APPENDIX D:
FISH

Compiled by Dr P Kotze, Clean Stream Biological Services

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ABBREVIATIONS

EWR – Ecological Water Requirements
FD – Fast Deep
FS – Fast Shallow
FRAI – Fish Response Assessment Index
NRU – Natural Resource Unit
MRU - Management Resource Unit
ORS – Orange River System
RAU – Resource Assessment Unit
SD – Slow Deep
SS – Slow Shallow

D1 BACKGROUND

Based on available information, seventeen (17) fish species indigenous to South Africa have previously been recorded in the Orange River System and its tributaries (including the Molopo River and Lesotho tributaries (Table D1). Another eight alien fish species and one translocated indigenous species are furthermore known to occur within the Orange River System and its tributaries (Table 1.1).

Table D1 Fish species of the Orange River System

ABBREVIATION	GENERAL NOTES ON SPECIES & DISTRIBUTION
AMOS	This species indicated as having peripheral occurrence throughout Orange River main stem. A catadromous fish species generally occurring in the east flowing rivers of South Africa. This species requires migration to the sea for oceanic breeding in the Indian ocean of Madagascar. As this species cannot complete its life cycle in the Orange River, it is though that this species may have entered the system as juveniles crossing the watershed during very wet years. Benade (1993) however states that reduced incidence of flow-peaks following impoundment curtailed migration of this species into Orange River (Skelton, 1993. Deacon *pers. comm.,* 2010. Jubb 1959, Benade, 1993)
ASCL	Endemic to Orange-Vaal River system. Present throughout Orange System. Indicated as one of most threatened species in Orange River System. IUCN (2007) rated least concern. (SA Red Data Book 1987 rare (indeterminate).
BANO	Skelton & Cambray (1981) indicate that there is no obvious physical reason why this species cannot exist in lower Orange River. Only sampled in middle Orange (to Prieska), possible absence during 1980 survey from lower Orange ascribed to potential unsuitable temperature regimes. Could also be related to natural historic drainage lines. BANO tend to be excluded from areas occupied by juveniles of larger cyprinids (BAEN, etc.).
BAEN	Naturally endemic to Orange-Vaal system. Translocated to other systems in South Africa.
BBRI (cf.)	Previously recorded in upper Molopo System (JLB Smith, 1994). The type locality for BBRI is the Sabie River in Mpumalanga and it is presently though that this (or similar) species found in some other regions may in fact be a different species. May represent an endemic species in to Upper Molopo of the ORS and merit special conservation attention. It is of some concern that this species was not sampled during 2010 surveys at locality previously recorded.
BHOS	Endemic to Orange River System. Only present downstream of Augrabies falls. Anatomically *B. hospes* is more suited to strong swimming than any other small Barbus species in Southern Africa. IUCN (2007): Least concern (IUCN 1996 near threatened, SA Red Data book 1987 rare (indeterminate).
BKIM	Endemic to Orange-Vaal River system. IUCN (2007): Near Threatened. NEMBA (2004): Vulnerable
BPAL	Known from Vaal tributaries, and also record for upper Molopo region. Not expected to occur naturally in middle or lower Orange River (possibly in upper OR). Skelton & Cambray (1981). (Absent from Cape parts of OR).
BPAU	Relatively common Barbus species in many of South African rivers. Abundant in especially middle and lower OR.
BTRI	Populations of BTRI in Orange River have distinct body pigmentation, suggesting that the Orange River population is genetically distinct (BKS, 1996). BTRI considered to be vulnerable, especially in lower Vaal. Also concern about population in Fish River. Low abundance in Lower OR. Historic records below and above Augrabies falls.
CGAR	Common and widespread occurring throughout Orange-Vaal system, and many other rivers in South Africa.
LCAP	Naturally endemic to Orange-Vaal system. Translocated to other systems in South Africa.
LUMB	Skelton & Cambray (1981):Very scarce during 1980 survey in middle and lower Orange. Described as not very successful lotic species (especially in face of competition with LCAP). Benade (1993): Traditionally widespread in Orange River System above Augrabies, has become restricted to mainly upper Orange River dams. Probably flow regulation, and siltation of breeding habitats (egg smothering). LUMB, has effectively disappeared below Vanderkloof Dam. Benade (1983) recommended that it be considered for inclusion as Red Data listed (threatened) for ORS. Jubb (1967) indicates its distribution range in the Orange River as upstream of Augrabies falls. Some records in FROC database (Kleynhans et al. 2007) for this species below falls (possibility of colonization from Fish River?). Introduced indigenous OMOS may compete with LUMB in lower OR for food (detritus) and therefore be a possible contributing factor to their scarcity/absence.
MBRE	The Augrabies Falls form the upstream barrier of distribution range in Orange River.

ABBREVIATION	GENERAL NOTES ON SPECIES & DISTRIBUTION
	Unconfirmed records in Molopo River downstream of Mafikeng? (could be introduced).
PPHI	BKS 1996: Cichlids have become invasive between Boegoeberg & Augrabies). PPHI surprisingly common in a wide variety of habitats along the Middle and Lower Orange (Skelton & Cambray 1981;Cambray 1982b). Gaige *et al* (1980) indicated no previous records in Orange River, only being present in Wondergat and Kuruman eye.
PQUA	The endangered (IUCN, 2007) Maluti minnow (*Pseudobarbus quathlambae*) have been recorded in the upper reaches of the Orange River within Lesotho, and as the type locality of this species is in the Umkomazana River in Kwa-Zulu Natal (1930's) (Skelton, 1991). Currently knowns from only few localities within Lesotho.
TSPA	BKS 1996: Cichlids have become invasive between Boegoeberg & Augrabies). ***Tilapia sparrmanii*** was, in contrast to PPHI, rather scarce in middle/lower Orange River, suggesting the possibility of competitive exclusion by the aggressive haplochromine. TSPA of upper Molopo River genetically & morphologically distinct from other known conspecific populations.
Alien and Indigenous Introduced Species	
OMOS	Introduced indigenous species (Benade, 1993). Present in lower Orange only and unlikely to spread due to preference for warmer water (>22C; Skelton, 1993). Present in Fish river and main stem below Vioolsdrift (Gaiger, 1975, Skelton & Cambray, 1981). IUCN (2007) Near threatened due to hybridization. Augrabies falls fortunately barrier for further instream colonization, although cold should also be limiting factor. This species will compete with other naturally occurring indigenous fish species (especially in terms of food-diatoms, detritus and to some extent invertebrates) negatively impacting on the ecological integrity of the lower OR (may compete for food with LUMB – detritus)
CAUR*	Alien (probably Far-East)
CCAR*	Alien (Europe and Asia)
CIDE*	Alien (China)
GAFF*	Alien (North America)
LMAC*	Alien (North America)
OMYK*	Alien (North America)
MSAL*	Alien (North America)
STRU*	Alien (Europe and North-east Africa)

D2 METHODOLOGY

D2.1 REFERENCE CONDITIONS

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their expected frequency of occurrence (FROC) under reference habitat conditions (Kleynhans *et al.,* 2007). The approach followed to determine the reference condition was based on known fish distribution data for the area together with an estimation of habitat conditions at the site under pre-disturbance conditions.

D2.2 Habitat composition

Base on all available knowledge, observations made on site and description of reference conditions of other specialist components (such as hydrology, water quality, geomorphology and riparian vegetation) at the site or reach, estimation was made of the general habitat composition available for fish under reference conditions.

D2.3 Fish species composition

Table D2 provides a list of all fish species expected or previously sampled/observed in the Orange River study area covered by the current study. These abbreviations will be used in the discussion section of the document. These species differ in their preference for different velocity-depth categories and cover features (Table D3). They furthermore have different tolerance levels to changes in their environment (Table D4). These aspects play an important determining role in the fish assemblages expected under reference condition and present under current conditions at a site or river reach. This information was therefore used explicitly in determining reference conditions as well as in the interpretation of the present ecological state. Kleynhans *et al. (*2007) provided an overview of available fish distribution information for the rivers of South Africa as well as setting reference conditions (species and their relative FROC) of selected sites (with emphasis on the National River Health monitoring sites). This information is currently seen as the most comprehensive and reliable fish information for setting reference conditions, and was therefore used as the primary source of information. It was however amended with all relevant fish information available to the author.

Table D2 Fish species (abbreviations and scientific names) of the Orange River System

ABBREVIATION	SCIENTIFIC NAMES
AMOS	*ANGUILLA MOSSAMBICA* (PETERS 1852)
ASCL	*AUSTROGLANIS SCLATERI* (BOULENGER, 1901)
BAEN	*LABEOBARBUS AENEUS* (BURCHELL, 1822)
BANO	*BARBUS ANOPLUS* (WEBER, 1897)
BBRI (cf.)	*BARBUS BREVIPINNIS* (JUBB, 1966)
BHOS	BARBUS HOSPES (BARNARD, 1938)
BKIM	*LABEOBARBUS KIMBERLEYENSIS* (GILCHRIST & THOMPSON, 1913)
BPAL	*BARBUS PALLIDUS* (SMITH, 1841)
BPAU	BARBUS PALUDINOSUS (PETERS, 1852)
BTRI	*BARBUS TRIMACULATUS* (PETERS, 1852)
CAUR*	*CARASSIUS AURATUS* (LINNAEUS, 1758)
CCAR*	*CYPRINUS CARPIO* LINNAEUS, 1758

ABBREVIATION	SCIENTIFIC NAMES
CGAR	CLARIAS GARIEPINUS (BURCHELL, 1822)
CIDE*	*CTENOPHARYNGODON IDELLA* (VALENCIENNES, 1844)
GAFF*	*GAMBUSIA AFFINIS* (BAIRD & GIRARD, 1853)
LCAP	*LABEO CAPENSIS* (SMITH, 1841)
LMAC*	*LEPOMIS MACROCHIRUS* (RAFINESQUE, 1819)
LUMB	*LABEO UMBRATUS* (SMITH, 1841)
MBRE	*MESOBOLA BREVIANALIS* (BOULENGER, 1908)
MSAL*	MICROPTERUS SALMOIDES
OMOS	OREOCHROMIS MOSSAMBICUS
OMYK*	*ONCORHYNCHUS MYKISS* (WALBAUM, 1792)
PPHI	PSEUDOCRENILABRUS PHILANDER (WEBER, 1897)
PQUA	*PSEUDOBARBUS QUATHLAMBAE* (BARNARD, 1938)
STRU*	SALMO TRUTTA
TSPA	TILAPIA SPARRMANII SMITH, 1840

*Alien fish species

Table D3 Habitat preference of expected indigenous fish species in terms of velocity-depth categories and cover features (from Kleynhans, 2003)

