E-FLOWS FOR THE LIMPOPO RIVER BASIN:

ENVIRONMENTAL FLOW DETERMINATION

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(Submitted in fulfilment of Milestone 10: Draft E-flows Synthesis Report)

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The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society and the private sector to solve water problems in developing countries and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in

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Limpopo River Commission, Mozambique

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Project:

This project was part of a Resilient Waters Project https://chemonics.com/projects/natural-resources-management-and-water-security-in-southern-africa/ entitled *Natural Resource Management and Water Security in Southern Africa*.

This specific project undertaken by IWMI was titled *Environmental flows for the Limpopo River - building more resilient communities and ecosystems through improved management of transboundary natural resources*

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Below is the list of Project Reports. This report is highlighted

Report number	Report title E-FLOWS FOR THE LIMPOPO RIVER BASIN:
1	Inception Report
2	Basin Report
3	From Vision to Management
4	Specialist Literature and Data Review
5	Present Ecological State - Drivers of Ecosystem Change
6	Present Ecological State - Ecological Response to Change
7	Environmental Flow Determination
8	Risk of Altered Flows to the Ecosystem Services

Cover photo: The Limpopo River, May 2021. Picture G. O'Brien

PROJECT TITLE:

Environmental flows for the Limpopo River - building more resilient communities and ecosystems through improved management of transboundary natural resources

REPORT TITLE:

E-flows for the Limpopo River Basin: Environmental Flow Determination.

PROJECT OBJECTIVES:

This project will provide the necessary evidence to secure environmental flows (e-flows) for increasing the resilience of communities and ecosystems in the Limpopo Basin to changes in streamflow resulting from basin activities and climate change.

TERMS OF REFERENCE:

USAID has funded Chemonics to implement the Resilient Waters Program. In turn this project was a response to a Grant call that had as its overall goal "*to build more resilient communities and ecosystems through improved management of transboundary natural resources*……".

The International Water Management Institute (IWMI) was commissioned by Resilient Waters to undertake a project titled: *Environmental flows (e-flows) for the Limpopo River - building more resilient communities and ecosystems through improved management of transboundary natural resources*. The study incorporated the PROBFLO method to determine e-flows and eveluate the risk of altered flows and non-flow variables to the ecosystems services in the Limpopo Basin. The project has resulted in two final reports including:

- Environmental flow determination in the Limpopo Basin.
- Risk of altered flows to the ecosystems services of the Limpopo Basin.

This report presents the "Environmental flow determination for the Limpopo Basin." This report focuses on the approach adopted to establish e-flows for the basin.

PROJECT HIGHLIGHTS

This list provides key outcomes of the environmental flow determination using PROBFLO for the Limpopo Basin.

- The Limpopo River Basin is spatially one of the largest river basins in the southern Africa, and contains some of the highest biodiversity and complex ecosystem processes of the river systems in the region.
- The water resources of the Limpopo Basin are shared by Botswana, Zimbabwe, Mozambique and South Africa and are over utilised, resulting in unsustainable conditions throughout the basin.
- The environmental flows (e-flows) of the Limpopo Basin represent the volume, timing, duration and frequency of natural flows that are required to maintain the river ecosystems of the basin that will provide important ecosystem services for the vulnerable African communities in the region who depend on the water resources for subsistence.
- The e-flows will allow us to determine how much water is needed to protect the resource and how much can be used so that a suitable balance can be achieved.
- The study used historical data, and data collected from field surveys and experiments undertaken at 18 river sites throughout the Limpopo Basin during the dry period (or low flow period) in 2012 and during the wet period of 2021. These sites were selected to represent the majority of rivers in the basin but excluded the Changane River tributary in the extreme lower end of the basin, which is a brackish wetland system.
- Historically the Marico, Crocodile, Matlabas, Lephalale, Mogalakwena, Luvuvhu, Olifants/Elephantes, Letaba, Bubye and Limpopo main stem from the Marico/Crocodile confluence to the estuary were perennial flowing all year round (MAR of ±20730 10^6m^3 or 89% of flows in the basin). The smaller Ngotwane, Mokolo and Sand Rivers were historically seasonal, flowing once a year (MAR of ±302 10^6m^3 or 1.3% of flows in the basin). The Bonwapitse, Lotsane, Motloutse, Shashe, Mzingwani, Mwanedzi and Shingwedzi Rivers were ephemeral and only flowed when freshet and flood flows occurred associated with rainfall events in these arid regions (MAR of ±2251 10^6m^3 or 9.7% of flows in the basin).
- Today the upper reaches of the main stem Limpopo River from the confluence of the Marico/Crocodile to Lephalale River and the lower reaches from the Elephantes to the estuary are still perennial, along with the Luvuvhu, Olifants/Elephantes and Letaba Rivers (MAR of ±11192 10^6m^3 or 74.2% of flows in the basin). Today the historically perennial Lephalale, Mogalakwena and Bubye Rivers are ephemeral and the historically perennial Marico, Crocodile, Matlabas, and rest of the Limpopo River main stem are now seasonal. The rest of the basin including the historically seasonal Ngotwane, Mokolo and Sand Rivers are all-ephemeral. Today the total seasonal flows are MAR of ±1685 10^6m^3 or 11.2% and ephemeral flows are MAR of ±2209 10^6m^3 or 14.6%.
- Today a total 8197 10^6m^3 or 35% of the flows in the river are abstracted.
- The majority of flows in the basin today are available during seasonal freshets and or floods.
- Different percentages of the total water are required to provide the e-flows required by the ecosystem, ranging from 20% to 49% of the MAR of flows for rivers in the basin. Note that while the middle and lower reaches of the main stem Limpopo River require 15.7% and 20.2% of the MAR as base flows, between $500m^3/s$ and $2000m^3/s$ floods are periodically required (once every three years), thus raising the overall e-flow requirements to >30% of the MAR.
- The proposed total volume of water required to meet e-flows to sustain the ecosystems of the Limpopo River in their present or recommended condition are less than total present flows, but the majority of present available flows are available only during freshet and floods events.

Today the majority of the base e-flow requirements to maintain perennial and or seasonal rivers are not available due to over abstraction.

- Ground water contributes to the base surface river flows and maintains pools in rivers throughout the seasonal and ephemeral parts of the basin. These groundwater dependent river flows and pools provide refuge areas for aquatic life and contribute to the overall resilience of the ecosystem, particularly during dry periods.
- Positive results from providing e-flows will include:
    - Nine of the 18 sites that have recently been seasonal/ephemeral rivers, will return back to their more natural perennial flow state;
    - the ecological condition of the rivers throughout the basin (excluding the Luvuvhu River) will improve compared to the present, and
    - overall water quality in the basin will improve, and
    - the availability of and condition of ecosystem services throughout the basin will improve.
- Proper implementation of e-flows will therefore ensure that the timing, duration and flow volume of rivers that naturally flowed all year round do not stop flowing during the dry season, and that all rivers have enough flow during relevant months throughout a year to sustain the aquatic ecosystem and thus those beneficiaries who depend on them.

