

# *Setting the Thresholds of Potential Concern for River Flow and Quality*

## **Rationale**

All of the seven major rivers which flow in an easterly direction through the Kruger National Park (KNP) originate in the higher lying areas west of the KNP where they are highly utilised (Du Toit, Rogers and Biggs 2003). The KNP lies in a relatively arid (490 mm KNP average rainfall) area and thus the rivers are a crucially important component for the conservation of biodiversity in the KNP (Du Toit, Rogers and Biggs 2003).

Population growth in the eastern Lowveld of South Africa during the past three decades has brought with it numerous environmental challenges. These include, but are not limited to, extensive planting of exotic plantations, overgrazing, erosion, over-utilisation and pollution of rivers, as well as clearing of indigenous forests from large areas in the upper catchments outside the borders of the KNP. The degradation of each river varies in character, intensity and causes with a substantial impact on downstream users. The successful management of these rivers poses one of the most serious challenges to the KNP. However, over the past 10 years South Africa has revolutionised its water legislation (National Water Act, Act number 36 of 1998). This Act substantially elevated the status of the environmental needs, through defining the ecological reserve as a priority water requirement. In other words this entails water of sufficient flow and quality to maintain the integrity of the ecological system, including the water therein, for human use.

With the current levels of abstraction in the upper catchments, the KNP quite simply does not receive the water quantity and quality required to maintain the in-stream biota. For example, *Opsaridium peringueyi* (southern barred minnow) had disappeared from the Olifants River by 1989. *Opsaridium peringueyi* requires well-aerated, flowing, clean water, which it is certainly not receiving. It reappeared briefly following the 2000 floods, but has not been recorded since. *Chiloglanis swierstrae* (lowveld catlet) disappeared from the Letaba River following the 2000 floods. It is presumed that this is either due to eutrophication (algae covering the substrate), or the changed nature or character of the substrate. *Anguilla mossambica* (African longfin eel) and *A. marmorata* (marbled eel) which migrate from the rivers to breed off the eastern side of Madagascar have also not been recorded in the Olifants River in the last 15 years (although occasionally there have been reports of eels being found in the upper Olifants catchment). Obstructions such as the Massangir Dam wall thus have a substantial impact on these eels moving back up the river systems.

The TPCs have thus been used to track and warn of long-term trends of below minimum levels of water flow. The trend of low quality water is also alarmingly low in most of the rivers, primarily due to the many different land uses upstream. This upstream degradation combined with the decreasing flow levels results in unacceptable low quality water in the KNP Rivers particularly at during low flow periods.

## **Discussion**

### **River flow**

During the past 15 years substantial work and resources have been applied to the problem of determining minimum flow requirements for South African Rivers; termed the In-stream Flow Requirements (IFR). These have been determined for all the KNP's major rivers (see table 2 for the references and Fig 1 for flow monitoring stations).

During the initial development of the TPCs, the IFRs were adopted as the river flow TPCs for the KNP. This was based on the knowledge that the IFRs were well researched and calculated, and trying to develop other thresholds would be superfluous. Rogers and Bestbier (1997) provide a good explanation of the process of developing a framework for deriving the "desired state" and setting TPCs. They caution however, that although the IFRs were developed as a statement of flow requirements, they are in practice a set of minimum flows which should avoid unacceptable biodiversity loss. Thus, these TPCs should be used with caution and subject to revision. Continuously having rivers flowing just on, or below the IFR levels is only just acceptable and certainly not the point to which we should aspire. In the short to medium term, however, we are faced with the reality of increasing pressures on our rivers. The realisation of the IFR levels throughout the year will be a substantial improvement in flow status for most of the rivers within the KNP.

In the opposite manner, unnatural high flows will lead to biodiversity impacts as well (Pof 1997). The practice of releasing high water volumes during low flow periods or releasing a weekly or monthly overall volume in one bulk amount does not provide organisms such as fish with the necessary breeding and other cues or might provide them at the wrong time of year. The unexpected fluctuations in the water levels also affect the physiological functioning of the aquatic organisms.

### **River quality**

Water quality monitoring is a national programme under the auspices of the national Department of Water Affairs and Forestry. DWAF supply and maintain the equipment, consumables, analyse the samples and maintain a national database. The KNP participates in the programme by taking the samples and sending them to the relevant laboratories. Thus, in a manner similar to the flow TPCs, the stringent quality requirements set by DWAF primarily for drinking water have been adopted by the KNP as TPCs, as these are stringent enough for satisfactory ecosystem requirements as well (see Table 3 for references and Fig. 2. for the quality monitoring stations in the KNP). This is mainly due to the fact that most of the rivers are also used for potable (drinking water) at some point (in some of the KNP rest camps and then in Mozambique). Further, the current standards contain the most (and strictest) information available. Thus, in this manner, the KNP contributes to allowing water of sufficient quality to pass through, and maintains the ecological component (reserve) in the best possible state.

## **Future work and needs**

### **Flow**

The current TPCs (constructed from the IFRs) are still considered robust and useful measures of water flow/quantity. In most cases the IFR will form the foundation of the determination of the environmental reserve for each river.