ABBREVIATION	SLOW-DEEP (<0.3 m/s; >0.5 m)	SLOW-SHALLOW (<0.3 m/s; <0.5 m)	FAST-DEEP (>0.3 m/s; >0.3 m)	FAST-SHALLOW (>0.3 m/s; <0.3 m)	OVERHANGING VEGETATION	BANK UNDERCUT	SUBSTRATE	AQUATIC MACROPHYTES	WATER COLUMN
AMOS	3.4	1.1	3.4	3.3	1.3	4.1	4.9	1.4	0.5
ASCL	3.4	2.3	2.3	3.8	0.3	3.5	4.4	0.1	0.9
BAEN	3.5	2.5	3.5	4	0.7	1.5	4	2	4
BANO	4.1	4.3	0.9	2.5	4	2.7	2.3	3.2	1.1
BBRI	3.3	4.3	1	1.2	4.7	4.1	1.7	0	0
BHOS	?	?	?	?	?	?	?	?	?
BKIM	3.7	2	4.3	3.8	0	0	1.8	0	3.3
BPAL	2	3.8	0	0	2.8	2	3.5	2.3	1
BPAU	3.9	3.9	2.2	2.6	4.2	2.4	1.9	3.6	3.5
BTRI	3.9	3.2	2.3	2.7	3.9	2.6	2.3	2.8	2.8
BTRV	0	3	0	0	0	4	0	0	0
CCAR	4.7	3.2	2.1	1.5	2.7	3	3	2.6	3
CGAR	4.3	3.4	1.2	0.8	2.8	2.9	2.8	3	2.6
LCAP	4.2	3	3.3	2.5	0.5	2	4.2	1.5	3.2
LUMB	4.5	2.7	1	0.9	0.6	0.1	4.2	0.8	2.5
MBRE	4.3	4.2	0.2	0.5	1.8	0.5	0.7	1	5
MSAL	4.5	3	0.8	0.8	3.1	3	3.1	3.2	1.7
OMOS	4.6	3.8	1.4	0.8	3	1.9	2.1	2.8	3.9
OMYK	3.4	2.2	4.4	3.4	1.8	2.2	4.7	0.9	2.2
PQUA	0	4	0	5	2	3	4	2	4
STRU	2.8	2	4.7	3.9	1.8	2.3	4.8	0.7	2
TSPA	3	4.3	0.9	1.5	4.5	1.9	2.5	3.6	1.1

0 = NO PREFERENCE, IRRELEVANT;
>0 - 0.9 = VERY LOW PREFERENCE -COINCIDENTAL?
>1 - 1.9 = LOW PREFERENCE
>2 - 2.9 = MODERATE PREFERENCE
>3 - 3.9 = HIGH PREFERENCE
>4-5 = VERY HIGH PREFERENCE

Table D4 Relative intolerance ratings of expected fish species in terms of various aspects (Kleynhans, 2003)

ABBREVIATION	TROPHIC SPECIALIZATION	HABITAT SPECIALIZATION	FLOW REQUIREMENT	REQUIREMENT: UNMODIFIED WATER QUALITY	AVERAGE OVERALL INTOLERANCE RATING
AMOS	2.8	2.8	2.8	2.5	2.8
ASCL	2.9	2.3	3.2	2.6	2.7
BAEN	2.5	1.8	3.3	2.5	2.5
BANO	2.8	2.8	2.3	2.6	2.6
BBRI	3.3	3.5	4.1	4.1	3.8
BHOS	?	?	?	?	?
BKIM	3.8	3.4	3.8	3.6	3.6
BPAL	3	3.5	2.8	3.3	3.1
BPAU	1.6	1.4	2.3	1.8	1.8
BTRI	3.1	1.4	2.7	1.8	2.2
BTRV	3	3	3	3	3
CCAR	1.2	1.4	2.1	1.1	1.4
CGAR	1	1.2	1.7	1	1.2
LCAP	3.4	3.1	3.5	2.8	3.2
LUMB	2.8	2	2.7	1.6	2.3
MBRE	3.1	2.2	1.1	2.8	2.3
MSAL	3.2	2	1.1	2.3	2.2
OMOS	1.2	1.9	0.9	1.3	1.3
OMYK	2.9	3	3.3	4.5	3.4
PQUA	?	4	?	4	?
STRU	3	3	3.2	4.4	3.4
TSPA	1.6	1.4	0.9	1.4	1.3

0 - 1.9 = TOLERANT; >2 - 2.9 = MODERATELY TOLERANT

>3 - 3.9 = MODERATELY INTOLERANT >4-5.0 = INTOLERANT

? – UNCERTAIN/NOT AVAILABLE

D3 RESULTS AND DISCUSSION

D3.1 EFR O1: HOPETOWN

D3.1.1 Summary of driver and response information applicable to fish assessment

Hydrology:

VARIABLE	RESPONSE	REASONS	IHI ratings
Base flows	?		4
Seasonality	?		
Zero flows	?		0
Moderate floods	Artificial floods twice daily. Major changes. Increase	hydro-electric releases	-3
Large floods	The daily floods are probably moderate floods. Large floods frequency will have changed due to the large US dams		

Water quality:
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

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).

Diatoms:
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).

Geomorphology:
The PES for geomorphology is a B/C category (77%) (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.
Morphological change - Channel bed rating: 0.94
Upstream-downstream connectivity: 4

IHI (Instream):
Instream IHI EC=D/E (largely to seriously modified). Biggest impacts related to hydrological modification (4), bed modification (3) (sedimentation=3 and benthic growth=3) and Physico-chemical (3) (Louw, 2010).

Riparian vegetation (marginal zone)

VEGRAI = B/C. The intensity of marginal zone vegetation removal was rated as 0 (none) and the extent as 0 (none). Exotic vegetation invasion of the marginal zone was also described as low (0) in intensity (Mackenzie, 2010). Marginal zone rated as falling in EC of C/D (primary impacted by water quantity).

Table D5 Description of reference conditions, present state and impacts on the marginal zone vegetation that would provide overhanging vegetation as cover for fish (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal	Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (Gomphostigma virgatum, *Salix mucronata* subs. mucronata) and non-woody (*Phragmites australis*, *Cyperus marginatus*) vegetation.	Predominated by dense stands of *Phragmites* australis with a distinct lack of woody marginal zone species such as *Gomphostigma virgatum* and *Salix mucronata*, although these species occur with very low abundance. The frequency of inundation disturbance is likely to prohibit recruitment of these species while reeds are able to withstand and even benefit.
Exotic Vegetation		
Water Quantity		
Water Quality		

D3.2 DESCRIPTION OF FISH REACH

EFR O1 Hopetown falls within the Lowland geomorphic zone and EcoRegion (level II) 26.01, Natural resource unit A, Management Resource Unit Orange B within quaternary catchment D33G. The fish habitat segment or reach selected for the purpose of the fish assessment of site EFR O1 includes the reach from the Van Der Kloof Dam to confluence of Vaal River.

D3.3 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR O1 under reference conditions is provided in Table D6.

Table D6 Estimated habitat composition available to fish in reach EFR O2 under natural/reference conditions

Velocity-Depth Category	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	3	2	3	3
Overhanging vegetation:	3	3	2	2
Undercut banks & root wads:	2	2	1	1
Substrate:	3	3	4	4
Instream vegetation:	2	2	1	1
Water Column:	5	1	5	1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition: Based on the available fish distribution data and expected habitat composition of the river reach of site EFR O1, eleven indigenous fish species have a high to definite probability of occurrence under reference conditions in this reach (Table D7). The expected habitat composition at the site also met the requirements of this fish species. The

expected FROC provided in Kleynhans et al. (2007) for site D3ORAN-HOPET was broadly used to determine the reference FROC for reach EFR O1, with changes made based on other information.

PRESENT ECOLOGICAL STATUS: FISH

Table D7 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
ASCL	3	2	Flow modification (fluctuating water levels) due to hydro power releases result in decreased suitability of preferred habitats (especially FS, FI over rocky substrates).
BAEN	5	4	Still abundant but must have reduced FROC due to flow modification (especially flushing and laying dry spawning and nursery habitats)
BANO	3	0.5	Not sampled during 210 survey. Expected to still be present in very reduced FROC. Impacted greatly by flow modification (loss of SS and SD habitats and overhanging vegetation due to fluctuations) and presence of predatory alien MSAL.
BKIM	3	1	Not sampled during 2010, but expected to still be present in highly reduced FROC. Impacts similar than BAEN but may be more profound on this species being top of food chain. Predator that will also be influenced by increase turbidity (esp. related to presence of alien CCAR) and cascading impact on other fish and invertebrates as food sources. Also deterioration of breeding habitats.
BPAU	3	1	Not sampled during 2010. Expected to still be present in highly reduced FROC. Impacted mainly by flow modification (loss of SS & SD habitats with vegetation as cover. Also influenced by alien predatory MSAL.
BTRI	3	2	Present but in reduced FROC due to loss of especially habitats, and potential impact by alien predatory MSAL.
CGAR	4	2	Not sampled during 2010, but should still be present. Though to be impacted by flow modification as this species has preference for slow habitats. Eggs and juveniles may therefore be flushed away or left dry by continuous water fluctuations (associated with hydro power releases).
LCAP	5	4	Still abundant but must have reduced FROC due to flow modification (especially flushing and laying dry spawning and nursery habitats)
LUMB	5	2	Not sampled during 2010, but should still be present. Though to be impacted by flow modification as this species has preference for slow habitats. Also potentially impacted by alien CCAR through competitive feeding in bottom substrates.
PPHI	3	2.5	Sampled during 2010. Though to still be abundant with slight impact related to flow modification (due to loss of slow habitats and vegetation as cover).
TSPA	3	2	Sampled during 2010. Though to still be abundant with slight impact related to flow modification (due to loss of slow habitats and vegetation as cover).
CONFIDENCE RATING	**3**	**3**	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D8 Fish Response Assessment Index (FRAI) results for the EFR O1 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-1.5	100
	Response of species with high to very high preference for FAST-SHALLOW conditions	-1.5	
	Response of species with high to very high preference for SLOW-DEEP conditions	-2.0	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-2.0	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-2.0	85
	Response of species with a very high to high preference for undercut banks and root wads	-1.0	
	Response of species with a high to very high preference for a particular substrate type	-1.5	
	Response of species with a high to very high preference for instream vegetation	-3.0	
	Response of species with a very high to high preference for the water column	-1.5	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0	72
	Response of species moderately intolerant of no-flow conditions	-2	
	Response of species moderately tolerant of no-flow conditions	-3	
	Response of species tolerant of no-flow conditions	-2	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0.0	39
	Response of species moderately intolerant of modified physico-chemical conditions	-3.0	
	Response of species moderately tolerant of modified physico-chemical conditions	-1.5	
	Response of species tolerant of modified physico-chemical conditions	-2.0	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	59
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	3.0	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	1.0	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	3.0	48
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	2.0	
	The impact/potential impact of introduced habitat modifying spp?	2.0	
	How widespread (frequency of occurrence) are habitat modifying spp?	3.0	
FRAI SCORE (%)		**57.6**	
FRAI CATEGORY		**C/D**	
FRAI CATEGORY DESCRIPTION		**Moderately to Largely modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

D3.4 EFR O2: BOEGOEBERG

D3.4.1 Summary of driver and response information applicable to fish assessment

Hydrology:

VARIABLE	RESPONSE	REASONS	IHI ratings
Base flows	Distribution still similar but much lower in the wet season and a little bit lower in the dry season.	The reason for the difference is the large dams upstream and highly regulated flows from Vanderkloof Dam.	4
Seasonality	No change (Distribution still similar but much lower in the wet season and a little bit lower in the dry season).		
Zero flows	Very low flows do occur under natural conditions but no zero flows were evident in natural or current day flows.		-0.5
Moderate floods	Small and medium heavily impacted due to many large dams. Floods even up to 1:10 years can be lost.		-3
Large floods	Very large floods probably not affected.		