SUMMARY

This report documents the culmination of a project to determine the e-flows for the Limpopo River Basin using the PROBFLO Approach. E-flows are those volumes of water, present at the appropriate time of year, that need to remain in a river to maintain the ecosystem on which society depends. E-flows thus describe the flow of water that should be protected to keep the river sustainable, not only for the sake of the ecosystem itself, but for the multiple users who depend on the ecosystem for services. Only when these e-flows are protected, then surplus water can safely and sustainably be withdrawn for use.

The e-flow determination process that has been used in this project is based on the state-of-the-art PROBFLO technique. This is a holistic approach that fully embraces all ecological components of the river and goes beyond what is normally considered in e-flow assessments, it considers the ecological and social consequences or provision of ecosystem services to users. This report documents how e-flows were determined, what the e-flows are and how much water is needed during different months of the year to support the river ecosystem at multiple sites distributed across the Limpopo Basin.

Several supporting documents have been produced (see table above) and can be referred to by the reader for a greater depth of understanding of how the e-flows were derived and importantly what evidence was used to determine e-flows. The final report that follows after this report describes the risk of altered flows to the supporting, regulating, provisioning and cultural ecosystem services, which has application for consideration of trade-offs between e-flows and the past, present and future human use of the water from the rivers, and is thus useful for the implementation and management of e-flows.

A total of 18 sites were selected for e-flow determination, all of which have been selected to adequately represent all of the river reaches of the Limpopo Bain (see Figure i). These sites were selected purely for their biophysical characteristics and data availability and not because of their political location (the preponderance of sites in South Africa is entirely due to the greater number of tributaries and the availability of existing data). Apart from the Shashe River, the e-flows for the seasonal and ephemeral rivers in Botswana that are considered in the next risk assessment report were determined without site surveys, but through the extrapolation of information from nearby sites. This process was used to

include all of the smaller seasonal and ephemeral tributaries of the basin in the risk assessment report (next report). The Changane River tributary that enters the Limpopo just above the estuary was characterised as a saline wetland system during the monograph study in 2012 and not comparable with the other rivers/tributaries of the inland portion of the basin, as such it was excluded from this study.

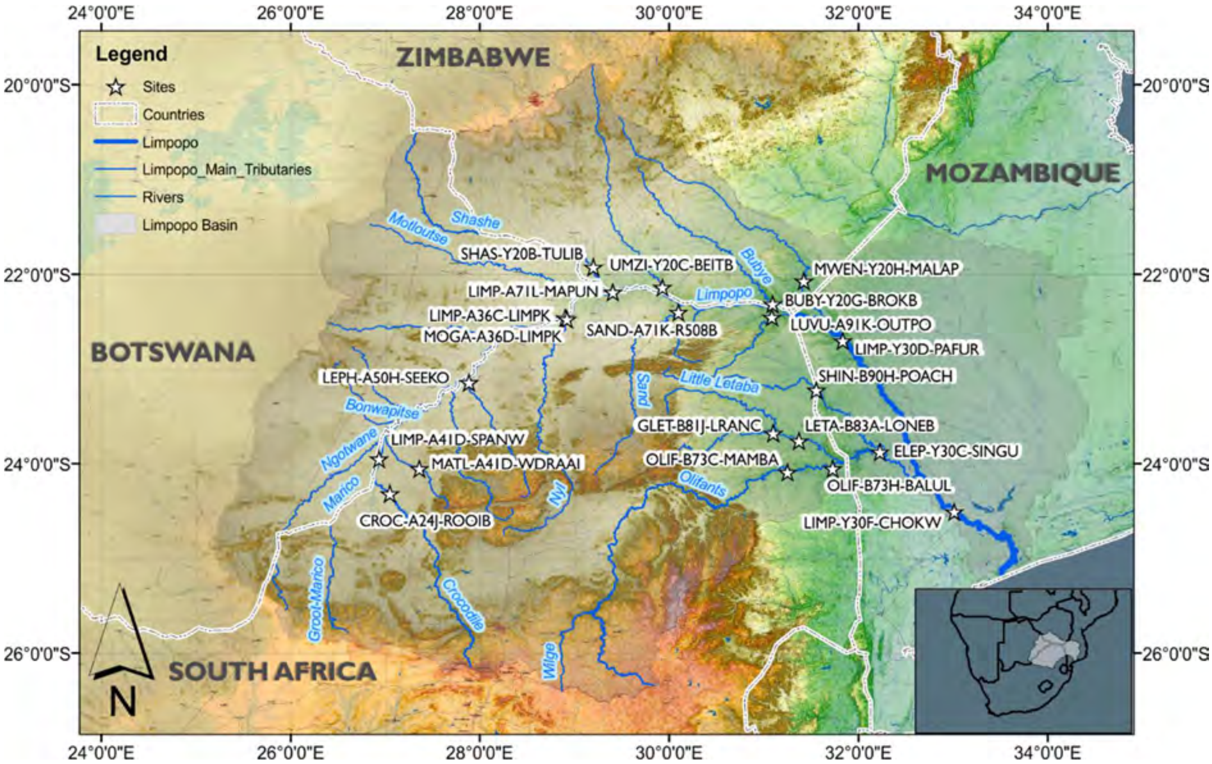


Figure i: River sites identified and included in the e-flow assessment for the Limpopo Basin. E-flows are also determined for the generally dry tributaries in Botswana, but no specific sites were used. The Changane tributary just above the estuary was excluded from survey because it is a saline wetland with minimal channel flow.

The PROBFLO e-flow determination approach combines Relative-Risk Modelling and the use of Bayesian Networks through an eight step process. This is diagrammatically illustrated in Figure ii.