In line with our revised thinking around TPCs providing rates of change towards thresholds, the river flow TPCs should to be reconsidered. Ideally, to track rates of approach towards thresholds, we would like to model / forecast potential flow rates according to various scenarios of rainfall, abstraction and reserve release. Another example may include being able to predict the effects of future land use / water use changes on river flow and so set TPCs on the land use change rather than water use. This would be in line with the stated aim for TPCs as measures of primary response to causative factors rather than to secondary or tertiary factors / responses.

### **Quality**

One of the major challenges faced in monitoring the water quality TPCs is the substantial time lag between the sampling and results becoming available (between 2-3 months). This leads to a reactive rather than proactive approach to dealing with deteriorating water quality and specifically siltation or pollution events. Therefore it has been accepted that the value of the quality TPCs will have to, in the short to medium term, be accepted as a mechanism for monitoring water quality trends over time. Water Quality Objectives on a catchment basis are being developed by all stakeholders and KNP is actively involved. To this end, a report will be compiled and submitted annually providing quality trends for major KNP Rivers and will highlight potential TPC exceedances and appropriate responses. In the long-term the use of real-time data loggers and probes for quality is being investigated.

## References

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Table 1: River catchments

River / catchment	Length of river in SA (km)	Length of river in KNP (km)	% of river in KNP
Crocodile	316	113	36
Letaba	481	125	26
Limpopo	736	29	4
Luvuvhu	225	79	35
Olifants	704	98	14
Sabie	178	102	57
Shingwedzi	159	100	63

Table 2: References for IFR determination

River / catchment	Reference	Year
Limpopo	No IFR has been done to date	na
Luvuvhu	Louw and O'Keefe	1999
Shingwedzi	DWAF	1991
Letaba	Letaba	1996
Olifants	DWAF	1991
Sabie-Sand	Tharme	1997
Crocodile	DWAF, CSIR	1991, 2002

Table 3: References for water quality standards

River / catchment	Reference	Year
Limpopo	na	na
Luvuvhu	DWAF	1996a
	DWAF	1996b
	Rogers and Bestbier	1997
Shingwedzi	DWAF	1996a
	DWAF	1996b
	Rogers and Bestbier	1997
Letaba	DWAF	1996a
	DWAF	1996b
	Rogers and Bestbier	1997
Olifants	DWAF	1996a
	DWAF	1996b
	Kühn	1991
Sabie-Sand	DWAF	1996a
	DWAF	1996b
	Rogers and Bestbier	1997
Crocodile	DWAF	1996a
	DWAF	1996b
	Rogers and Bestbier	1997