Water quality:

PAI=C: Potential variables of concern include toxics (from Koekemoer, 2010), temperature, oxygen (Sherman, 2010; Koekemoer, 2010). Potential presence of herbicides and pesticides (not confirmed).

Diatoms= B/C:

The category for site EFR O2 based on diatoms collected in June 2010 is a B category. The biological water quality fluctuated between a B and C EC during 2005, 2008 – 2009, and 2010. It is evident that there is a gradual deterioration within the reach from Boegoeberg Dam to Augrabies. Nutrient levels are elevated throughout the reach and agriculture seems to be the major impact in this reach. Chloride concentrations were problematic during July 2005 in this reach. Although elevated at times organic pollution does not seem to be a major problem in this reach. Nutrients were elevated for all sampling years indicating continuous impact, while salinity may be problematic at times. The EC for this reach is a B/C (Koekemoer, 2010).

Geomorphology:

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).
Transport capacity (hydrology) highest rating (2.53)
Morphological change - Channel bed rating: 1 (small)
Upstream-downstream connectivity: -0.5 (small change)
Upstream dams impact on sediment supply (-4/10).

IHI (Instream):

Instream IHI EC= C/D (moderately to largely modified). Biggest impacts related to hydrological modification (4), Physico-chemical (2) and bed modification (2) (Louw, 2010).

Riparian vegetation (marginal zone):

VEGRAI = B. The intensity of marginal zone vegetation removal was rated as 0.5 and the extent as 1. Exotic vegetation invasion of the marginal zone was also described as absent (0) in intensity (Mackenzie, 2010). Marginal zone rated as falling in EC of B (largely natural).

Table D9 Description of reference conditions, present state and impacts on the marginal zone vegetation that would provide overhanging vegetation as cover for fish (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal	Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*G. virgatum*, *S. mucronata* subs. mucronata and subs. capensis) and non-woody (*P. australis*, *C. marginatus*) vegetation.	Cobble and bedrock areas have a vibrant population of *G. virgatum*. Other dominants however are *S. mucronata*, *P. Australis, C. marginatus*, *P. decipiens*, P. lapathifolia and *C. dactylon.*
Exotic Vegetation		
Water Quantity		
Water Quality		

D3.5 DESCRIPTION OF FISH REACH

EFR O2 falls within the Lowland geomorphic zone and EcoRegion (level II) 26.05, Natural resource unit D, Management Resource Unit Orange D (RAU D.1) within quaternary catchment D73C. The fish habitat segment or reach selected for the purpose of the fish assessment of site EFR O2 includes the reach from the Boegoeberg Dam wall to end of EcoRegion 26.05 (reference conditions most probably applicable to entire Lowland geomorphic zone stretch, therefore including a section of EcoRegion 29.01).

D3.6 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR O2 under reference conditions is provided in Table D10.

Table D10 Estimated habitat composition available to fish in reach EFR O2 under natural/reference conditions (during wet season baseflow)

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	3	2	4	3
Overhanging vegetation:	3	3	3	2
Undercut banks & root wads:	2	2	2	2
Substrate:	3	3	4	4
Instream vegetation:	3	3	2	2
Water Column:	5	1	4	1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition: Based on available information, at least eleven indigenous fish species have been previously sampled in this reach of the Orange River (Table D11). Three alien fish species (CCAR, GAFF, CIDE) have also been sampled in this river reach.

Based on the available fish distribution data and expected habitat composition of the river reach of site EFR 02, eleven indigenous fish species have a high to definite probability of occurrence under

reference conditions in this reach (Table D11). The expected habitat composition at the site under reference conditions also met the requirements of this fish species. The expected FROC provided in Kleynhans *et al.* (2007) for site D7ORAN-SEEKO was broadly used to determine the reference FROC for reach EFR O2 (see SURVEYDATA sheet of FRAI for rationale behind reference fish species and their expected FROC under natural conditions).

D3.6.1 PRESENT ECOLOGICAL STATUS: FISH

Table D11 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
ASCL	3	2	Change in hydrology, loss of fast shallow habitats over rocky substrates, expected to reduce FROC of this species.
BAEN	5	4	Still abundant but must have reduced FROC due to flow modification (reduced fast habitats, especially impact on spawning and nursery habitat). Water quality may also impact especially early life stages. Moderately tolerant to water quality changes.
BANO	2	0.5	Not sampled during 2010 survey. Expected to still be present in very reduced FROC. Potentially impacted by loss of habitats through modified flows (reduced flow, less overhanging vegetation, and water quality). Flow modification (reduced flow) has a negative impact on the marginal vegetation (riparian and aquatic), a preferred habitat component of this species. Dominance and high abundance of juveniles of larger cyprinids (such as BAEN & LCAP) may also impact this species negatively (Skelton & Cambray, 1981). Impact from CIDE may result in some loss of aquatic vegetation and negatively impacting on vegetation species.
BKIM	3	1.5	Not sampled during 2010, but expected to still be present in reduced FROC (based on angling records). Impacts similar than BAEN but may be more profound as this species is at the top of the food chain (trophic specialist). Impacted by flow modification, water quality deterioration and habitat deterioration. Moderately intolerant to wq changes.
BPAU	4	3.5	Sampled during 2010 and other sites in reach (FROC database). Expected to be present in reduced FROC. Impacted mainly by flow modification (loss of SS & SD habitats with vegetation as cover). Some loss of vegetation and vegetated habitat. Impact from CIDE may result in some loss of aquatic vegetation and negatively impacting on vegetation species.
BTRI	3	2.5	Most abundant species sampled in 2010. Still present in close to natural conditions, with slight modifications related to flow alteration (reduced overhang) and potential water quality modification.
CGAR	3	2.5	Sampled in 2010. Tolerant species expected to still be present in close to natural FROC. Potentially impacted by loss of deep habitats, as well as reduced floodplain-channel connectivity, and some reduction in marginally vegetated areas.
LCAP	5	4.5	Still abundant but expected to have slightly altered FROC due to reduced flows and water quality modification.
LUMB	3	0.5	Not sampled during 2010, but should still be present. 1982 SAIAB record for Prieska. Thought to be impacted by flow modification as this species has preference for slow habitats. Also potentially impacted by alien CCAR through competitive feeding in bottom substrates and bio-turbation from CCAR - smothering of eggs.
PPHI	3	2.5	Sampled during 2010. Thought to be abundant with slight impact related to flow modification (loss of marginal vegetation habitats). May have actually increased in abundance in this reach (reference states Cichlids have become invasive). Alien species will also have negative impact on this species - CCAR – bio-turbation; GAFF - predation on eggs and fry; CIDE - loss of aquatic vegetation.
TSPA	2	1.5	Sampled during 2010. Though to be abundant with slight impact related to flow modification (loss of marginal vegetation habitats). May have actually increased in abundance in this reach (reference states Cichlids have become invasive). Alien species will also have negative impact on this species - CCAR – bio-turbation; GAFF - predation on

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
			eggs and fry; CIDE - loss of aquatic vegetation.
CONFIDENCE RATING	**3**	**3**	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D12 Fish Response Assessment Index (FRAI) results for the EFR O2 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-1.0	100
	Response of species with high to very high preference for FAST-SHALLOW conditions	-1.5	
	Response of species with high to very high preference for SLOW-DEEP conditions	-1.5	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-1.0	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-1.0	85
	Response of species with a very high to high preference for undercut banks and root wads	-1.0	
	Response of species with a high to very high preference for a particular substrate type	-1.5	
	Response of species with a high to very high preference for instream vegetation	-1.5	
	Response of species with a very high to high preference for the water column	-1.0	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0.0	72
	Response of species moderately intolerant of no-flow conditions	-1.0	
	Response of species moderately tolerant of no-flow conditions	-2.0	
	Response of species tolerant of no-flow conditions	-0.5	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0.0	39
	Response of species moderately intolerant of modified physico-chemical conditions	-2.5	
	Response of species moderately tolerant of modified physico-chemical conditions	-1.0	
	Response of species tolerant of modified physico-chemical conditions	-1.0	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	59
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	3.0	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	2.0	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	2.0	48
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	2.0	
	The impact/potential impact of introduced habitat modifying spp?	2.0	
	How widespread (frequency of occurrence) are habitat modifying spp?	2.0	
FRAI SCORE (%)		**66.9**	
FRAI CATEGORY		**C**	
FRAI CATEGORY DESCRIPTION		**Moderately modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from

reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

D3.7 EFR O3 AUGRABIES

D3.7.1 Summary of driver and response information applicable to fish assessment

Hydrology:

VARIABLE	RESPONSE	REASONS	IHI ratings
Base flows	Distribution still similar but much lower in the wet season and a little bit lower in the dry season.	The reason for the difference is the large dams upstream and highly regulated flows from Vanderkloof Dam.	4
Seasonality	Slight change (Distribution still similar but much lower in the wet season and a little bit lower in the dry season).	Large Dams	
Zero flows	Zero flow only occur for 1 month under Natural conditions. No zero flows occurred under current conditions.	Releases (for irrigation etc.)	-0.5
Moderate floods	Small and medium heavily impacted due to many large dams. Floods even up to 1:10 years can be lost.	Many large dams	-3
Large floods	Yes, but probably at smaller scale than the moderate floods. Lag effect. Very large floods probably not affected.	Many large dams	

Water quality: PAI=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 (Sherman, 2010).

Diatoms= B/C

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).

Geomorphology:

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 main stem trap sediments and reduce the sediment load. These reduced loads are being partially replenished by tributary inputs (Rountree, 2010).

Transport capacity (hydrology) highest rating (3.03)

Morphological change - Channel bed rating: 1.5 (small)

Upstream-downstream connectivity: 0 (no change)

Upstream dams impact on sediment supply (-3/10).

Channel-flood zone connectivity: -2.