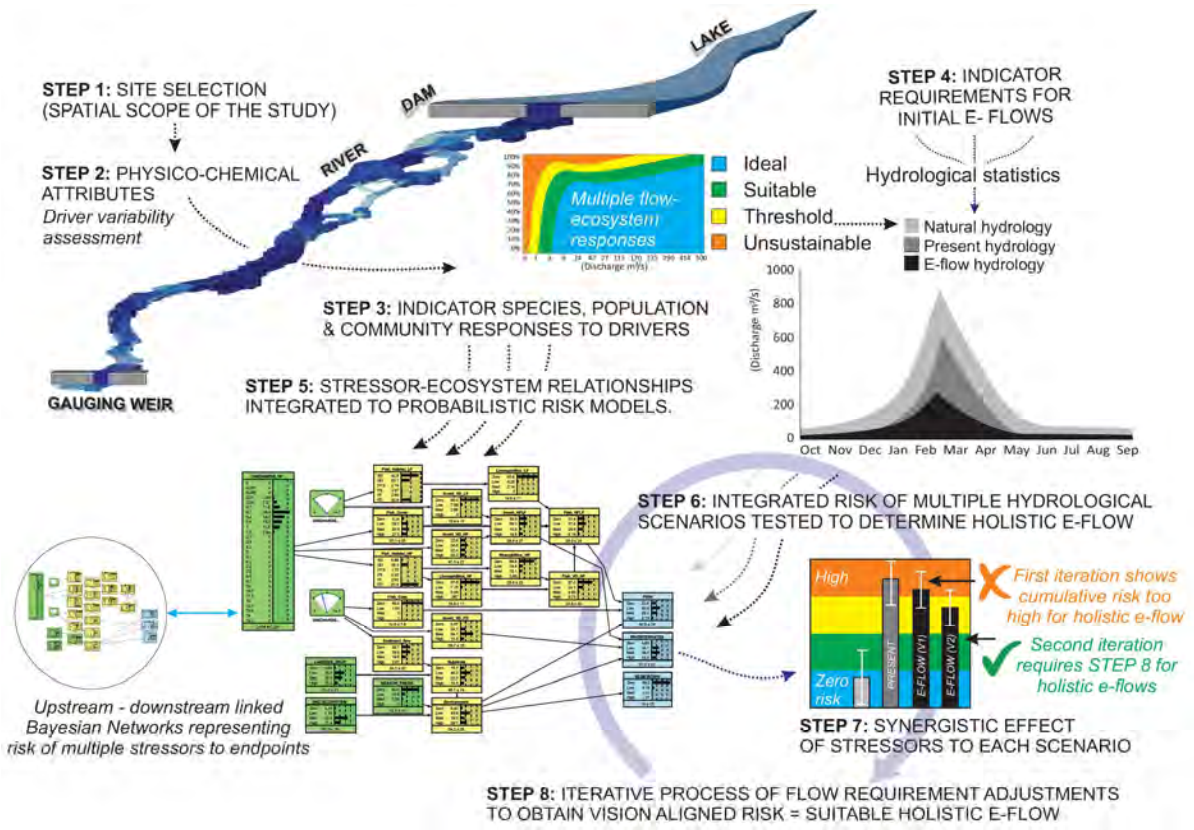


Figure ii: The PROBFLO approach followed for the determination of e-flows for the Limpopo River.

Step 1 - identifies sites that are representative of the river reaches in the basin, generally in the lower reaches of tributaries and periodically down the main-stem, to represent the effects of altered flows in the upstream catchment. Criteria for site selection are based on biophysical characteristics and consider site representativeness of the reach characteristics, access to the site for bio-physical surveys, existing data especially hydrological, and local and regional land use or resource development scenarios. The local management objectives and the vision for each river reach in terms of its protection vs. use/development is also considered.

Step 2 - is where the natural and present-day physico-chemical drivers of the ecosystem (especially the quantity and quality of water and the resulting hydraulic habitat) are described, important because of their role in support of the river ecosystems.

Step 3 – this step describes the natural and present-day "response" of the ecosystems (especially the riparian vegetation, fish, and invertebrates) to the drivers in Step 2, thus the way that the fish, for example, have responded to the river flows. The project specialists document the species, populations and community indicators for each of these components, and note their preferences for the volume, timing, duration and frequencies of river flows. These are the flow-ecosystem relationships that characterise a sustainable ecosystem and are captured in the e-flow determination.

Step 4 – using the understanding of the flow-ecosystem relationship for each ecological component obtained in Step 3, a first and very cursory flow-requirement is determined but for each component separately. This requirement is also designed to ensure that the ecosystem meets with the management vision for the resource.

Step 5 – while using evidence from each site to identify suitable attributes of socio-ecological systems being evaluated and how they (the attributes) interact along risk pathways, a probabilistic, Bayesian Network model is developed to represent the holistic consequences of multiple flow and non-flow stressors to the ecosystem endpoints. Here spatial and temporal system relationships are represented by links within or between models for each site. These risk assessment models are developed and tested using observed data/knowledge of how the ecosystem endpoints respond to differences between the present and natural flows.

Step 6 – with a parametrised socio-ecological risk model, the cumulative risk of flow and non-flow stressors to the cursory flow requirements established in Step 4 can take place. This step is used to initiate the determination of holistic e-flow requirements that include the cumulative impact of multiple flow and non-flow stressors.

Step 7 – the integrated risks to the ecological endpoints determined in Step 6 are evaluated and compared against initial flow requirements. In this step alterative requirements for indicators are considered so that their contribution to e-flows determination is improved.

Step 8 – the preliminary e-flows from above are integrated with the hydrological model to ensure that any discrepancies are removed. ***This produces the final river e-flow requirements for the study***. This adaptive process can be applied through multiple iterations to result in a suitable "integrated, holistic" e-flow for each river reach which is also synchronised between river reaches.

Data collection

This e-flow study is based on high levels of evidence achieved by the collection of a variety of data. During multi-week surveys, data describing all of the ecological components were collected, and are detailed for the physical drivers (Report 4: *Present Ecological State of the Limpopo River: Drivers of Ecosystem Change*) and the biological responses to these drivers (Report 6: *Present Ecological State of the Limpopo River: Ecological Responses to Change*). All of this data was used to describe the present-day state of the hydrology, water quality, geomorphology and hydraulics, as well as the riparian vegetation, fish and aquatic invertebrates (see Figure iv - viii). This present ecological state data is used to determine the flows necessary to sustain the ecosystem in a pre-defined condition. This is Step 3 of PROBFLO.

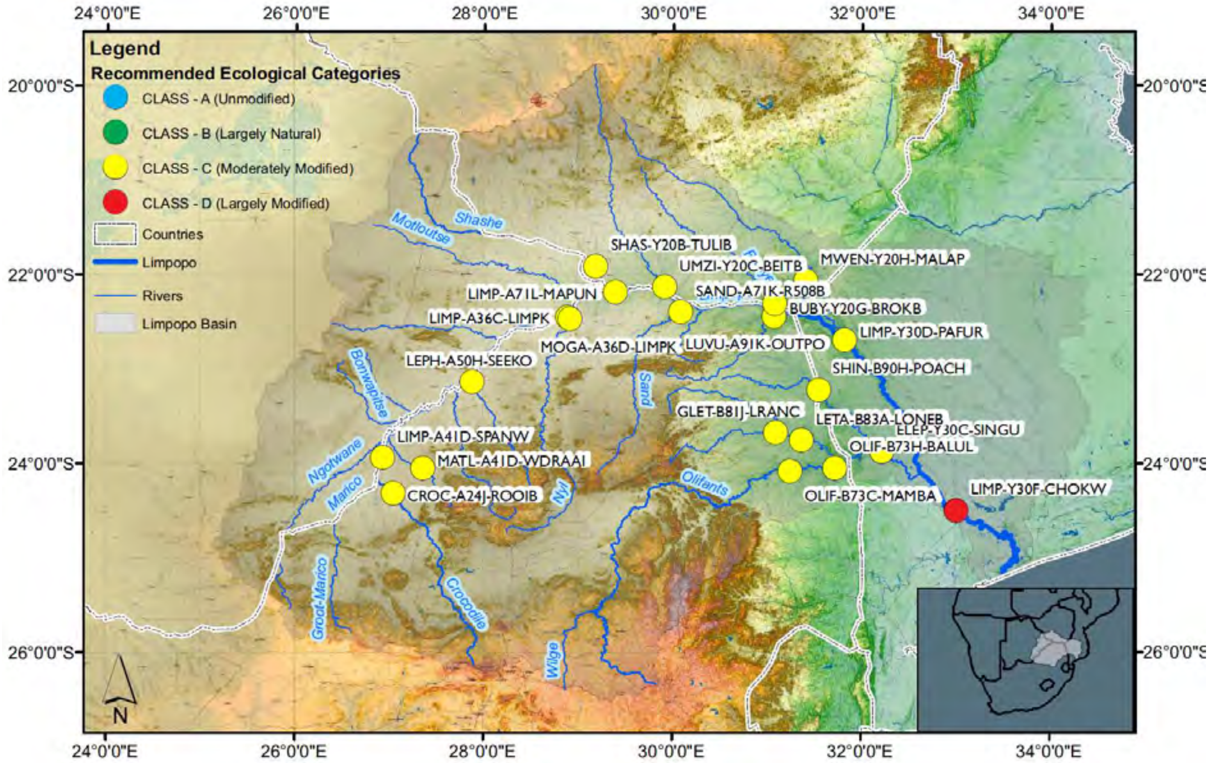


Figure iv: Recommended integrated ecological categories for the river sites selected in the study representing the vision for the sustainable use and protection of water resources in the Limpopo Basin. classification using A-F EcoClassification (refer to the driver and responder sites).