# Water Flow Monitoring Points in The Kruger National Park



Fig. 1. Water flow monitoring stations in the KNP



# Water Quality Monitoring Points in The Kruger National Park

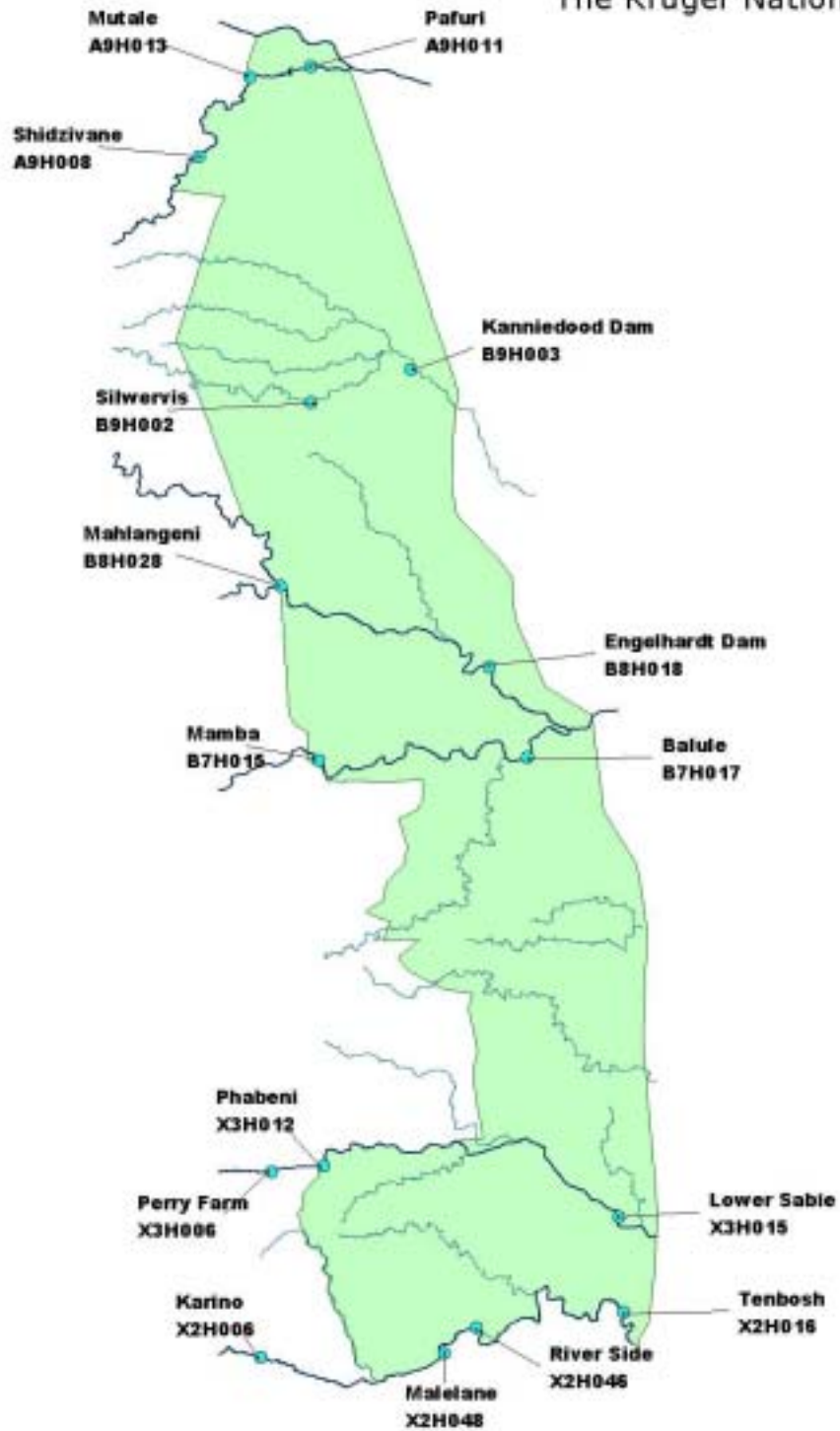


Fig 2 Water quality monitoring points

Table 1: Luvuvhu River IFR

<b>IFR MAINTENANCE LOW FLOWS</b>	<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>JAN</b>	<b>FEB</b>	<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>	<b>TOTAL 10<sup>6</sup> m<sup>3</sup>/s</b>	<b>% of MAR</b>
Flow (m <sup>3</sup> /s)	0.5	0.55	0.7	1.3	1.7	2	1.5	0.95	0.9	0.75	0.7	0.6		
Depth (m) section	0.4	0.41	0.44	0.52	0.56	0.6	0.55	0.47	0.46	0.44	0.44	0.41		
Volume (10 <sup>6</sup> m <sup>3</sup> )	1.3	1.4	1.9	3.5	4.1	5.4	3.9	2.5	2.3	2	1.9	1.6	31.8	8.5
<b>IFR MAINTENANCE HIGH FLOWS</b>														
Flow (instantaneous peak m <sup>3</sup> /s)	1.6	2	21 2	6 3	46 4	21 4	3							
Depth (m) section	0.55	0.6	1.2.6	.82 .66	1.5 .71	1.2 .71	0.66							
Duration (days)														
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.17	0.23	3.9	1	8	3.5	0.23						17.03	4.5

<b>IFR DROUGHT LOW FLOWS</b>	<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>JAN</b>	<b>FEB</b>	<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>	<b>TOTAL 10<sup>6</sup> m<sup>3</sup>/s</b>	<b>% of MAR</b>
Flow (m <sup>3</sup> /s)	0.2	0.22	0.3	0.4	0.4	0.5	0.4	0.3	0.26	0.25	0.24	0.22		
Depth (m) section	0.28	0.29	0.33	0.37	0.37	0.4	0.37	0.33	0.31	0.31	0.3	0.29		
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.5	0.6	0.8	1.1	1.1	1.3	1	0.8	0.7	0.7	0.6	0.6	9.8	2.6
<b>IFR MAINTENANCE HIGH FLOWS</b>														
Flow (instantaneous peak m <sup>3</sup> /s)		1	6	3	21	2								
Depth (m) section		0.48	0.82	0.665	1.19	0.6								
Duration (days)														
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.02	0.08	0.06	0.09	2	0.03						0.01	2.29	0.01

**Table 2: Shingwedzi River IFR**

<b>Water consumed</b>	<b>Volume of water required (10<sup>6</sup> m<sup>3</sup>)</b>	
	<b>Scenario A</b>	<b>Scenario B</b>
<b>Humans and animals</b>	1	1
Flow maintenance	8	0
Fish spawning and migration	6	2
Evaporation	3	2
Evapo transpiration	10	7
Seepage	5	6
Absolute minimum flow Total	33 (60% MAR)*	22 (40% MAR)*
Plus additional flow for maintenance of flora and fauna	16	16
Desired total flow	49 (89% MAR)*	38 (69% MAR)*

\*It is assumed that floods with a five-year return period would not be materially affected by abstraction. Therefore these percentages should in reality be slightly higher, as the five-year return period floods are included in calculations of the MAR.