IHI (Instream):

Instream IHI EC= D (largely modified). Biggest impacts related to hydrological modification (4), Physico-chemical (3) and bed modification (2.3). Sediment = 3, Benthic growth = 2. (Louw, 2010).

Riparian vegetation (marginal zone)

VEGRAI = C. The intensity of marginal zone vegetation removal was rated as 2 and the extent as 3. Exotic vegetation invasion of the marginal zone was also described as absent (0) in intensity (Mackenzie, 2010). Marginal zone rated as falling in EC of B (largely natural).

Table D13 Description of reference conditions, present state and impacts on the marginal zone vegetation that would provide overhanging vegetation as cover for fish (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal Exotic Vegetation Water Quantity Water Quality	Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*G. virgatum*, *S. mucronata* subs. mucronata) and non-woody (*P. australis*, *C. marginatus*) vegetation.	Sparce cover, with recent flood scour observed. LB mostly open *C. dactylon* and *C. marginatus*. Cobble areas have a vibrant population of *G. virgatum*. Other dominants are S. mucronata and *P. australis* and these feature well on RB, but have almost completely been removed on LB by high grazing pressure. *C. dactylon* also shows evidence of grazing and form lawns where it occurs.

D3.8 DESCRIPTION OF FISH REACH

EFR O3 falls within the Lowland geomorphic zone and EcoRegion (level II) 28.01, Natural resource unit E, Management Resource Unit Orange E within quaternary catchment D81B. The fish habitat segment or reach selected for the purpose of the fish assessment of site EFR O3 includes the entire Lowland geomorphic zone within EcoRegion 28.01 (in the river section between Augrabies falls and Onseepkans).

D3.8.1 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR O3 under reference conditions is provided in Table D14.

Table D14 Estimated habitat composition available to fish in reach EFR O3 under natural/reference conditions (during wet season baseflow)

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	3	2	3	2
Overhanging vegetation:	3	2	2	1
Undercut banks & root wads:	2	1	3	1
Substrate:	2	2	4	4
Instream vegetation:	2	2	2	1
Water Column:	5	2	5	2

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition: Based on available information, at least twelve indigenous fish species have been previously sampled in this reach of the Orange River. Two alien fish species (CCAR and GAFF) and one introduced indigenous fish species (OMOS) is also known to be present in this reach.

Based on the available fish distribution data and expected habitat composition of the river reach of site EFR 03, twelve indigenous fish species have a high to definite probability of occurrence under reference conditions in this reach (Table D15). The expected habitat composition at the site under reference conditions also met the requirements of this fish species. The expected FROC provided in Kleynhans *et al.* (2007) for site D7ORAN-BLOUP was broadly used to determine the reference FROC for reach EFR O3 (see SURVEYDATA sheet of FRAI for rationale behind reference fish species and their expected FROC under natural conditions.

D3.8.2 PRESENT ECOLOGICAL STATUS: FISH

Table D15 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
ASCL	2	1	Not sampled during 2010 survey at site, but thought to still be present in reach at reduced FROC. Change in hydrology, loss of FS & FD habitats over rocky substrates, expected to reduce FROC of this species.
BAEN	4	3	Still abundant but may have a reduced FROC due to flow modification (reduced flow resulting in loss of fast habitats and spawning and nursery habitat). Reduced water quality may also impact early life stages. Possible predation impact on eggs and fry from GAFF - may reduce FROC.
BHOS	3	1.5	Although not sampled during current survey, expected to still be present with a reduced FROC. Most probably impacted by flow modification as well as water quality deterioration. Possible predation impact on eggs and fry from GAFF - may reduce FROC.
BKIM	3	2	Sampled during 2010 but expected to occur at reduced FROC. Impacts similar than BAEN but may be more profound on this species being top of food chain (trophic specialist). Impacted by flow modification, water quality deterioration and habitat deterioration. Possible predation impact on eggs and fry from GAFF - may reduce FROC.
BPAU	3	2	Sampled during 2010 in low abundance and known presence at other sites in reach (FROC database). Expected to be present in reduced FROC. Impacted mainly by flow modification (loss of SS & SD habitats with vegetation as cover). Loss of marginal vegetation result in reduced habitat and therefore lower abundance of this species (also feeding and breeding habitats). Possible predation impact on eggs and fry from GAFF - may reduce FROC.
BTRI	3	2.5	Relatively abundant in reach during 2010 survey. Potentially impacted to some extent by reduced flows (loss of habitat, including overhanging vegetation). Possible predation impact on eggs and fry from GAFF - may reduce FROC.
CGAR	4	3.5	Sampled in 2010 and large specimens observed below Augrabies falls. Tolerant species expected to still be present in close to natural FROC. Potentially impacted by loss of deep habitats, as well as reduced floodplain-channel connectivity, and marginal vegetation (especially inundation for breeding purposes). Possible predation impact on eggs and fry from GAFF - may reduce FROC.
LCAP	5	4	Still abundant but expected to have slightly altered FROC due to reduced flows and water quality modification. Possible predation impact on eggs and fry from GAFF - may reduce FROC.
LUMB	1	0.5	Sampled in 1980 above Augrabies falls (SAIAB record). Not sampled during 2010, but expected to still be present in reduced FROC. Thought to be impacted by flow modification as this species has preference for slow habitats. Also potentially impacted by alien CCAR through competitive feeding in bottom substrates. Introduced indigenous OMOS may compete with LUMB in lower OR for food (detritus) and therefore be a possible contributing factor to their scarcity/absence. Possible predation impact on eggs and fry from GAFF - may reduce FROC.
MBRE	4	3.5	Abundant during 2010 survey. Expected to still occur at relatively high FROC, slightly reduced from natural. Possibly impacted by flow modification (loss of SD and SS habitat and water column for cover). Potentially also impacted by water quality deterioration. Possible predation impact on eggs and fry from GAFF - may reduce FROC.

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
PPHI	4	3	Sampled during 2010. Thought to be relatively abundant with slight impact related to flow modification (loss of marginal vegetation habitats). Possible predation impact on eggs and fry from GAFF - may reduce FROC.
TSPA	4	3	Sampled during 2010. Thought to be abundant with slight impact related to flow modification (loss of marginal vegetation habitats). Possible predation impact on eggs and fry from GAFF - may reduce FROC.
CONFIDENCE RATING	**2.5**	**3.5**	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D16 Fish Response Assessment Index (FRAI) results for the EFR O3 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-1.0	100
	Response of species with high to very high preference for FAST-SHALLOW conditions	-1.5	
	Response of species with high to very high preference for SLOW-DEEP conditions	-1.0	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-1.0	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-1.0	94
	Response of species with a very high to high preference for undercut banks and root wads	-1.5	
	Response of species with a high to very high preference for a particular substrate type	-1.5	
	Response of species with a high to very high preference for instream vegetation	-1.0	
	Response of species with a very high to high preference for the water column	-1.0	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0.0	82
	Response of species moderately intolerant of no-flow conditions	-1.0	
	Response of species moderately tolerant of no-flow conditions	-1.5	
	Response of species tolerant of no-flow conditions	-0.5	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0.0	47
	Response of species moderately intolerant of modified physico-chemical conditions	-1.5	
	Response of species moderately tolerant of modified physico-chemical conditions	-1.0	
	Response of species tolerant of modified physico-chemical conditions	-1.0	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	61
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	0.5	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	0.5	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	2.0	51
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	2.0	
	The impact/potential impact of introduced habitat modifying spp?	2.0	
	How widespread (frequency of occurrence) are habitat modifying spp?	2.0	
FRAI SCORE (%)		**76.9**	
FRAI CATEGORY		**C**	
FRAI CATEGORY DESCRIPTION		**Moderately modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

D3.9 EFR O4_VIOOLSDRIF

D3.9.1 Summary of driver and response information applicable to fish assessment

Hydrology:

VARIABLE	RESPONSE	REASONS	IHI ratings
Base flows	Distribution patterns changed slightly but are much lower in the wet season and a little bit lower in the dry season for the current flows.	The reason for the difference is the large dams upstream and highly regulated flows from Vanderkloof Dam.	-3.5
Seasonality	Slight change (Distribution still similar but much lower in the wet season and a little bit lower in the dry season).	Large Dams	
Zero flows	Only under Natural conditions, a total of 7 months over the 68 year period. The longest duration found is two months.	Releases (for irrigation etc.)	1
Moderate floods	Small and medium heavily impacted due to many large dams. Floods even up to 1:10 years can be lost.	Many large dams	-3
Large floods	Yes, but probably at smaller scale than the moderate floods. Lag effect. Very large floods probably not affected.	Many large dams	

Water quality: PAI=C

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. 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). Elevations in nutrient levels are also evidence of this trend. The concentration of some metals were reported to be intermittently high at Pella and Vioolsdrift – some evidence of these elevations was seen, although data is very limited (Sherman, 2010).

Diatoms= B/C

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

Geomorphology:

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).

Transport capacity (hydrology) highest rating (2.79)
Morphological change - Channel bed rating: 0.7)
Upstream-downstream connectivity: 0 (no change)
Upstream dams impact on sediment supply (-2/10).
Channel-flood zone connectivity: -2.

IHI (Instream)

Instream IHI EC= D (largely modified). Biggest impacts related to hydrological modification (2.2), Physico-chemical (3) and bed modification (3). Sediment = 3, Benthic growth = 3. (Louw, 2010).

Riparian vegetation (marginal zone):
VEGRAI = C (74). The intensity of marginal zone vegetation removal was rated as 1 and the extent as 4. Exotic vegetation invasion of the marginal zone was also described as absent (0) in intensity (Mackenzie, 2010). Marginal zone rated as falling in EC of B/C.

Table D17 Description of reference conditions, present state and impacts on the marginal zone vegetation that would provide overhanging vegetation as cover for fish (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal	Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*G. virgatum*, *S. mucronata* subs *mucronata*) and non-woody (*P. australis*, *C. marginatus*) vegetation.	Mostly open bedrock with some alluvium. P. australis, *S. mucronata* and *G. virgatum* are dominants.
Exotic Vegetation		
Water Quantity		
Water Quality		

D3.10 DESCRIPTION OF FISH REACH

EFR O4 falls within the Lowland geomorphic zone and EcoRegion (level II) 28.01, Natural resource unit E, Management Resource Unit Orange F within quaternary catchment D82F. The fish habitat segment or reach selected for the purpose of the fish assessment of EFR O3 includes the entire Lowland geomorphic zone within EcoRegion 28.01 (in the river section between Vioolsdrift weir and the Fish River confluence).

D3.10.1 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR O4 under reference conditions is provided in Table D18.

