAI table for EFR O4

PERENNIAL (Y/N)	**y**
GEOMORPH ZONE	**LOWLAND**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.5	N	4.0	60.0		60.0
Salts	1.0	NONE SPECIFIED	4.0	50.0		50.0
Nutrients	3.0	NONE SPECIFIED	3.0	70.0		70.0
Water Temperature	3.0	N	3.0	60.0		60.0
Water clarity	1.0	NONE SPECIFIED	4.0	50.0		50.0
Oxygen	2.0	N	3.0	65.0		65.0
Toxics	3.0	N	3.0	100.0		100.0
CALCULATED PC MODIFICATION RATING	2.09	MEAN CONF →	3.43			
FINAL PC MODIFICATION RATING	2.09					
P-C RATING BASED ON DEFAULT WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
58.20	C/D					
P-C RATING BASED ON ADJUSTED WEIGHTS						
P-C CATEGORY %	P-C CATEGORY					
58.24	C/D					

There is an increase in EC from Prieska to Vioolsdrift along the reaches of the lower Orange River. This is due to a cumulative effect of irrigation return flows (although limited agriculture in the immediate area) and evaporative losses along the river. The last significant volume of water is abstracted and return flows from the bulk of the flow in the river during dry periods (DWAF, 1998). Elevations in nutrient levels are also evidence of this trend. The concentration of some metals was reported to be intermittently high at Pella and Vioolsdrift – some evidence of these elevations was seen, although data is very limited.

A health incident (blisters and skin rashes after rafting in the Orange River) and fish kills were reported in the Richtersveld (De Hoop camp and Grasdrif respectively) upstream of EFR O4 during April 2008, with an additional fish kill incident in May 2008 (Bezuidenhout, SANParks, *pers. comm*., November 2010). Causes are unknown although fish kills might be related to seasonal temperature changes and human skin conditions due to toxic blue-green algae or *Schistosome cercarial dermatitis* (Palmer, Nepid Consultants, *pers. comm*., November 2010). The latter is also known as swimmer's itch, duck itch or cercarial dermatitis. It is a short-term, immune reaction occurring in the skin of humans that have been infected by water-borne schistosomatidae.

The flatworm parasite schistosomatidae that causes swimmer's itch uses both freshwater snail and vertebrates as hosts in their life cycles. During one of these life stages the cercaria leave the water snails and swim freely in the fresh water looking for water birds and can hit the skin of the swimmer. The schistosomatidae penetrates, dies in the skin immediately and cannot infect humans, but gives inflammatory immune reactions.

C10 CONCLUDING NOTES

There is extensive irrigation practised in the Vaal and Orange River system where *herbicides and pesticides* are used (ORASECOM, 2007). These could be present in the return flows and conveyed in the surface runoff to the river systems. The current water quality database does not support the identification of pesticides and herbicides in the rivers. It is recommended that a pesticide and herbicide monitoring program should be initiated to determine the extent of the problem, or toxicity testing should be undertaken at hot spots.

A *nutrient* management strategy needs to be developed for areas where high levels of eutrophication can be seen from point sources such as sewage works as well as diffuse sources associated with runoff from urban areas and agriculture. Modelling tools for nutrients have also not developed adequately and nutrient pathways are not sufficiently understood.

It is recommended that the high *salinity levels* indicated by few diatom samples be treated with caution, as this is not shown by physico-chemical data. Salinity levels in the Caledon system seem to be naturally elevated. Diatoms indicating salinity would therefore be expected.

The following comments were made about *Monitoring Networks and Databases* in the ORASECOM report on monitoring in the Orange-Senqu River Basin (November 2009, draft document), based on the UNDP/GEF's preliminary Transboundary Diagnostic Analysis recently completed.

- Water quality monitoring networks are poorly developed in Lesotho and Namibia. Analyses are confined to basic parameters such as pH, TDS and common anions and cations. However, microbiological analysis is carried out in Lesotho.
- South Africa has a sophisticated and extensive monitoring system although there are a number of deficiencies in the data sets available, particularly along the Lower Orange River.
- Water quality monitoring programmes in the different areas of the Orange River Basin vary in frequency of measurement and water quality variables tested for. The water quality variables tested for depends on the sources of pollution present in the catchments. In general monthly grab samples are taken and at minimum the concentrations of the major cations and anions are determined.

The following comments were included regarding *Transboundary Impacts*.

- The main pollution sources in the Orange-Senqu River Basin lie in the Vaal catchment (salinity, eutrophication, acid mine drainage, heavy metals) which is effectively operated as a closed loop. However, the major irrigation areas of the Vaal-Haarts scheme and the Sand-Vet catchment are holding significant quantities of salts, which may be released downstream as soon as the assimilative capacity of the soils is reached.
- The movement of heavy metals and persistent organic pollutants (POPs) and their potential threat to the water users throughout the River Basin is not known and requires further study.
- Localised eutrophication and microbial pollution is known along the Caledon River, along the Orange River downstream of Lesotho and downstream of the Upington irrigation area to Namibia. However, there is insufficient information to determine the transboundary extent of this pollution.

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