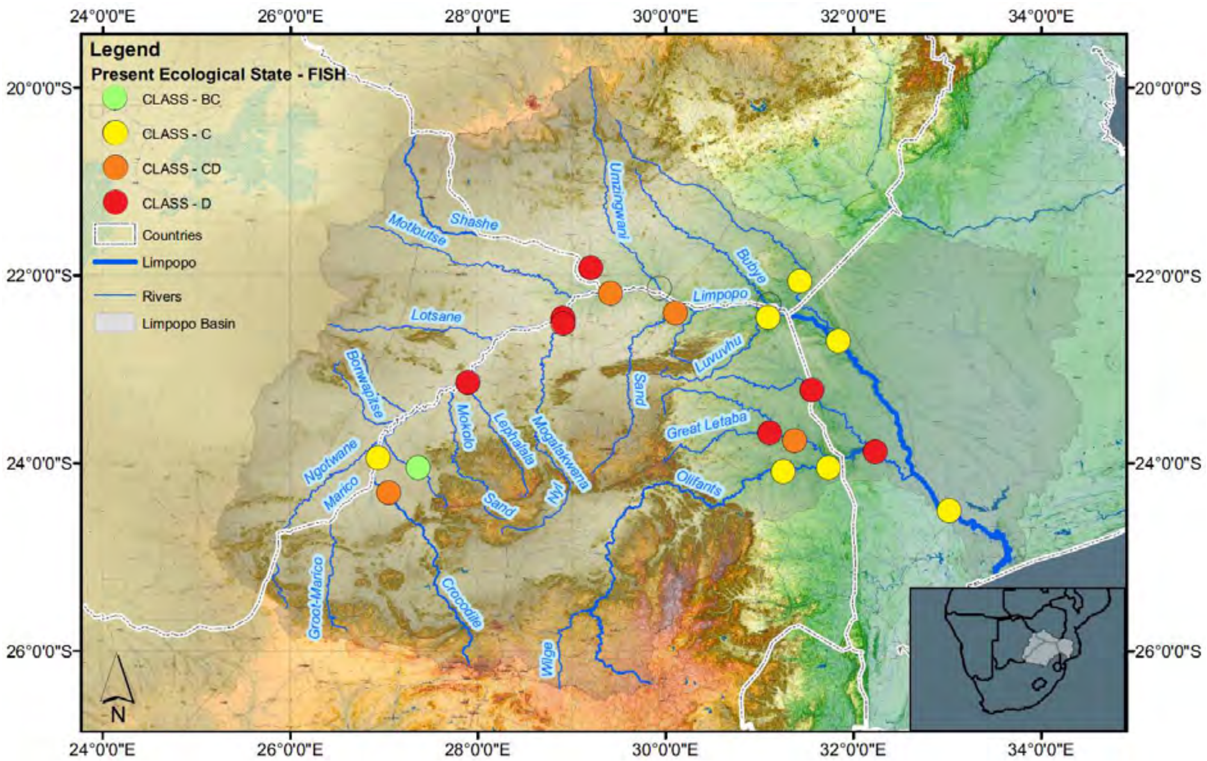


Figure v: Present ecological categories for the fish component of the river sites selected in the study using the A-F EcoClassification (refer to the driver and responder sites).

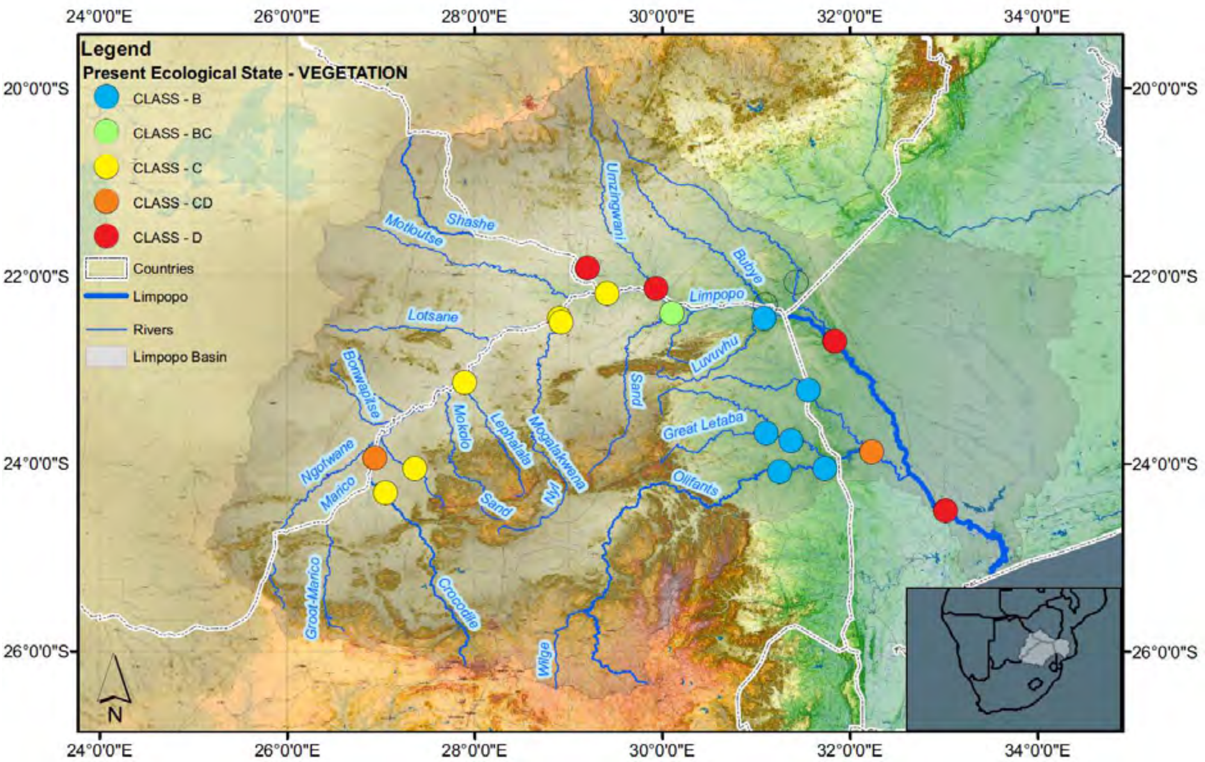


Figure vii: Present ecological categories for the vegetation component of the river sites selected in the study using the A-F EcoClassification (refer to the driver and responder sites).