**Table 3: Letaba River IFR**

Days in month	OCT 31	NOV 30	DEC 31	JAN 31	FEB 28.25	MAR 31	APR 30	MAY 31	JUN 30	JUL 31	AUG 31	SEP 30
<b>MAINTENANCE</b>												
Low flow (m <sup>3</sup> /s)	0.9	1.2	1.5	2.2	2.5	2.4	2	1.7	1.4	1.2	1	0.9
Volume (10 <sup>6</sup> m <sup>3</sup> /month)	2.18	2.8	3.24	5.32	4.81	5.18	5.18	4.55	3.63	3.21	2.68	2.33
Freshet (m <sup>3</sup> /s)	3	6	6	6	6	6						
Duration (days)	3	3	3	3	3	3						
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.39	0.78	0.78	0.78	0.78	0.78						
Flood (m <sup>3</sup> /s)			30		50	30						
Duration (days)			7		7	7						
Volume (10 <sup>6</sup> m <sup>3</sup> )			3.89		4.32	3.89						
<b>Total volume</b>	<b>2.57</b>	<b>3.58</b>	<b>7.91</b>	<b>6.1</b>	<b>9.9</b>	<b>9.85</b>	<b>5.18</b>	<b>4.55</b>	<b>3.63</b>	<b>3.21</b>	<b>2.68</b>	<b>2.33</b>
<b>DROUGHT</b>												
Low flow m <sup>3</sup> /s)	0.2	0.3	0.4	0.45	0.5	0.44	0.37	0.3	0.28	0.26	0.24	0.22
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.48	0.7	0.97	1.09	1.09	1.06	0.96	0.8	0.73	0.7	0.64	0.57
Freshet (m <sup>3</sup> /s)	2	3	6	3	6	3						
Duration (days)	3	3	3	3	3	3						
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.26	0.39	0.78	0.39	0.78	0.39						
<b>Total volume</b>	<b>0.74</b>	<b>1.09</b>	<b>1.75</b>	<b>1.48</b>	<b>1.87</b>	<b>1.45</b>	<b>0.96</b>	<b>0.8</b>	<b>0.73</b>	<b>0.7</b>	<b>0.64</b>	<b>0.57</b>

**Table 4: Olifants River IFR**

Virgin MAR 1968 x 10 <sup>6</sup> m <sup>3</sup>	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 <sup>6</sup> m <sup>3</sup>	% of MAR
<b>IFR MAINTENANCE LOW FLOWS</b>														
Discharge (m <sup>3</sup> /s)	7	10.3	11.8	16	20	17	12.9	11	9.4	8.2	7.4	7		
Max depth (m)	.46	.53	.56	.63	.69	.65	.58	.55	.51	.48	.47	.46		
Monthly volume (10 <sup>6</sup> m <sup>3</sup> )	18.75	26.7	31.6	42.85	48.38	45.53	33.44	29.46	24.36	21.96	19.8	18.14	<b>361</b>	<b>18.3</b>
<b>IFR MAINTENANCE FLOODS / FRESHETS</b>														
Discharge (m <sup>3</sup> /s)	14	50	30	50	150	50	26							
Max depth (m)	.6	1	.81	1	1.55	1	.77							
Duration (days)	3	5	4	5	7	5	4							
Return period (yr)	1	1	1	1	1	1	1							
Monthly volume (10 <sup>6</sup> m <sup>3</sup> )	1.09	8.13	6.6	6.96	32.8	6.76	2.38						<b>64.7</b>	<b>3.3</b>
<b>IFR DROUGHT LOW FLOWS</b>														
Discharge (m <sup>3</sup> /s)	2	2.8	3.1	4.1	5	4.3	3.3	2.9	2.5	2.2	2.1	2		
Max depth (m)	.28	.32	.33	.37	.4	.37	.34	.32	.3	.29	.28	.28		
Monthly volume (10 <sup>6</sup> m <sup>3</sup> )	7.36	7.26	8.3	10.98	12.1	11.52	8.55	7.77	6.48	5.89	5.62	5.18	<b>95</b>	<b>4.8</b>
<b>IFR DROUGHT FLOODS / FRESHETS</b>														
Discharge (m <sup>3</sup> /s)	4	10	20	10	50	10	6							
Max depth (m)	.36	.53	.69	.53	1	.53	.43							
Duration (days)	2	3	4	3	5	3	2							
Return period (yr)	1	1	1	1	1	1	1							
Monthly volume (10 <sup>6</sup> m <sup>3</sup> )	.24	1.12	3.07	.92	9.21	.89	.33						<b>15.8</b>	<b>8</b>

**Table 5a: Sabie River IFR (Downstream of Marite confluence)**

<b>BUILDING BLOCKS</b>		<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>JAN</b>	<b>FEB</b>		<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>
<b>Maintenance IFR</b>	Magnitude (m <sup>3</sup> /s)	2	3	5	6	6		6	5	4	3.5	3	2.6	2.3
Base flows	Depth (m)													
	Volume (MCM)	5.3	7.8	13.4	16.1	14.5		16.1	13	10.7	9.1	8	7	6
	FDC % V	100	100	100	100	100		100	100	100	100	100	100	100
	FDC % V	79	87	86	76	85		86	90	90	86	86	83	80
Higher flows	Magnitude (m <sup>3</sup> /s)	9	12	30	17	50	190	16	14					
	Depth (m)													
	Duration (d)	3	3	7	5	10	14	5	5					
	Return period (y)	1:1	1:1	1:1	1:1	1:1	1:3	1:1	1:1					
	Volume (MCM)	0.9	1.2	7.6	2.4	19	100	2.1	3					
	FDC % V	67	46	10	26	4	0.4	28	36					
	<b>FDC % V</b>	33	23	6	15	3	0.3	16	19					