Table D18 Estimated habitat composition available to fish in reach EFR O4 under natural/reference conditions (during wet season baseflow)

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	3	2	3	2
Overhanging vegetation:	3	2	2	1
Undercut banks & root wads:	2	1	3	1
Substrate:	3	3	5	5
Instream vegetation:	2	2	1	1
Water Column:	5	2	5	2

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition: Based on available information, at least twelve indigenous fish species have been previously sampled in this reach of the Orange River. Two alien fish species (CCAR and GAFF) and one introduced indigenous fish species (OMOS) is also known to be present in this reach.

Based on the available fish distribution data and expected habitat composition of the river reach of EFR 04, twelve indigenous fish species have a high to definite probability of occurrence under reference conditions in this reach (Table 3.15). The expected habitat composition at the site under

reference conditions also met the requirements of this fish species. The expected FROC provided in Kleynhans *et al.* (2007) for site D8ORAN-VIOO was broadly used to determine the reference FROC for reach EFR O4 (see SURVEYDATA sheet of FRAI for rationale behind reference fish species and their expected FROC under natural conditions.

D3.10.2 PRESENT ECOLOGICAL STATUS: FISH

Table D19 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
ASCL	1	0.5	Not sampled during 2010 survey at site, but thought to still be present in reach at reduced FROC (Sampled at Pella by P. Ramolla during 2008/9). Change in hydrology, loss of FS & FD habitats over rocky substrates (especially in low flow period), expected to reduce FROC of this species. Decreased substrate quality associated with increased nutrients and therefore increased algal growth, reduce habitat quality with resultant decreased FROC
BAEN	5	3.5	Still abundant but must have reduced FROC due to flow modification (reduced fast habitats, especially impact on spawning and nursery habitat). Water quality may also impact especially early life stages. (increased toxics, and nutrients reduce habitat condition (substrate algae).
BHOS	4	2	Sampled at relative high abundance during current survey, but thought to be impacted by reduced flows (loss of fast habitats) as well as water quality deterioration
BKIM	3	1	Sampled during 2010 but expected to occur at reduced FROC. Impacts similar than BAEN but may be more profound on this species being top of food chain (trophic specialist). Impacted by flow modification, water quality deterioration and habitat deterioration.
BPAU	4	3	Sampled during 2010 in low abundance and known presence at other sites in reach (FROC database). Expected to be present in reduced FROC. Impacted mainly by flow modification (loss of SS & SD habitats with vegetation as cover). Loss of marginal vegetation results in reduced habitat and therefore abundance of this species (also feeding and breeding habitats).
BTRI	4	3	Relatively abundant in reach during 2010 survey. Potentially impacted to some extent by reduced flows (loss of habitat, including overhanging vegetation).
CGAR	4	3.5	Sampled in 2010 and large specimens observed below Augrabies falls. Tolerant species expected to still be present in close to natural FROC. Potentially impacted by loss of deep habitats, as well as reduced floodplain-channel connectivity, and marginal vegetation (especially inundation for breeding purposes).
LCAP	5	4	Still abundant but expected to have slightly altered FROC due to reduced flows and water quality modification. Increased nutrient may stimulate substrate algal growth, which may be to the advantage for this species, resulting in higher abundance than under natural condition. This is however negative for the overall biotic integrity, as domination by any species result in a shift in the natural equilibrium.
LUMB	1	0.5	Not sampled during 2010, but expected to still be present in reduced FROC. Though to be impacted by flow modification as this species has preference for slow habitats (Lentic habitats rather than lotic habitats). Also potentially impacted by alien CCAR through competitive feeding in bottom substrates. Introduced indigenous OMOS may compete with LUMB in lower OR for food (detritus) and therefore be a possible contributing factor to their scarcity/absence.
MBRE	4	3.5	Abundant during 2010 survey. Expected to still occur at relatively high FROC, slightly reduced from natural. Possibly impacted by flow modification)loss of SD and SS habitat and water column for cover. Potentially also impacted by water quality deterioration (toxics and nutrients).
PPHI	4	3	Sampled during 2010. Thought to be relatively abundant with slight impact related to flow modification (loss of marginal vegetation habitats).
TSPA	4	3	Sampled during 2010. Thought to be abundant with slight impact related to flow modification (loss of marginal vegetation habitats).

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
CONFIDENCE RATING	2.5	3.5	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D20 Fish Response Assessment Index (FRAI) results for the EFR O4 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-1.5	100
	Response of species with high to very high preference for FAST-SHALLOW conditions	-2.0	
	Response of species with high to very high preference for SLOW-DEEP conditions	-1.5	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-1.0	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-1.0	94
	Response of species with a very high to high preference for undercut banks and root wads	-1.5	
	Response of species with a high to very high preference for a particular substrate type	-1.5	
	Response of species with a high to very high preference for instream vegetation	-1.0	
	Response of species with a very high to high preference for the water column	-1.0	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0.0	82
	Response of species moderately intolerant of no-flow conditions	-1.5	
	Response of species moderately tolerant of no-flow conditions	-1.5	
	Response of species tolerant of no-flow conditions	-0.5	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0	47
	Response of species moderately intolerant of modified physico-chemical conditions	-3	
	Response of species moderately tolerant of modified physico-chemical conditions	-1	
	Response of species tolerant of modified physico-chemical conditions	-1	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	61
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	0.5	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	1.0	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	3.0	51
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	2.0	
	The impact/potential impact of introduced habitat modifying spp?	2.0	
	How widespread (frequency of occurrence) are habitat modifying spp?	2.0	
FRAI SCORE (%)		**65.2**	
FRAI CATEGORY		**C**	
FRAI CATEGORY DESCRIPTION		**Moderately modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)
-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

D3.11 EFR C5: UPPER CALEDON

D3.11.1 Summary of driver and response information applicable to fish assessment

Hydrology:
Minimal change from natural.

Water quality & Diatoms:
PAI=B/C and Diatoms EC=B. Potential variables of concern include organics, suspended solids and toxins (Sherman, 2010; Koekemoer, 2010)

Geomorphology:
GAI=C (70%). This is primarily attributed to the high sediment loads (sands and fines) being introduced from the upstream hillslopes and associated drainage lines. Loss of woody vegetation along the banks has been extensive in the 1964-2010 period (duration of the aerial photographic record) and this may have caused some of the bank destabilisation evident at the site. The sand and fine loads are far higher than what could be expected under Reference conditions, and this has caused in-channel and lower riparian changes. Channel bed rating: 3 (Large: clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are however not influenced). Sediment supply: highest rating (change) of all geomorphological components in GAI.

IHI (Instream):
Instream IHI EC=B (largely natural). Biggest impacts related to bed modification (sedimentation=2 and benthic growth=2.5) and physico-chemical modification (nutrients & water clarity) (Louw, 2010).

Riparian vegetation (marginal zone):
VEGRAI = C. The intensity of marginal zone vegetation removal was rated as moderate (2) and the extent as 5 (extreme). Exotic vegetation invasion of the marginal zone was also described as was rated as low (1) in intensity and extreme (5) in extent (Mackenzie, 2010). Marginal zone however rated as falling in EC of C (moderately modified from natural).

Table D21 Description of reference conditions, present state and impacts on the marginal zone vegetation that would provide overhanging vegetation as cover for fish (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal	Expect the marginal zone to be dominated by sedge and hydrophilic grass species, with the small woody, *Gomphostigma virgatum* restricted to riffle habitats. Where the marginal zone is narrow and steep (and does not support sedges easily, woody obligates are expected (*S. mucronata* and *Cliffortia nitidula* mainly).	Patchy, open boulder / cobble with *G. virgatum* and *S. mucronata* as woody indigenous riparian obligates. Alluvial deposits with cobble areas dominated by sedges, especially *C. marginatus.* Composition close to reference, but cover has been reduced by high grazing and trampling pressure. Reduced base flows would favour sedge establishment, but this is not evident due to the overriding effect of domestic stock. Because grasses are more palatable than sedges, the latter has
Exotic Vegetation		
Water Quantity		
Water Quality		

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
		increased at the expense of the former under the current grazing regime. Increased sediment loads do not appear to have resulted in changes to riparian vegetation.

D3.12 DESCRIPTION OF FISH REACH

EFR C5 falls within the lower foothills geomorphic zone and EcoRegion (level II) 15.03, Natural resource unit A, Management Resource Unit Caledon B. The fish habitat segment or reach selected for the purpose of the fish assessment of site EFR C5 includes the lower foothills section of EcoRegion 15.03 that includes site EFR C5.

D3.13 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR C5 under reference conditions is provided in Table D22.

Table D22 Estimated habitat composition available to fish in reach EFR C5 under natural/reference conditions

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	1	2	1	3
Overhanging vegetation:	2	3	1	1
Undercut banks & root wads:	1	1	1	1
Substrate:	2	2	3	4
Instream vegetation:	1	1	0	0
Water Column:	2	1	2	1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition:
Indigenous fish species previously sampled in the Caledon River system in the region of site EFR C5 include the Chubbyhead barb (*Barbus anoplus*), Smallmouth yellowfish (*Labeobarbus aeneus*) and the Orange-Vaal Labeo (*Labeo capensis*) (Table 5.3). Records also exist of two alien fish species previously sampled in the area which include Rainbow trout (*Onchorychus mykkis*) and Brown trout (*Salmo trutta*). Other indigenous species know to occur in the Caledon River system include the Sharptooth catfish (*Clarias gariepinus*), Largemouth yellowfish (*Labeobarbus kimberleyensis*), Rock catfish (*Austroglanis sclateri*), Moggel (*Labeo umbratus*), Southern mouthbrooder (*Pseudocrenilabrus philander*) and Banded tilapia (*Tilapia sparrmanii*). The endangered Maluti minnow (*Pseudobarbus quathlambae*) have also been recorded in the upper reaches of the Orange River within Lesotho, and as the type locality of this species is in the Umkomazana River in Kwa-Zulu Natal (1930's) (Skelton, 1991).

Based on the available fish distribution data and expected habitat composition of the river reach of site EFR C5, three fish species had a high to define probability of occurrence under reference conditions, namely BANO, BAEN and LCAP (Table 3.19). It is furthermore thought that ASCL also have a relatively high probability to have occurred at the site under reference condition and that its absence during recent years may well be due to habitat deterioration. The expected spatial frequency of occurrence (FROC) of these species was based on professional judgement and is

provided in Table D23. The remainder of the indigenous species mentioned above had a low probability of occurrence based on natural distribution and habitat suitability and there were not enough evidence or support to include these species as naturally expected from this reach. CGAR is a tolerant species and it is thought that if this species naturally occurred in the area, it would have been sampled/observed previously. The absence of deep pools in this area (even under natural condition) may also be a limiting habitat factor for especially adults of this species. CGAR, as well as LUMB, would most probably have naturally occurred further downstream where adequate slow-deep habitats were available (lowland geomorph zone). Jubb (1972) indicated that TSPA was introduced into the Caledon River and this species may therefore naturally have been absent from this river system. The presence of PPHI under natural conditions is also uncertain and there is not enough evidence of the potential presence of PQUA to include as an expected species, and due to its general occurrence and preference for headwater streams.