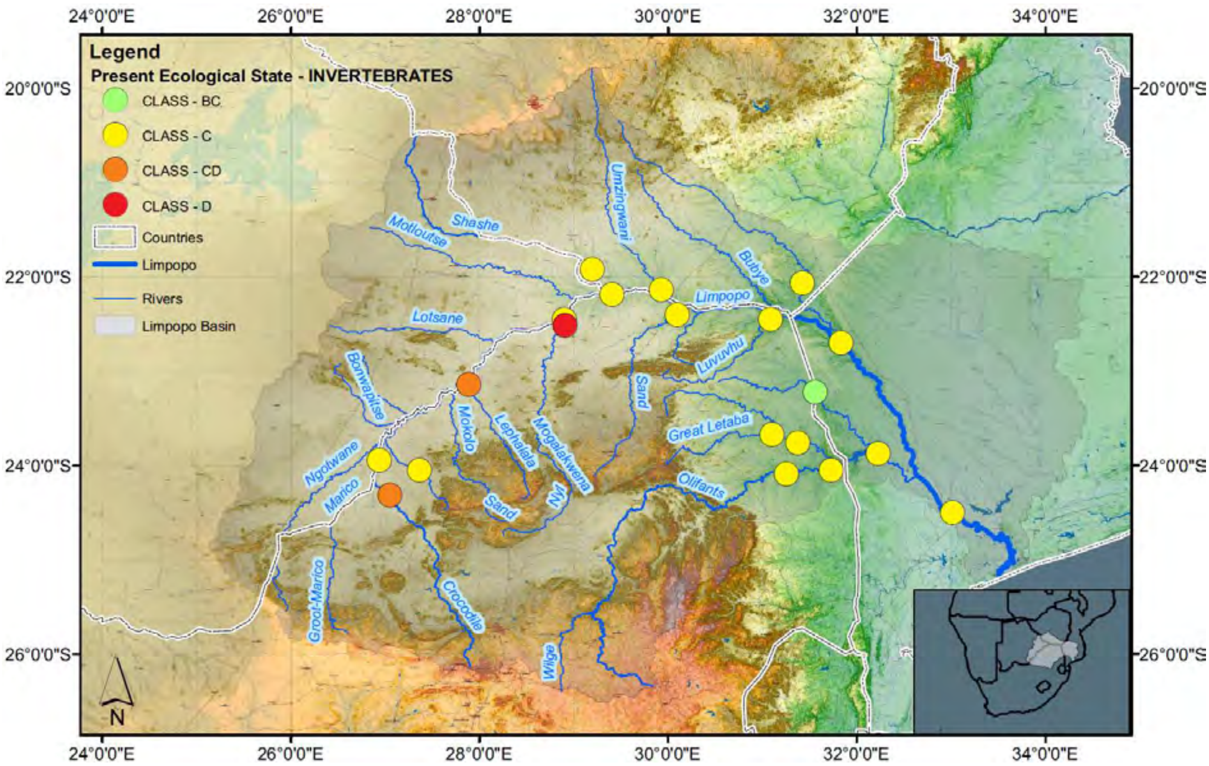


Figure viii: Present ecological categories for the invertebrates component of the river sites selected in the study using the A-F EcoClassification (refer to the driver and responder sites).

The relationship between the drivers of change, in particular the river flows, and the biological responses needs to be described. Below is an example of the relationship between flow and habitat suitability for fish (Figure ix).

FISH_ECO_VD

m³/s	Zero	Low	Med	High
0	0	0	1	99
0.8	0	0	30	70
1.6	1	10	39	50
2.4	1	34	45	20
3.2	1	63	31	5
3.9	20	53	26	1
8.8	50	48	1	1
15.5	85	14	1	0
24.2	95	5	0	0
34.7	90	9	1	0
47.1	85	10	5	0
61.3	75	20	5	0
77.4	65	30	5	0
95.3	65	30	5	0
115.1	65	30	5	0
136.8	65	30	5	0

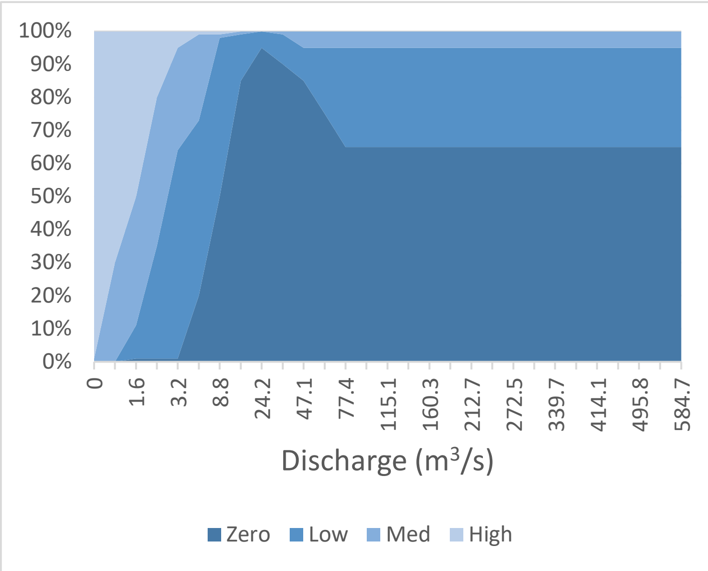


Figure ix: Flow-ecosystem relationship established in the study to represent the suitability of velocity-depth habitat characteristics for rheophillic indicator fishes (Labeo spp.), associated with discharge based on hydraulic relationships between flows and velocity-depth habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which are graphically presented (right). Zero, low, moderate and high-risk ranks included.

Using these relationships, PROBFLO then determines the preliminary e-flow requirements for each of the biological components (e.g. the fish), to ensure there is always sufficient water, in each month of the year, to satisfy the biota. This data is then integrated to ensure that all biota are catered for, for example the fish, invertebrates and vegetation are all catered for (Table ii).

Table ii: Integrated monthly average base flow discharge (m³/s) requirements from the fish, invertebrates and vegetation indicator components for the CROC-A24J-ROOIB site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	4.0	9.0	9.0	9.0	9.0	9.0	9.0	4.0	4.0	4.0	4.0	4.0
50			7.0	8.0	8.0	8.0	8.0	8.0				
80	2.4	3.2	3.2	3.2	3.2	3.2	3.2	2.4	2.4	2.4	2.4	2.4
99.9	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Following an integrated procedure such as this, eventually the complete e-flows are determined for each site, that are synchronised between ecological components and also between river reaches. The final e-flow results are shown below in Table iii.

Table iii: Summary of the e-flow statistics established in the study using indicator requirements for each site. Note the e-flow requirements for the Groot Letaba River, Letaba River and Olifants River have been extracted from formal gazettes and only tested in this study.