<b>Capping flows</b>		<b>Note irrigation demands</b>											
<b>DROUGHT IFR</b>	Magnitude (m <sup>3</sup> /s)	1.5	1.9	2.3	2.6	3	2.8	2.5	2.3	2.1	1.9	1.7	1.6
	Depth (m)												
	Volume (MCM)	4	4.9	6.2	7	7.2	7.5	6.5	6.2	5.4	5.1	4.5	4.1
	FDC % V	100	100	100	100	100	100	100	100	100	100	100	100
	FDC % V	90	95	97	99	98	99	99	99	96	95	94	92
<b>Base flows</b>													
<b>Higher flows</b>	Magnitude (m <sup>3</sup> /s)		3.8	4.6	5.2	6	5.6	5					
	Depth (m)												
	Duration (d)		3	3	3	3	3	3					
	Return period (y)		1:1	1:1	1:1	1:1	1:1	1:1					
	Volume (MCM)		0.25	0.3	0.34	0.39	0.36	0.32					
	FDC % V		99	98	96	92	94	97					
	<b>FDC % V</b>		78	69	63	54	58	65					

<b>Maintenance IFR</b>	Base flow	Higher flows	<b>Total</b>	<b>Drought IFR</b>	Base flow	Higher flows	<b>Total</b>
Volume (MCM)	127	63.2	<b>190.2</b>	Volume (MCM)	68.6	2	<b>70.6</b>
As % of MAR	(V) 23.2 (P) 33.8	(V) 11.6 (P) 16.9	<b>(V) 34.8 (P) 50.7</b>	As % of MAR	(V) 12.5 (P) 18.3	(V) 0.4 (P) 0.5	<b>(V) 12.9 (P) 18.8</b>
<b>MAR (MCM)</b>	(V) 547	(P) 375					
<b>MEDIAN ( MCM)</b>	(V) 466	(P) 298					

**Table 5b: Sabie River IFR (Inside the KNP)**

<b>BUILDING BLOCKS</b>		<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>JAN</b>	<b>FEB</b>		<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>
<b>Maintenance IFR</b>	Magnitude (m <sup>3</sup> /s)	4.5	6	9	10	12		11	10	8	6	5	4.5	4
Base flows	Depth (m)													
	Volume (MCM)	12.1	15.5	24.1	26.8	29		29.5	25.9	21.4	15.4	13.4	12.1	10.4
	FDC % V	94	94	90	90	82		85	89	92	95	97	98	98
	FDC % V	33	49	54	52	64		62	54	43	49	50	44	44
Higher flows	Magnitude (m <sup>3</sup> /s)	9	12	30	17	50	200	16	14					
	Depth (m)													
	Duration (d)	3	3	7	5	10	14	5	5					
	Return period (y)	1:1	1:1	1:1	1:1	1:1	1:3	1:1	1:1					
	Volume (MCM)	0.6	0.8	6.3	1.5	16.4	100	1.1	0.9					
	FDC % V	68	47	10	27	5	0.4	29	37					
	<b>FDC % V</b>	34	24	6	15	3	0.3	16	20					

<b>Capping flows</b>		<b>None specified</b>											
<b>DROUGHT IFR</b>	Magnitude (m <sup>3</sup> /s)	2.5	3.5	4	5	6	5.5	4.5	3.5	3	2.5	2	2
	Depth (m)												
	Volume (MCM)	6.7	9.1	10.7	13.9	14.5	14.7	11.7	9.4	7.8	6.7	5.3	5.2
	FDC % V	100	100	100	100	90	100	100	100	100	100	100	100
	FDC % V	72	80	92	92	87	89	94	93	91	91	92	88
<b>Base flows</b>													
<b>Higher flows</b>	Magnitude (m <sup>3</sup> /s)		7			10							
	Depth (m)												
	Duration (d)		3			5							
	Return period (y)		1:1			1:1							
	Volume (MCM)		0.4			0.9							
	FDC % V		84			60							
	<b>FDC % V</b>		46			30							

<b>Maintenance IFR</b>	Base flow	Higher flows	<b>Total</b>	<b>Drought IFR</b>	Base flow	Higher flows	<b>Total</b>
Volume (MCM)	235.7	55.5	<b>291.2</b>	Volume (MCM)	115.7	1.3	<b>117</b>
As % of MAR	(V) 42.1 (P) 60.6	(V) 9.9 (P) 14.3	<b>(V) 52 (P) 74</b>	As % of MAR	(V) 20.7 (P) 29.7	(V) 0.2 (P) 0.3	<b>(V) 20.9 (P) 30</b>
<b>MAR (MCM)</b>	(V) 560	(P) 389					
<b>MEDIAN ( MCM)</b>	(V) 476	(P) 308					