Table D23 Available fish distribution information (presence/date sampled) used to assist in the determination of reference conditions and PES

Site Code:	CAL1	CAL 4	EFR C5	D2CALE-EWR03#	D2LCAL-EWR01	13CF10
≈ Distance (in km) from site EFR C5:	5km upstream	2km upstream	0	40km downstream	In Little Caledon (tributary)	In Little Caledon (tributary)
EcoRegion:	15.03	15.03	15.03	15.01	15.03	15.03
Geomorph zone:	E-Lower foothills	E-Lower foothills	E-Lower foothills	F-Lowland River	E-Lower foothills	Upper foothills
Quaternary:	D21A	D21A	D21A	D21H	D21D	D21D
BANO	2006	2006	2006	FROC	2003	FROC
BAEN	2006	2006	2006, 2010	FROC	2003	
LCAP				FROC	2003	
OMYK*				FROC	2003	
STRU*					2003	

FROC – From Kleynhans *et al.* (2007) database.

Site EWR03_Caledon sampled during September 2003, no fish present.

*Alien species

D3.14 PRESENT ECOLOGICAL STATUS: FISH

Table D24 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
BANO	4	2	Loss of overhanging vegetation as cover, bank erosion, and especially due to presence of aggressive alien predatory fish species.
BAEN	4	3	Decreased habitat quality relayed to sedimentation of substrates (due to catchment and bank erosion). Possibly also reduced flows. Also impacted by migration barriers.
LCAP	4	0	Expected to be lost from this river reach due to the extreme impact on its preferred habitats, namely loss of bottom substrates in especially fats habitats (riffle and rapids). The increased turbidity also resulted in decreased algal growth and therefore reduced food availability for this species.
ASCL	2	0	Extreme loss of bottom substrates of good quality due to extensive erosion resulting in sedimentation ob bottom substrates have resulted in complete loss of this species (due to habitat loss). Food source reduction (invertebrates) may have also contributed to this loss.

CONFIDENCE RATING	**3**	**4**	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D25 Fish Response Assessment Index (FRAI) results for the EFR C5 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-3.0	73
	Response of species with high to very high preference for FAST-SHALLOW conditions	-2.5	
	Response of species with high to very high preference for SLOW-DEEP conditions	-3.0	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-2.5	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-2.5	100
	Response of species with a very high to high preference for undercut banks and root wads	-5.0	
	Response of species with a high to very high preference for a particular substrate type	-3.5	
	Response of species with a high to very high preference for instream vegetation	-2.5	
	Response of species with a very high to high preference for the water column	-2.5	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0.0	97
	Response of species moderately intolerant of no-flow conditions	-3.5	
	Response of species moderately tolerant of no-flow conditions	-2.5	
	Response of species tolerant of no-flow conditions	0.0	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0.0	57
	Response of species moderately intolerant of modified physico-chemical conditions	0.0	
	Response of species moderately tolerant of modified physico-chemical conditions	-3.0	
	Response of species tolerant of modified physico-chemical conditions	0.0	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	50
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	1.0	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	0.0	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	3.0	72
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	1.0	
	The impact/potential impact of introduced habitat modifying spp?	n/a	
	How widespread (frequency of occurrence) are habitat modifying spp?	n/a	
FRAI SCORE (%)		**43**	
FRAI CATEGORY		**D**	
FRAI CATEGORY DESCRIPTION		**Largely modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

D3.15 EFR C6: LOWER CALEDON

Summary of driver and response information applicable to fish assessment

Hydrology:

VARIABLE	RESPONSE	REASONS
Base flows	Decreased	irrigation & urban use
Seasonality	No change	-
Zero flows	Some records and observations (records since 1920's).	-
Moderate floods	Decreased	(upstream dams).
Large floods	No change.	-

Water quality & Diatoms:

PAI=C and Diatoms EC=C. Potential variables of concern include turbidity (range 20 to 22 230 measured between 200 and 2001), possibly toxins (Bloem Water data), suspended solids and the toxin aluminium (Sherman, 2010; Koekemoer, 2010). Potential presence of herbicides and pesticides (not confirmed). Salinity levels in the Caledon system seem to be naturally elevated (Sherman, 2010)

Geomorphology:

GAI=D (55%). This site is in the backup zone of Gariep Dam, and thus the site is strongly influenced by silt deposits in this zone. Vegetation in the riparian zone appears to be stable from 1944-2010 (the duration of the aerial photo record). This is primarily attributed to the extremely high sediment loads (sands and fines) being introduced from the upstream hillslopes and associated drainage lines, and from bottom releases. The sand and fine loads are far higher than what could be expected under Reference conditions, and this has caused in-channel and lower riparian changes.

Morphological change - Channel bed rating: 4.5 (serious to extreme)

Upstream-downstream connectivity: 2 (moderate)

IHI (Instream):

Instream IHI EC=E (seriously modified). Biggest impacts related to bed modification (sedimentation=5 and benthic growth=4) and hydrology rating? (Louw, 2010).

Riparian vegetation (marginal zone):

VEGRAI = B. The intensity of marginal zone vegetation removal was rated as 0 (none) and the extent as 0 (none) (scoured from floods), within nature reserve, therefore no overgrazing, or unnatural clearing). Exotic vegetation invasion of the marginal zone was also described as none (0) in intensity and extent (Mackenzie, 2010). Marginal zone rated as falling in EC of B (largely natural).

Table D26 Description of reference conditions, present state and impacts on the marginal zone vegetation that would provide overhanging vegetation as cover for fish (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal	Expect the marginal zone to be dominated by sedge and hydrophilic grass species, with the small woody, *G.*	Mostly open cobble/boulder and alluvial deposits. Scour damage from recent floods is high. Sedges and *G. virgatum* are sparse and a mix of *P. australis* and *S.*
Exotic Vegetation		
Water Quantity		

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Water Quality	*virgatum* restricted to riffle habitats. Where the marginal zone is narrow and steep (and does not support sedges easily, woody obligates are expected (*S. mucronata* and *C. nitidula* mainly).	*mucronata* dominate steeper alluvial banks.

D3.16 DESCRIPTION OF FISH REACH

EFR C6 falls within the lowland geomorphic zone and EcoRegion (level II) 26.03, Natural resource unit E, Management Resource Unit Caledon D within quaternary catchment D24J. The fish habitat segment or reach selected for the purpose of the fish assessment of site EFR C6 includes the reach from the start of EcoRegion 26.03 to the inflow into the Gariep Dam (all Lowland geomorphic zone).

D3.17 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR C6 under reference conditions is provided in Table D27.

Table D27 Estimated habitat composition available to fish in reach EFR C6 under natural/reference conditions

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	3	2	1	2
Overhanging vegetation:	3	3	2	2
Undercut banks & root wads:	1	1	1	1
Substrate:	2	2	3	3
Instream vegetation:	1	1	0	0
Water Column:	4	2	3	2

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition: Eight indigenous fish species previously sampled in the Caledon River system at site EFR C6 as well as at sites up- and downstream of the site (Table D28). Records also exist of one alien fish species, namely CCAR, previously sampled at the site. Some references indicate the potential presence of Rainbow trout (*Oncorhynchus mykiss*) and Brown trout (*Salmo trutta*) in this reach, and especially in the Gariep Dam downstream of the site (Chutter *et al.,* 1996).

Based on the available fish distribution data and expected habitat composition of the river reach of site EFR C6, eight indigenous fish species have a high to define probability of occurrence under reference conditions (Table D28). These species were all considered as expected species under reference conditions at this site in Kleynhans et al. (2007). The occurrence of TSPA and PPHI under natural conditions in this area is uncertain. Jubb (1972) indicated that TSPA was introduced into the Caledon River and this species may therefore naturally have been absent from this river system.

Table D28 Available fish distribution information (presence/date sampled) used to assist in the determination of reference conditions and PES

Site Code:	13CF11	13CF1	EFR C6	Gariep Dam
≈ Distance (in km) from site EFR C6:	>120 km upstream (Rietspruit ds of Knelpoort)	>100 km upstream (in Webedacht Dam)	0	20 km downstream
EcoRegion:	11.03	11.03	26.03	26.03
Geomorph zone:	Lower foothills	Lowland	Lowland	n/a
Quaternary:	D23J	D23J	D24J	
ASCL			FROC	
BANO	FROC	FROC	FROC	
BAEN	FROC	FROC	FROC, 2010	
BPAU			FROC	
BKIM		FROC	FROC	
CGAR	FROC	FROC	FROC, 2010	
LCAP		FROC	FROC, 2010	
LUMB	FROC	FROC	FROC	
CCAR*	FROC	FROC	FROC	
OMYK*				?
STRU*				

FROC – From Kleynhans *et al.* (2007) database.

*Alien species

D3.18 PRESENT ECOLOGICAL STATUS: FISH

Table D29 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
ASCL	3	1	Loss of prefered FS habitats through flow modification (reduced flows) and SD through sedimentation of pools. Deterioration in rocky bottom substrate habitats (rapids & riffles) as a result of extreme sedimentation/siltation. Potential water quality impacts through high turbidity (clogging gills, reduce feeding). Moderately intolerant to flow changes.
BANO	4	1	Some loss of preferred SD habitats though sedimentation of pools. Loss of overhanging vegetation and cover by large rocky substrates that are embedded. Potentially also water quality (esp. high turbidity).
BAEN	4	3	Loss of preferred velocity depth categories FS & FD due to flow modification, and SD as result of sedimentation of pools. Deterioration in preferred substrate (rocky bottom) due to sedimentation, resulting in reduced spawning success and feeding grounds. Potentially also water quality impact (esp. high turbidity). Moderately intolerant to flow changes.
BPAU	4	3	Slight deterioration expected due to some loss of SD/water column (sedimentation of pools) but primarily as a result of loss in overhanging vegetation.
BKIM	3	1	Moderately intolerant species that react soon to alterations. Moderate intolerance for water quality change, and will be seriously influenced by increased turbidity due to predatory behaviour of adults (reduced feeding success), together with reduced food sources. Loss of preferred FS and FD habitats as result of flow modification ,and SD as result of sedimentation of pools. Reduced substrate quality due to sedimentation will have serious impact on spawning success as well as feeding of especially juveniles/sub-adults.
CGAR	5	3	Tolerant species expected to have suffered only a slight reduction in FROC. This will be associated to loss of deep pool (through sedimentation) as well as reduced food source availability.
LCAP	5	4	Moderately intolerant species, but still relatively abundant in this reach. Slight reduction in FROC as result of habitat loss (FS & FD related to flow modification) and SD due to sedimentation of pools.