Rivers	E-flow site	nMAR ($10^6 m^3$)	% Drought	% Base-flow	% Floods	% Total
Crocodile River	CROC-A24J-ROOIB	596	9.48	25.73	9.37	35.09
Limpopo River	LIMP-A41D-SPANW	591	6.31	24.67	12.4	37.07
Matlabas River	MATL-A41D-WDRAAI	40	1.04	10.64	39.23	49.86
Lephalale River	LEPH-A50H-SEEKO	142	8.79	18.09	21.02	39.11
Limpopo River	LIMP-A36C-LIMPK	801	3.03	23.15	11.35	34.51
Mogalakwena River	MOGA-A36D-LIMPK	243	13.98	19.24	17.82	37.06
Shashe River	SHAS-Y20B-TULIB	687	0	5.33	11.96	17.29
Limpopo River	LIMP-A71L-MAPUN	1684	2.6	16.15	8.12*	24.27$^{\#}$
				>2000 m^3/s (3-5year flood for >7 days).		
Umzingwani River	UMZI-Y20C-BEITB	438	0	4.74	15.5	20.23
Sand River	SAND-A71K-R508B	74	0	9.02	23.41	32.43
Luvuvhu River	LUVU-A91K-OUTPO	560	12.29	24.1	15.97	40.06
Mwenedzi River	MWEN-Y20H-MALAP	412				
Limpopo River	LIMP-Y30D-PAFUR	2792	1.16	10.46	1.63*	12.08$^{\#}$
				Add >2000 m^3/s (3-5year flood for >7 days).		
Shingwedzi River	SHIN-B90H-POACH	87	0.93	15.57	16.34	31.91
Groot Letaba River	GLET-B81J-LRANC	441	***	***	***	42.53
Letaba River	LETA-B83A-LONEB	642	***	***	***	***
Olifants River	OLIF-B73H-BALUL	1918	10.01	17.72	3.34	21.06
Elefantes River	ELEP-Y30C-SINGU	2552	5.52	15.65	3.56*	19.21$^{\#}$
				Add >500 m^3/s (3-5year flood for >5 days).		
Limpopo River	LIMP-Y30F-CHOKW	5572	2.57	10.69	5.08*	15.77$^{\#}$
				Add >1600 m^3/s (3-5year flood for >7 days).		

These e-flow requirements are considered necessary to maintain the wellbeing of the river ecosystems in a sustainable state and would allow there to be a balance between the abstraction or alteration of the flow regime and the protection of the ecosystem. The e-flows include separate consideration of drought flows and also of flood requirements, all of which are necessary to maintain river ecosystems.

The e-flow requirements shown in Table iii are all considerably more than what is presently in the rivers suggesting that existing abstraction and or alteration of instream flows must be managed to meet these e-flow requirements. Importantly the e-flows proposed for nine of the sites, will return rivers now seasonal, back to a perennial state, although with reduced flow compared to their natural states. Some seasonal rivers which were naturally so, will remain like this. The upper and lower Limpopo River sites, Crocodile, Lephalale, Mwenedzi, Luvuvhu and Olifants Rivers are presently in a perennial state, and which should remain in this condition. Sustained perenniality of these rivers will ensure that the ecosystem of these sites become sustainable, an improvement over their presently unsustainable condition.

The aim of this project was to provide the necessary evidence for e-flow determination and determine e-flows for increasing the resilience of vulnerable human communities and ecosystems in the Limpopo Basin to changes in streamflow resulting from basin activities and climate change. This report meets the first part of the aim and includes the e-flow requirements to maintain the ecosystems in a suitable condition. The next report will consider the socio-ecological implications of altered flows.

In the description of the e-flows, it is important to appreciate that there is considerable uncertainty associated with the available quantitative data, so it is important that future implementation of the e-flows is done within an adaptive management environment so that the e-flows can be improved over time.

The final risk assessment report that comes after this one provides information on the risk that the flows may be affecting the wellbeing of the ecological and social systems of the Limpopo River Basin and considers how trade-off decisions between use allocation and protection will affect the sustainability of the river resources.

Consideration of groundwater in the Limpopo River e-flows assessment – an innovation to the e-flow process

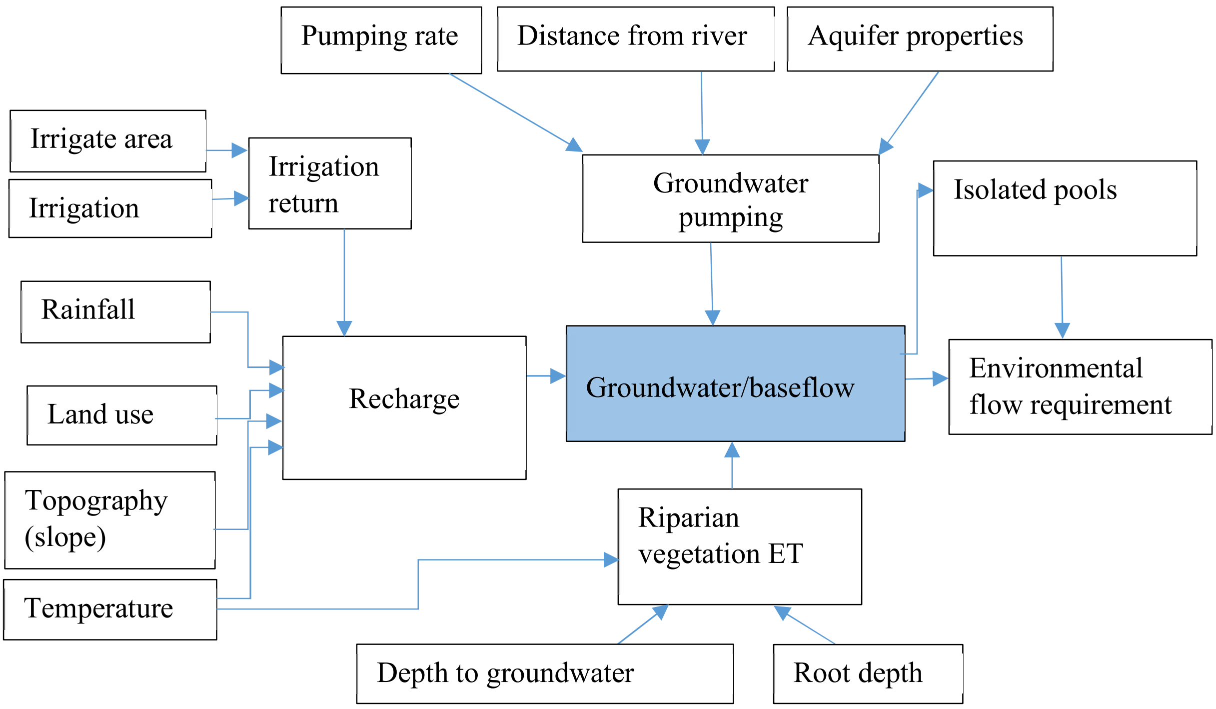
The Limpopo River especially in its lower reaches is dominated by alluvial sediments and in many parts has become seasonal (see data below). Because of this it was anticipated that the groundwater contribution especially to baseflows would be a vital part of this e-flow assessment. Also important was the contribution of groundwater to the maintenance of pools during the dry season of these seasonal river reaches. Both the baseflow and the maintained pools provide critical refuge habitats for aquatic life and thus needed to be incorporated into the e-flows model.