**Table 5c: Sabie River IFR (At Skukuza)**

<b>BUILDING BLOCKS</b>		<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>JAN</b>	<b>FEB</b>		<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>	
<b>Maintenance IFR</b>	Magnitude (m <sup>3</sup> /s)	3	4	5	6	9		8	7	6	5.2	4.5	4	3.4	
	Depth (m)	0.82	0.89	0.96	1.02	1.17		1.12	1.07	1.02	0.97	0.93	0.89	0.85	
	Base flows	8	10.4	13.4	16.1	21.8		21.4	18.1	16.1	13.5	12	10.7	8.8	
	FDC % V	100	99	99	100	94		96	98	98	98	98	98	98	98
	FDC % V	54	69	86	79	74		77	76	65	59	55	48	49	
<b>Higher flows</b>	Magnitude (m <sup>3</sup> /s)	9	12	30	20	50	180	21	18						
	Depth (m)	1.17	1.3	1.83	1.57	2.21	3.54	1.6	1.51						
	Duration (d)	3	3	7	5	10	14	5	5						
	Return period (y)	1:1	1:1	1:1	1:1	1:1	1:3	1:1	1:1						
	Volume (MCM)	0.8	1	7.6	3	17.7	100	2.8	2.4						
	FDC % V	70	66	18	65	25	5	70	80						
	<b>FDC % V</b>	10	25	8	40	20	1	50	42						

<b>Capping flows</b>		<b>None specified</b>											
<b>DROUGHT IFR</b>	Magnitude (m <sup>3</sup> /s)	2	2.5	3	3.5	4	3.7	3.3	3.1	2.8	2.5	2.3	2.1
	Depth (m)	0.73	0.77	0.82	0.85	0.89	0.87	0.84	0.82	0.8	0.77	0.76	0.74
	Volume (MCM)	5.3	6.5	8	9.4	9.7	9.9	8.6	8.3	7.2	6.7	6.2	5.4
	FDC % V	100	100	100	100	100	100	100	100	100	100	100	100
	FDC % V	72	87	92	97	95	95	95	93	90	87	81	77
<b>Base flows</b>													
<b>Higher flows</b>	Magnitude (m <sup>3</sup> /s)		5	6	7	8	7	6					
	Depth (m)		0.96	1.02	1.07	1.12	1.07	1.02					
	Duration (d)		3	3	3	3	3	3					
	Return period (y)		1:1	1:1	1:1	1:1	1:1	1:1					
	Volume (MCM)		0.3	0.4	0.4	0.5	0.4	0.3					
	FDC % V		96	97	99	96	99	100					
	<b>FDC % V</b>		58	78	65	77	81	85					

<b>Maintenance IFR</b>	Base flow	Higher flows	<b>Total</b>	<b>Drought IFR</b>	Base flow	Higher flows	<b>Total</b>
Volume (MCM)	170.3	62.7	<b>233</b>	Volume (MCM)	91.2	2.3	<b>93.5</b>
As % of MAR	(V) 28.7 (P) 41.3	(V) 10.6 (P) 15.2	<b>(V) 39.3 (P) 56.5</b>	As % of MAR	(V) 15.4 (P) 22.1	(V) 0.4 (P) 0.6	<b>(V) 15.8 (P) 22.7</b>
<b>MAR (MCM)</b>	(V) 594	(P) 412					
<b>MEDIAN ( MCM)</b>	(V) 512	(P) 338					

**Table 5d: Sabie River IFR (Downstream of Sand River confluence)**

<b>BUILDING BLOCKS</b>		<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>JAN</b>	<b>FEB</b>		<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>
<b>Maintenance IFR</b>	Magnitude (m <sup>3</sup> /s)	4	8	10	13	18		14	10	8	6	4	4	3
Base flows	Depth (m)													
	Volume (MCM)	10.7	20.7	26.8	34.8	43.5		37.5	25.9	21.4	15.5	10.7	10.7	7.8
	FDC % V	96	77	87	80	71		81	93	94	96	100	98	99
	FDC % V	38	33	53	48	58		62	63	53	57	67	53	56
Higher flows	Magnitude (m <sup>3</sup> /s)	8	12	30	20	45	180	21	18					
	Depth (m)													
	Duration (d)	3	3	7	5	10	14	5	5					
	Return period (y)	1:1	1:1	1:1	1:1	1:1	1:3	1:1	1:1					
	Volume (MCM)	0.5	0.5	6	3.7	11.7	96	1.5	1.7					
	FDC % V	81	56	15	27	8	0.9	26	33					
	<b>FDC % V</b>	45	30	10	17	6	0.8	16	19					

<b>Capping flows</b>							<b>None specified</b>						
<b>DROUGHT IFR</b>	Magnitude (m <sup>3</sup> /s)	3	3.5	4	4.5	5							
	Depth (m)												
	Volume (MCM)	8	9.1	10.7	12.1	12							
	FDC % V	100	100	100	100	100							
	FDC % V	54	70	90	92	91							
<b>Base flows</b>													
<b>Higher flows</b>	Magnitude (m <sup>3</sup> /s)			12		10							
	Depth (m)												
	Duration (d)			3		3							
	Return period (y)			1:1		1:1							
	Volume (MCM)			1		0.6							
	FDC % V			56		69							
	<b>FDC % V</b>			30		36							

<b>Maintenance IFR</b>	Base flow	Higher flows	<b>Total</b>	<b>Drought IFR</b>	Base flow	Higher flows	<b>Total</b>
Volume (MCM)	266	48.3	<b>314</b>	<b>Volume (MCM)</b>	108.9	1.6	<b>110.4</b>
As % of MAR	(V) 37.6 (P) 53.4	(V) 6.8 (P) 9.7	<b>(V) 44.4</b> <b>(P) 63.1</b>	<b>As % of MAR</b>	(V) 15.4 (P) 21.9	(V) 0.2 (P) 0.3	<b>(V) 15.6</b> <b>(P) 22.1</b>
<b>MAR (MCM)</b>	(V) 708	(P) 498					
<b>MEDIAN ( MCM)</b>	(V) 607	(P) 394					