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
			Sedimentation of rocky substrates and high turbidity-reduced algal growth will reduce food source availability.
LUMB	4	2	Loss of preferred SD habitat as result of sedimentation of pools. Pool bottom substrates also altered from natural reducing natural food sources (juveniles on invertebrates and adults on detritus and mud).
CONFIDENCE RATING	**3**	**3**	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D30 Fish Response Assessment Index (FRAI) results for the EFR C6 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-1.5	100
	Response of species with high to very high preference for FAST-SHALLOW conditions	-2.5	
	Response of species with high to very high preference for SLOW-DEEP conditions	-2.0	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-2.0	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-2.5	90
	Response of species with a very high to high preference for undercut banks and root wads	-3.0	
	Response of species with a high to very high preference for a particular substrate type	-1.5	
	Response of species with a high to very high preference for instream vegetation	-2.0	
	Response of species with a very high to high preference for the water column	-1.5	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0.0	89
	Response of species moderately intolerant of no-flow conditions	-2.0	
	Response of species moderately tolerant of no-flow conditions	-2.5	
	Response of species tolerant of no-flow conditions	-2.0	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0	58
	Response of species moderately intolerant of modified physico-chemical conditions	-3	
	Response of species moderately tolerant of modified physico-chemical conditions	-2	
	Response of species tolerant of modified physico-chemical conditions	-2	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	40
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	3.0	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	1.0	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	0.5	29
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	0.5	
	The impact/potential impact of introduced habitat modifying spp?	4.0	
	How widespread (frequency of occurrence) are habitat modifying spp?	4.0	
FRAI SCORE (%)		**55**	
FRAI CATEGORY		**D**	
FRAI CATEGORY DESCRIPTION		**Largely modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

D3.19 EFR K7: LOWER KRAAI

D3.19.1 Summary of driver and response information applicable to fish assessment

Hydrology:

VARIABLE	RESPONSE	REASONS	IHI ratings
Base flows	Decreased from natural (wet and dry season)	Abstraction for small towns and irrigation, as well as afforestation.	-1.5
Seasonality	No change		
Zero flows	Increased occurrence: Zero flows very seldom occur under natural conditions on a monthly basis, although very low (almost zero) do occur once or twice over the simulation period. For the current conditions zero monthly flows occur fairly often except during wet periods		0
Moderate floods	Small decrease in small floods		0.5
Large floods	None		

Water quality & Diatoms:
PAI = A/B and Diatoms = C. Potential variables of concern include nutrients (probably related to farming activities) and the toxin aluminium (source unknown, may be natural or anthropogenic, although most like to be related to water treatment facilities) (Sherman, 2010; Koekemoer, 2010). Potential presence of herbicides and pesticides (not confirmed). Salinity levels in the Caledon system seem to be naturally elevated (Sherman, 2010). *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).

Geomorphology:
GA = A/B (90.6%). Agricultural intensity has declined since the 1980's. Many of the slopes previously cultivated are now abandoned to pasture or grassland. The morphology is dynamic but overall stable. The site is considered to be close to the Reference Condition. Cobbles and gravels are mobile - there is **no embeddedness** at the site. **Some bank** and catchment **erosion** may have been initiated by intensive agricultural actions in previous decades, but the there is no evidence of excessive fines in the active channel. This suggests that this impact is minor (Rountree, 2010).
Morphological change - Channel bed rating: 0 (none)
Upstream-downstream connectivity: 0.5 (small change)

IHI (Instream):
Instream IHI EC=B/C (largely natural to moderately modified). Biggest impacts related to bed modification (1.7) (sedimentation=1 and benthic growth=2) and Physico-chemical (1.5) (Louw, 2010).

Riparian vegetation (marginal zone):
VEGRAI = C. The intensity of marginal zone vegetation removal was rated as 0 (none) and the extent as 0 (none). Exotic vegetation invasion of the marginal zone was also described as low (0.5) in intensity (Mackenzie, 2010). Marginal zone rated as falling in EC of B/C (largely natural to moderately modified).

Table D31 Description of reference conditions, present state and impacts on the marginal zone vegetation that would provide overhanging vegetation as cover for fish (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal	Expect the marginal zone to be dominated by sedge and hydrophilic grass species, with the small woody, *G. virgatum* restricted to riffle habitats. Where the marginal zone is narrow and steep (and does not support sedges easily, woody obligates are expected (*S. mucronata* mainly).	Mostly open cobble/boulder and some alluvial deposits. *G. virgatum, S. mucronata* and *C. marginatus* are dominant species.
Exotic Vegetation		
Water Quantity		
Water Quality		

D3.20 DESCRIPTION OF FISH REACH

EFR K7 falls within the Lowland geomorphic zone and EcoRegion (level II) 26.03, Natural resource unit B, Management Resource Unit Kraai C within quaternary catchment D13M. The fish habitat segment or reach selected for the purpose of the fish assessment of site EFR K7 includes the reach from the start of EcoRegion 26.03 to the inflow into the Orange River (all Lowland geomorphic zone) (reference conditions most probably applicable to entire Lowland geomorphic zone stretch, therefore including a section of EcoRegion 18.04).

D3.21 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR K7 under reference conditions is provided in Table D32.

Table D32 Estimated habitat composition available to fish in reach EFR K7 under natural/reference conditions

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	3	2	2	2
Overhanging vegetation:	2	2	1	1
Undercut banks & root wads:	3	1	2	1
Substrate:	3	3	5	5
Instream vegetation:	2	2	1	1
Water Column:	4	2	3	2

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition: Based on available information, at least six indigenous fish species have been previously sampled in the lower Kraai River (Table D33). Another indigenous fish species (ASCL) have been sampled upstream of site EFR K7, and have been included n the expected species list for site D1KRAAI_CORAN (Kleynhans, 2007). No records of alien fish species are available in the lower Kraai River, but four species, namely CCAR, MSAL, OMYK & STRU are known to occur further upstream in the Kraai River. There is a high probability that some or all these species may therefore also frequent or occur in the Lower Kraai River.

Based on the available fish distribution data and expected habitat composition of the river reach of site EFR K7, seven indigenous fish species have a high to definite probability of occurrence under

reference conditions in this reach (Table D33). This include ASCL that as this species are known from localities both up- and downstream (Orange River) of reach EFR K7, also within the same geomorph zone and EcoRegion. The expected habitat composition at the site also met the requirements of this fish species. The expected FROC provided in Kleynhans et al. (2007) for site D1KRAAI-CORAN was broadly used to determine the reference FROC for reach EFR K7.

Table D33 Available fish distribution information (presence/date sampled) used to assist in the determination of reference conditions and PES

Site Code:	D1HOLS-CKRAAI	EFR K7	D1Kraai-CORAN
≈ Distance (in km) from site EFR K7:	44km upstream	0	35km downstream (7km from confluence with Orange)
EcoRegion:	15.06	26.03	26.03
Geomorph zone:	Lower foothills	Lowland	Lowland
Quaternary:	D13G	D13M	D13M
ASCL	FROC		
BANO	FROC		FROC
BAEN	FROC	2010	FROC
BKIM			FROC
CGAR	FROC		FROC
LCAP	FROC	2010	FROC
LUMB	FROC		FROC
CCAR*	FROC		
MSAL*	FROC		
OMYK*	FROC		
STRU*	FROC		

FROC – From Kleynhans *et al.* (2007) database.
*Alien species

D3.22 PRESENT ECOLOGICAL STATUS: FISH

Table D34 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE *: PES	Reason for change in FROC from reference to PES
ASCL	2	1	Slight loss of preferred FS habitats through flow modification (reduced flows) and slight deterioration in rocky bottom substrate habitats (rapids & riffles) as a result of some sedimentation and benthic algal growth (related to nutrient enrichment). Potential slight water quality impacts through elevated nutrients and toxins.
BANO	4	2	Slight loss of overhanging vegetation as cover, potentially also water quality impact. Biggest threat is presence of predatory alien species.
BAEN	5	4	Slight change related to loss of preferred velocity depth categories FS & FD due to flow modification. Deterioration in substrate (rocky bottom) due to some sedimentation and benthic algal growth reduced spawning success. Potentially also water quality impact (nutrients & toxins). Juveniles impacted by alien predatory fish and slight impact related to migration barriers.
BKIM	3	2	Moderately intolerant species that react rapidly to alterations. Moderate intolerance for water quality change, and will be seriously influenced by increased turbidity due to predatory behaviour of adults (reduced feeding success). Mention of some high turbidity spells in lower Kraai at times. Slight loss of preferred FS and FD habitats as result of flow modification. Reduced substrate quality due to sedimentation and benthic algal growth.
CGAR	5	4	Tolerant species expected to have suffered only a slight reduction in FROC. This will be associated to reduced food source availability.

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE *: PES	Reason for change in FROC from reference to PES
LCAP	5	4	Moderately intolerant species, but still relatively abundant in this reach. Slight reduction in FROC as result of habitat loss (FS & FD related to flow modification). Deterioration in substrate (rocky bottom) due to some sedimentation and benthic algal growth reduced spawning success. Potentially also water quality impact (nutrients & toxins). Juveniles impacted by alien predatory fish and slight impact related to migration barriers.
LUMB	5	4	Slight change expected due to altered water quality, some sedimentation of pool substrates and presence of predatory alien fish species.
CONFIDENCE RATING	**3**	**3**	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D35 Fish Response Assessment Index (FRAI) results for the EFR K7 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-1	100
	Response of species with high to very high preference for FAST-SHALLOW conditions	-2	
	Response of species with high to very high preference for SLOW-DEEP conditions	-1	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-2	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-2.5	90
	Response of species with a very high to high preference for undercut banks and root wads	-2.5	
	Response of species with a high to very high preference for a particular substrate type	-1.0	
	Response of species with a high to very high preference for instream vegetation	-2.5	
	Response of species with a very high to high preference for the water column	-1.0	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0.0	89
	Response of species moderately intolerant of no-flow conditions	-1.0	
	Response of species moderately tolerant of no-flow conditions	-1.5	
	Response of species tolerant of no-flow conditions	-1.0	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0.0	58
	Response of species moderately intolerant of modified physico-chemical conditions	-1.5	
	Response of species moderately tolerant of modified physico-chemical conditions	-1.5	
	Response of species tolerant of modified physico-chemical conditions	-1.0	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	40
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	0.5	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	0.5	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	0.5	29
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	0.5	
	The impact/potential impact of introduced habitat modifying spp?	0.5	
	How widespread (frequency of occurrence) are habitat modifying spp?	0.5	
FRAI SCORE (%)		**73.7**	
FRAI CATEGORY		**C**	
FRAI CATEGORY DESCRIPTION		**Moderately modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

D3.23 EFR M8: UPPER MOLOPO

D3.23.1 Summary of driver and response information applicable to fish assessment

Hydrology:

VARIABLE	RESPONSE	REASONS	IHI ratings
Base flows	Reduced	(Mafikeng abstraction)	3 wetland IHI
Seasonality	?		
Zero flows	?		
Moderate floods	n/a	n/a	
Large floods	n/a	n/a	

Water quality & Diatoms:
Wetland IHI water quality = A/B, Diatoms (overall) = A/B (D for MRU C). (Koekemoer, 2010). Diatoms at measuring weir/gauge = A; Bosvarkpark = A (increase in nutrients from eye)(possibly due to large amount of dead vegetation/rotting reeds); Overall water quality in B due to spraying of reeds with herbicides (Sherman, 2010).