Detailed assessment of the contribution of groundwater to baseflows, and the maintenance of pools, is documented in *Report 4, Chapter 2: Specialist Literature and Data Review* (i.e. historical data and information); *Report 5, Chapter 6: Present Ecological State of the Limpopo River: Drivers of Ecosystem Change* (i.e. detailed data collected) and *Appendix C* of this report (i.e. how groundwater was included in the PROBFLO model).

The probable interactions between ground and surface-water flows were hypothesized in conceptual models for the study (see below). This was an evidence-driven process and depended on historical data/literature as well as data collected as part of this project. The conceptual models are important for understanding the groundwater contribution to setting e-flows and include the hydrological process from groundwater recharge and depletion as well as the contribution of pools to habitat provision. The conceptual model below demonstrates the relationship between groundwater recharge and abstraction and illustrates that groundwater levels subsequently have the potential to contribute to base river flows and e-flows and also support isolated pools within the rivers, thus expanding the resilience of the river to reduced flows.

This groundwater focused conceptual model was integrated into the formal e-flows model and Bayesian Network used to determine e-flows for the Limpopo River. The detailed conceptual model (Appendix C) demonstrates how the groundwater base flow contributions have been integrated into base-low and drought flow contributions that affect all ecosystem service endpoints considered. Specific contributions of groundwater to social and ecological variables considered in the study include contributions to; the (a) velocity-depth habitat characteristic nodes, (2) riparian habitat for vegetation, (3) water input flows, (4) dilution/flushing flows, and (5-7) instream habitat characteristics for supporting ecosystem services variables *viz.* fish, invertebrates and riparian vegetation and including pools. The presence of and condition of groundwater pools that may contribute to resource resilience and affect e-flow estimates have been included in the conditional probability tables of supporting service variables (instream habitat availability nodes) in risk regions where pools are present. The groundwater contributions have also been included in the conditional probability tables of the habitat change node in the resource resilience endpoint. Finally, knowledge of how water abstractions are made from groundwater ecosystems to increase resilience of human communities and the maintenance of water for domestic use endpoint was also considered.

Please see ***Appendix C*** *for a detailed description.*



Preliminary cause and effect conceptual for relationship of groundwater and e-flows

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LIST OF ABBREVIATIONS

DWS	Department of Water and Sanitation
EC	Electrical conductivity
EIS	Ecological Importance and Sensitivity
EMA	Environmental Management Act
EMSEZ	Electro Metallurgical Special Economic Zone
GCMs	General Circulation Models
GDP	Gross Domestic Product
GLeWAP	Groot Letaba Water Development Project
GMTCA	Greater Mapungubwe Transfrontier Conservation Area
GoB	Government of Botswana
GOM-DNA	Government of Mozambique - National Water Directorate
GoZ	Government of Zimbabwe
IMPACT	Int. Model for Policy Analysis of Agric. Commodities and Trade
IPCC	Inter-governmental Panel on Climate Change
IUA	Integrated Units of Analysis
IWRM	Integrated Water Resources Management
KNP	Kruger National Park
LBPTC	Limpopo Basin Permanent Technical Commission
LGC	Limpopo Groundwater Committee
LIMCOM	Limpopo Watercourse Commission
Limpopo RAK	Limpopo River Awareness Kit
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCC	Mzingwane Catchment Council
MCWAP	Mokolo Crocodile West Augmentation Project
NFEPA	National Freshwater Ecosystem Priority Areas
NMAR	Natural Mean Annual Runoff
ORWRDP	Olifants River Water Resources Development Project
PCRGLOBWB	PCRaster Global Water Balance
PES	Present Ecological State
PRR	Preliminary Risk Regions

RCMs	Regional Climate Models
RdM	República de Mozambique
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RESILIM O	Resilience in the Limpopo – Olifants
RESILIM	Resilience in the Limpopo
RQOs	Resource Quality Objectives
RSA	Republic of South Africa
RSAP	Regional Strategic Action Plans
SADC	Southern African Development Community
SARDC	Southern African Research and Documentation Centre
SASS5	South African Scoring System version 5
SWAT	Soil and Water Assessment Tool
UNFCCC	United Nations Framework Convention on Climate Change
WRC	Water Resource Class
WSM	Water Simulation Module
WWTWs	Wastewater Treatment Works
ZINWA	Zimbabwe National Water Authority

1 INTRODUCTION

The rivers of the socio-ecologically important Limpopo Basin are shared by Botswana, Zimbabwe, Mozambique and South Africa in southern Africa. These shared water resources have tremendous social, economic and ecological value and are required by vulnerable human communities who live in and make use of these resources in the basin. The rivers in the basin are heavily utilised by people for subsistence livelihoods and for commercial agriculture, industries and mines, and for rural and urban communities. The water resources of the Limpopo Basin are limited, over-utilised and the goods and services provided by the rivers in the basin are affected by droughts, resulting in water and food insecurity (Petri et. al. 2014). Climate variability has resulted in the unpredictability of the hydrological regime leaving the river in parts without flows for nearly 70% of the year (ADB, 2014). River flows and management of stressors in the catchment is therefore very important for the future sustainability of the water resources especially as growing populations will impose greater demands on available freshwater and associated ecosystem services.

Environmental flows (e-flows) have been described by the Brisbane declaration on environmental flows (2018) as *the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, livelihoods, and well-being* (Arthington et al, 2018). Environmental flows are essential to supporting sustainable development, addressing poverty alleviation and sharing benefits, but poor water resource use management results in changes in flows that reduce downstream ecosystem services that many communities are reliant on for their livelihoods (Hirji and Davis, 2009). To achieve a sustainable balance between the use and protection of the water resources in the Limpopo Basin a better understanding of the e-flow requirements of the rivers in the basin is required.

Some e-flow determination activities have already been undertaken in the Limpopo Basin (Table 1-1). This includes the implementation of the Resource Directed Measures (RDM) of the Department of Water and Sanitation (DWS) in South Africa, and their establishment of the "Ecological Reserve" flows which includes e-flows and daily water requirements of local human communities for their daily consumption and sanitation referred to as "basic human needs". In South Africa the RDM procedures resulting in the Ecological Reserve have previously been undertaken for the Marico River and Upper Crocodile tributaries, Mokolo, Matlabas and Shingwedzi, Letaba and Olifants tributaries of the Limpopo Basin. These e-flows have been established as a part of the RDM implementation procedures and include Water Resource Classification and Resource Quality Objective determination procedures for the Water Management Areas considered. They are generally not aligned to each other in the Limpopo Basin and nor with important and or sensitive ecosystems. In 2013 the Limpopo River Basin Monograph (LIMCOM, 2013) was completed which includes an Environmental Water Requirement (EWR) which is synonymous with e-flows and was carried out at eight sites in the Limpopo Basin. These eight sites span the entire transboundary basin and were surveyed to provide data for priority reaches on the main-stem of Limpopo and important tributaries in Mozambique and Zimbabwe. The LIMCOM (2013) Monograph also summarizes the many e-flow assessments that had been carried out by the South African DWS at that time, for tributaries located in South Africa. Subsequent surveys have taken place in South Africa but not on the mainstem river because of its transboundary nature and no other documented e-flow studies within the Limpopo Basin have been carried out in the other countries.