**Table 6: Sand River IFR**

<b>BUILDING BLOCKS</b>		<b>OCT</b>	<b>NOV</b>	<b>DEC</b>	<b>JAN</b>	<b>FEB</b>	<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>
<b>Maintenance IFR</b>	Magnitude (m <sup>3</sup> /s)	0.3	0.3	0.75	1	1.5	1.5	0.9	0.7	0.6	0.5	0.4	0.3
	Depth (m)	0.51	0.51	0.65	0.71	0.79	0.79	0.69	0.64	0.61	0.58	0.55	0.51
Base flows	Volume (MCM)	0.8	0.8	2	2.7	3.6	4	2.3	1.9	1.6	1.3	1.1	0.8
	FDC % V	85	88	91	95	87	87	90	92	91	92	93	92
	FDC % V	39	44	48	61	63	67	70	65	64	63	61	55
Higher flows	Magnitude (m <sup>3</sup> /s)	1.5	5	6	10	15	60	10					
	Depth (m)	0.79	1.1	1.16	1.33	1.49	2.16	1.33					
	Duration (d)	2	8	8	8	8	10	8					
	Return period (y)	1:1	1:1	1:1	1:1	1:1	1:3	1:1					
	Volume (MCM)	0.1	1.6	1.8	3.1	4.7	25.3	2.9					
	FDC % V	54	15	12	7	4	1	7					
	<b>FDC % V</b>	33	11	10	5	3	1	5					

<b>Capping flows</b>		<b>None specified</b>											
<b>DROUGHT IFR</b>	Magnitude (m <sup>3</sup> /s)	0.1	0.1	0.3	0.3	0.5	0.5	0.5	0.3	0.1	0.1	0.1	0.1
	Depth (m)	0.38	0.38	0.51	0.51	0.58	0.58	0.58	0.51	0.38	0.38	0.38	0.38
	Volume (MCM)	0.3	0.3	0.8	0.8	1.2	1.3	1.3	0.8	0.3	0.3	0.3	0.3
	FDC % V	94	95	94	98	95	93	95	98	100	98	98	98
	FDC % V	59	54	61	82	81	85	84	89	89	86	79	68
<b>Base flows</b>													
<b>Higher flows</b>	Magnitude (m <sup>3</sup> /s)			3	3	6							
	Depth (m)			0.96	0.96	1.16							
	Duration (d)			2	2	3							
	Return period (y)			1:1	1:1	1:1							
	Volume (MCM)			0.2	0.2	0.7							
	FDC % V			26	26	12							
	<b>FDC % V</b>			18	18	10							

<b>Maintenance IFR</b>	Base flow	Higher flows	<b>Total</b>	<b>Drought IFR</b>	Base flow	Higher flows	<b>Total</b>
Volume (MCM)	22.9	21.1	<b>44</b>	Volume (MCM)	8	1.1	<b>9.1</b>
As % of MAR	(V) 18.8 (P) 23.9	(V) 17.3 (P) 22	<b>(V) 36.1 (P) 45.9</b>	As % of MAR	(V) 6.6 (P) 8.3	(V) 0.9 (P) 1.1	<b>(V) 7.5 (P) 9.4</b>
<b>MAR (MCM)</b>	(V) 122	(P) 96					
<b>MEDIAN ( MCM)</b>	(V) 90	(P) 60					

**Table 7a: Crocodile River IFR – IFR Site 5: Malelane**

Virgin MAR 12.11 x 10 <sup>6</sup> m <sup>3</sup> (WR90)	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 <sup>6</sup> m <sup>3</sup>	% of MAR
<b>IFR MAINTENANCE LOW FLOWS</b>														
Flow (m <sup>3</sup> /s)	7.3	8.1	8.8	9.5	10.3	11	10.3	9.5	8.8	8.1	7.3	6.6		
Depth (m)														
FDC %	82	99	96	97	96	96	92	88	83	82	80	92		
Volume (10 <sup>6</sup> m <sup>3</sup> )	19.64	20.91	23.57	25.53	24.84	29.46	26.61	25.53	22.81	21.61	19.64	17.11	227.26	22.38
<b>IFR MAINTENANCE HIGH FLOWS</b>														
Flow (m <sup>3</sup> /s)	11	55	90	100	250	50	15							
Depth (m)														
Duration (days)	5	5	5	5	8	5	5							
Return period	1	1	1	1	2	1	1							
FDC %	65	28	16	17	7	50	86							
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.792	10.14	17.6	19.54	41.43	8.424	1.022						98.882	7.98
<b>TOTAL IFR MAINTENANCE</b>													<b>376.142</b>	<b>30.36</b>
<b>IFR DROUGHT LOW FLOWS</b>														
Flow (m <sup>3</sup> /s)	4.4	4.9	5.3	5.7	6.2	6.6	6.2	5.7	5.3	4.9	4.4	4		
Depth (m)														
FDC %	96	100	99	99	99	99	99	96	96	94	100	100		
Volume (10 <sup>6</sup> m <sup>3</sup> )	11.87	12.61	14.2	15.36	14.92	17.68	15.98	15.36	13.74	13.03	11.87	10.37	166.99	13.48
<b>IFR DROUGHT HIGH FLOWS</b>														
Flow (m <sup>3</sup> /s)	5	15	20	8	225	7	8							
Depth (m)														
Duration (days)	4	4	4	4	4	4	4							
Return period	1	1	1	1	2	1	1							
FDC %	93	88	85	98	8	98	95							
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.098	1.751	2.540	0.392	18.91	0.069	0.317						24.074	1.94
<b>TOTAL IFR DROUGHT</b>													<b>191.064</b>	<b>15.42</b>