Geomorphology:
Reach geomorphology = B (hydrology D/E).
Wetland IHI = B (%). (Rountree, 2010).
Change in baseflows (3/5 rating)
Water quality: A/B.

Riparian vegetation (marginal zone):
Upper section (between weir at eye and first road crossing (approx. 240m long) = A to A/B. Lower section (includes EFR M8) = D or C/D.

Table D36 Description of reference conditions, present state and impacts on the wetland zone vegetation (from VEGRAI, Mackenzie, 2010)

Impacts	Description of REFERENCE STATE	Description of PRESENT STATE
Vegetation Removal	A wide, weakly channelled, valley bottom wetland with permanent inundation is expected. The dominant species by far would be Phragmites australis.	Currently a channelised wetland with deep pools and patchy mosaic of reeds (*P. australis*), bullrushes (*T. capensis*), aqautic vegetation (*P. sweinfurthii*) and Pesicaria spp.
Exotic Vegetation		
Water Quantity		
Water Quality		

D3.24 DESCRIPTION OF FISH REACH

EFR M8 falls within the Lower foothills geomorphic zone and EcoRegion (level II) 11.01, Natural resource unit A, Management Resource Unit UM A within quaternary catchment D41A. The fish habitat segment or reach selected for the purpose of the fish assessment of site EFR M7 includes the reach from the entire NRU A (EcoRegion 11.01 section of upper Molopo River) (all Lower foothills geomorphic zone).

D3.25 REFERENCE CONDITIONS: FISH

Habitat composition: Based on available information and professional judgement (see also description of reference conditions for some drivers below), the expected habitat composition of the river reach EFR M8 under reference conditions is provided in Table D37.

Table D37 Estimated habitat composition available to fish in reach EFR M8 under natural/reference conditions

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	1	4	0	1
Overhanging vegetation:	1	1		1
Undercut banks & root wads:	1	2		1
Substrate:	0	0		0
Instream vegetation:	5	5		3
Water Column:	3	1		1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Species Composition: A report produced by JLB Smith (1994) indicated that previous studies had established the presence of six fish species inhabiting the waters of the spring (Molopo eye), viz. PPHI, TSPA, MSAL (alien), CGAR, BPAU and BBRI(cf.) (also mention of BAEN and TREN sampled in 1983, but not again - probably introduced for fodder for Bass). It can therefore be expected that under natural conditions, at least five fish species (PPHI, TSPA, CGAR, BPAU and BBRI(cf.) would have occurred in the Molopo Eye. During the current study, only PPHI and TSPA were sampled in the eye itself. PPHI, TSPA and CGAR were also sampled at a site in the upper Molopo section (between Molopo eye weir and first road crossing). The relative abundance of all fish species were very low. All available information indicate that the reference fish species assemblage of this reach would have been very similar as those of the Molopo eye site, namely PPHI, TSPA, CGAR, BPAU and BBRI(cf.). At site EFR M8 (Bosbokpark), two indigenous fish species, namely PPHI and TSPA, and one alien fish species MSAL were sampled during the April 2010 site visit. Carcasses of CGAR observed at the site as well as observations made by locals indicate the presence of this fish species at this site. The relative abundance of all fish species was low to moderate. All available information indicate that the reference fish species assemblage of this reach would have been very similar as those of the Molopo eye site, namely PPHI, TSPA, CGAR, BPAU and BBRI (cf.).

The FROC database (Kleynhans, 2007) includes 2 sites within the upper Molopo River within EcoRegion 11.01 (same as EFR site), and indicate the presence of BAEN (translocated), BBRI, BPAL, BPAU, MSAL, PPHI & TSPA. Due to the absence of fish data for reference conditions, and the translocation of fish species into the upper Molopo system (known introduced species include OMOS, BAEN, TREN, MSAL, CCAR and possibly MBRE) it is very difficult to determine the reference fish assemblage for this river section. This decreases the confidence of the PES assessment in terms of fish, which is further reduced as a result of the natural (expected) low fish species richness. The expected fish species of site EFR M8 was therefore based on all the available information regarding fish species previously sampled in the area, with special emphasis on expected habitat composition of the area under natural conditions. Based on available information (other drivers and responses) this area seems to have been a shallow (<0.5m on average) wide valley bottom wetland with primarily reeds as vegetative cover available to fish. The expected species list is therefore determined by the preference or ability of fish species that would occur in such habitats. Six fish species, namely BPAL, BBRI (cf), BPAU, CGAR, PPHI and TSPA is expected in this reach under natural conditions. There is some uncertainty regarding the

identification of BBRI and BPAL. The type locality for BBRI is the Sabie River in Mpumalanga and it is presently though that this (or similar) species found in some other regions may in fact be a different species. The presence of BPAL also seem doubtful, but this species in presently known to occur in the main stem and tributaries of the Orange-Vaal River system. Should the occurrence therefore be true, it may be a reflection of the association of the Molopo to the Orange-Vaal system, while the presence of BBRI again provides evidence of the historic connection of the Molopo River with the Limpopo system.

Table D38 Available fish distribution information (presence/date sampled) used to assist in the determination of reference conditions and PES

Site Code:	Molopo eye	3CWF54	3CWF55	EFR M8
≈ Distance (in km) from site EFR M8:	1 km upstream	?	0.2km upstream	0
EcoRegion:	11.01	11.01		11.01
Geomorph zone:	?	?	E-Lower foothills	E- Lower foothills
Quaternary:	D41A	D41A	D41A	
BAEN (T)	JLB Smith	FROC		
BBRI (cf)	JLB Smith		FROC	
BPAL		FROC		
BPAU	JLB Smith	FROC	FROC	
CGAR	JLB Smith		2010	(2010)
PPHI	JLB Smith & 2010	FROC	2010	2010
TSPA	JLB Smith & 2010	FROC	2010	2010
TREN (T)	JLB Smith			
MSAL*	JLB Smith	FROC	2010	

FROC – From Kleynhans *et al.* (2007) database.

*Alien species

T – Translocated species

D3.26 PRESENT ECOLOGICAL STATUS: FISH

Table D39 Description of the expected FROC and the changes under PES

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
BPAL	2	1	Moderately intolerant species: The habitats available at the site are thought to be adequate to sustain viable populations of this species. They were however not sampled during recent surveys in the area, but there is a possibility that they may well be present in highly reduced FROC. The deterioration in this species within the upper Molopo may be associated with some loss of SS habitat (replaced by SD due to weirs, crossings, channelization) but especially the presence of the destructive predatory alien MSAL. This species is moderately intolerant to water quality change, and although the general water quality is good in the area, past pollution incidences (such as spraying of reeds and pests, including Quelea finches, may have had a radical impact on this species. Increased presence of the omnivorous CGAR may also increase pressure on this species though predation.
BBRI (cf)	2	1	Moderately intolerant species: The habitats available at the site are thought to be adequate to sustain viable populations of this species. They were however not sampled during recent surveys in the area, but there is a possibility that they may well be present in highly reduced FROC. The deterioration in this species is thought to be associated with the presence of the destructive predatory alien MSAL, and potentially also due to altered flow regime (related to water abstraction from eye for Mafikeng). This species is also intolerant to water quality change, and although the general water quality is good in the area, past pollution incidences (such as

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE* CATEGORY A	FREQUENCY OF OCCURRENCE*: PES	Reason for change in FROC from reference to PES
			spraying of reeds and pests, including Quelea finches, may have had a radical impact on this species. Increased presence of the omnivorous CGAR may also increase pressure on this species though predation.
BPAU	3	2	Tolerant species: This is a tolerant species and the changes in habitat and slight water quality deterioration is not though to have had a significant impact on this species. Its reduced FROC (not sampled during recent survey in this reach) may well be attributed to the presence of the predatory alien MSAL. Flow alteration may also have had a small impact as this species is moderately intolerant to flow alterations. Increased presence of the omnivorous CGAR may also increase pressure on this species though predation.
CGAR	2	4	Tolerant species: This species is thought to have increased in FROC within the reach due to inundation (weirs, river crossings, etc.) creating more favourable deep habitats for this species.
PPHI	5	4	Tolerant species: The changes in habitat and water quality is not thought to have had any impact on the FROC of this species, and it is still very common in this river reach. A slight reduction in FROC from natural conditions is expected due to the presence of the alien predatory MSAL, and possibly also increased abundance/occurrence of the omnivorous indigenous CGAR.
TSPA	5	4	Tolerant species: The changes in habitat and water quality is not thought to have had any impact on the FROC of this species, and it is still very common in this river reach. A slight reduction in FROC from natural conditions is expected due to the presence of the alien predatory MSAL, and possibly also increased abundance/occurrence of the omnivorous indigenous CGAR.
CONFIDENCE RATING	**2**	**2**	

*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

Table D40 Fish Response Assessment Index (FRAI) results for the EFR M8 reach

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	0	72
	Response of species with high to very high preference for FAST-SHALLOW conditions	0	
	Response of species with high to very high preference for SLOW-DEEP conditions	-1	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-1	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-1	100
	Response of species with a very high to high preference for undercut banks and root wads	-1.5	
	Response of species with a high to very high preference for a particular substrate type	-2.5	
	Response of species with a high to very high preference for instream vegetation	-1	
	Response of species with a very high to high preference for the water column	-1.5	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	-2.5	82
	Response of species moderately intolerant of no-flow conditions	0	
	Response of species moderately tolerant of no-flow conditions	-2	
	Response of species tolerant of no-flow conditions	-0.5	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	-2.5	53
	Response of species moderately intolerant of modified physico-chemical conditions	-2.5	
	Response of species moderately tolerant of modified physico-chemical conditions	0	
	Response of species tolerant of modified physico-chemical conditions	-1	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	n/a	50
	Response in terms of distribution/abundance of spp with requirement for	2	

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
	movement between reaches or fish habitat segments		
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	1	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	3	63
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	3	
	The impact/potential impact of introduced habitat modifying spp?	0.5	
	How widespread (frequency of occurrence) are habitat modifying spp?	0.5	
FRAI SCORE (%)		**64.7**	
FRAI CATEGORY		**C**	
FRAI CATEGORY DESCRIPTION		**Moderately modified**	

*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

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