**Table 7b: Crocodile River IFR – IFR Site 6: Nkongoma**

Virgin MAR 1260 x 10 <sup>6</sup> m <sup>3</sup> (WR90)	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 <sup>6</sup> m <sup>3</sup>	% of MAR
<b>IFR MAINTENANCE LOW FLOWS</b>														
Flow (m <sup>3</sup> /s)	7.7	9.4	11.2	13	14.7	16.5	14.7	13	11.2	9.4	7.7	5.9		
Depth (m)														
FDC %	80	97	93	95	93	92	88	78	77	79	80	97		
Volume (10 <sup>6</sup> m <sup>3</sup> )	20.53	24.45	30	34.73	35.64	44.19	38.19	34.73	29.03	25.27	20.53	15.29	352.59	27
<b>IFR MAINTENANCE HIGH FLOWS</b>														
Flow (m <sup>3</sup> /s)	12	30	90	147	225	80	15							
Depth (m)														
Duration (days)	5	5	5	5	8	5	5							
Return period	1	1	1	2	2	1	1							
FDC %	61	62	17	8	8	30	88							
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.936	4.442	17.02	14.48	41.52	13.72	0.058						92.166	7.06
<b>TOTAL IFR MAINTENANCE</b>													<b>444.756</b>	<b>34.06</b>
<b>IFR DROUGHT LOW FLOWS</b>														
Flow (m <sup>3</sup> /s)	3.1	3.6	4	4.4	4.9	5.3	4.9	4.4	4	3.6	3.1	2.7		
Depth (m)														
FDC %	98	100	100	100	99	98	100	100	100	100	100	100		
Volume (10 <sup>6</sup> m <sup>3</sup> )	8.39	9.24	10.71	11.87	11.77	14.2	12.61	11.87	10.37	9.55	8.39	7	125.99	9.65
<b>IFR DROUGHT HIGH FLOWS</b>														
Flow (m <sup>3</sup> /s)	8	15	20	16	255	15	10							
Depth (m)														
Duration (days)	4	4	4	4	4	4	4							
Return period	1	1	1	1	2	1	1							
FDC %	79	87	85	92	8	93	93							
Volume (10 <sup>6</sup> m <sup>3</sup> )	0.841	1.976	2.765	1.999	21.61	1.676	0.887						31.755	2.43
<b>TOTAL IFR DROUGHT</b>													<b>157.745</b>	<b>12.08</b>

## **IFR REFERENCES**

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### ***SHINGWEDZI RIVER***

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### ***LETABA RIVER***

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### ***OLIFANTS RIVER***

Lower Olifants Comprehensive Ecological Reserve (Quantity): Olifants River Ecological Water Requirements Assessment by the Department of Water Affairs and Forestry- June 2001

### ***SABIE RIVER***

IFR of the Sabie-Sand River System: Proceedings of the IFR Workshop. DWAF by R Tharme 1997

### ***CROCODILE RIVER***

Ecological Reserve Determination for the Crocodile River Catchment, Incomati System, Mpumalanga. Report no. ENV-P-C 2002 009 by CSIR for DWAF

## Water Quality TPC's

<b>Variable</b>	Luv	Shi ng	Let	Olif	Sab	Cro c
<b>Water Quality Variables</b>						
Ammonium (ug/l)	0.76	15	15	10	15	15
pH	6.5- 8.5	6.5- 8.5	6.5- 8.5	6.5- 9	6.5- 8.1	6.5- 8.5
Nitrate/nitrite(mg/l)	6	6	6	6	0.2	6
Phosphorus(mg/l)	0.1	0.1	0.02	0.1	0.02	0.01
Sodium(mg/l)	100	100	100	100	11	100
Chloride(mg/l)	100	100	150	100	17	100
Fluoride(mg/l)	2	0.75	1	1.5	0.2	0.2
Cond(mS/m)	80	70	70	120	16	70
Calcium(mg/l)	32	32	32	32	9	32
Magnesium(mg/l)	30	30	30	30	6	30
Potassium(mg/l)	50	50	50	50	2	50
Silica(mg/l)	18	18	18	18	8.4	18
Sulphate(mg/l)	200	200	200	250	11	200
TDS(mg/l)	520	450	450	800	104	450
Turbidity (NTU)	8	8	8	8	8	8
Temperature					8-	
Heavy metals(ug/l)	*	*	*	*	25 *	*
Analytical methods (refer to DWAF)						
* = International standard						