Table 1-1 provides the name of each site (EWR site) and the name of the river and location where the site is located (River). The Present Ecological State (PES) refers to the overall health of various biophysical attributes of a river compared to the natural or close to natural reference condition (Kleynhans and Louw, 2007). The PES is presented as ecological categories ranging from A to F and are defined as: A – unmodified, natural; B – Largely natural with few modifications; C – Moderately modified; D – Largely modified; E – Seriously modified and F – Critically or extremely modified. A rivers importance to the maintenance of biological diversity and ecological functioning on a local and wider scale is referred to as its Ecological Importance (EI) and system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience) is known as Ecological Sensitivity (ES). Combined these are referred to as the Ecological Importance and Sensitivity (EIS) of a system and is classified as low, moderate, high and very high. The Recommended Ecological Category (REC) is a future state that needs to be achieved for the river and is based on the PES and EIS. Generally, if the EIS for a river is high or very high, the aim should be to improve the river if improvement is realistic and achievable through mitigation. If the EIS is moderate or low, the aim would be to maintain the river in the current PES but not lower than a D category. A PES of E or F is considered ecologically unacceptable, and remediation is required (Kleynhans and Louw, 2007). The %EWR (REC) refers to the percentage of the MAR required to achieve the REC.

Rural stakeholders within the Limpopo Basin still depend on the immediate ecosystem services they derive from the rivers of the Limpopo Basin (see Report 3 of this series "E-Flows for the Limpopo River Basin: From Vision to Management"), and are most vulnerable to altered flows, especially when climate change causes variation in seasonal flow patterns. A more comprehensive determination of e-flows and or improvements in the confidence of and alignment of existing -flow requirements in the Limpopo Basin, was considered extremely urgent. Thus, this project.

PROBFLO is a holistic e-flow determination that includes an e-flow consequence evaluation, nested in a framework approach that has been adapted in Africa and applied throughout the continent. The approach incorporates relative risk assessment and Bayesian Network (BN) probability modelling methods to generate probabilistic models representing the risk of multiple stressors affecting social and ecological endpoints. This approach incorporates a range of tools that can be used to determine the flow requirements of selected indicator components of ecosystems. The approach also evaluates the synergistic effects of e-flow scenarios to ensure that they are suitable in a holistic context and characterises and evaluates the relative risk of flow and non-flow stressors to social and ecological water resources on regional scales to contribute to water resource sustainability management.

The PROBFLO approach specifically includes regional scale ecological risk assessment methods to evaluate multiple sources of stressors, multiple stressors and diverse ecosystems that address multiple social and ecological endpoints (Landis and Wiegers, 1997; 2007). Endpoints have been defined as "specific entities and their attributes that are at risk and that are expressions of a management goal" (USEPA, 2003). PROBFLO is based on a Bayesian Network-Relative Risk Model (BN-RRM) established to evaluate a range of natural and anthropogenic stressors including water withdrawal, seasonality of flow, changes in groundwater levels, pollution, diseases, alien species and a range of altered environmental states. By implementing PROBFLO, we gain a quantitative perspective of the flow-related risks to the resilience of ecosystems and communities. Thus, we are able to link socioeconomic endpoints, for example, food security needs being met by fisheries, with sustainable e-flows. The tool's modular structure quantitatively shows the causal linkages between change drivers (e.g., climate, pollution, water withdrawal from both surface and groundwater) and ecosystem service degradation. It allows users to evaluate the drivers of change and the impact of mitigation measures (e.g. re-establishing flows in tributaries) on the provision of ecosystem services to users.

Table 1-1: Results of historical e-flow studies within the Limpopo Basin

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m³)	%EWR (REC)	LatDD	LongDD
LmEWR1r	Limpopo at Spanwerk	A41D	B/C	High	B/C	591.49	27.6	-23.9447	26.9308
LmEWR2r	Limpopo at Poachers Corner	A71L	B/C	Moderate	B/C	1683	30.9	-22.1842	29.4052
LmEWR3r	Mwanedzi at Malapati	Zimbabwe	C	Moderate	B/C	282.73	22	-22.0639	31.4231
LmEWR4r	Limpopo at Pafuri	Mozambique	C	Moderate	C	2792	30.9	-22.4596	31.503
LmEWR5r	Limpopo at Combomune	Mozambique	C	Moderate	C	3087	26.2	-23.4717	32.4438
LmEWR6r	Shingwedzi d/s Kanniedood Dam	B90H	B/C	Moderate	B	81.63	28.8	-23.1441	31.4728
# LmEWR7r	Limpopo at Chokwe	Mozambique	C	Moderate	C	5572	20.6	-24.5002	33.0104
LmEWR8r	Changane	Mozambique	B/C	Moderate	B/C	434.7	21.8	-24.11416	33.78387
LUV_EWR	Mutshindudi	A91G	C	High	B/C	47.47	29.86	-22.9147	30.48838
MAR_EWR 1	Kaaloog-se-Loop: Below gorge	A31A	B	Very high	B	10.539	76.32	-25.777	26.433
MAR_EWR 2	Groot Marico: Upstream confluence with Sterkstroom	A31B	B	Very high	B	42.08	50.26	-25.669	26.435
MAR_EWR 3	Groot Marico: Downstream Marico Bosveld Dam	A31F	C/D	High	C/D	65.083	23.62	-25.461	26.392
MAR_EWR 4	Groot Marico: Downstream Tswasa Weir	A32D	C	High	C	153.251	7.96	-24.706	26.424
MAR_EWR 5	Klein Marico Downstream Klein Maricopoort Dam	A31E	C	Moderate	C	29.8	4.67	-25.516	26.159

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m³)	%EWR (REC)	LatDD	LongDD
MAR_EWR 6	Polkadraaispruit before confluence with Marico	A31B	B/C	Moderate	B	9.866	31.87	-25.6469	26.4893
MAT_EWR 1	Matlabas Zyn Kloof	A41A	B	Very high	A	5.23	57.07	-24.412	27.60324
MAT_EWR 2	Matlabas at Haarlem East (A4H004)	A41C	C	High	B/C	32.8	33.23	-24.1601	27.47971
MAT_EWR 3	Mamba River Bridge	A41B	B/C	Moderate	B/C	9.54	35.49	-24.2127	27.50718
MAT_EWR 4	Matlabas at Phofu	A41C	B	Moderate	B	35.58	33.42	-24.0516	27.35922
MOK_EWR 1a	Mokolo at Vaalwater	A42C	C/D	High	B	84.84	22.6	-24.2894	28.0924
MOK_EWR 1b	Mokolo at Tobacco	A42E	B/C	High	B	135.03	17.6	-24.1783	27.9777
MOK_EWR 2	Mokolo at Ka'ingo	A42F	B/C	Very high	B	196.2	19.8	-24.065	27.7872
MOK_EWR 3	Mokolo below Mokolo Dam in the Gorge	A42G	B/C	Very high	B	214.5	12.5	-23.968	27.7269
MOK_EWR 4	Mokolo: Malalatau	A42G	C	Very high	B	253.3	16.5	-23.7712	27.7553
Olifants_EWR1	Olifants	B11J	E (D)	Moderate	C	184.52	18.6	-25.75944	29.3125
Olifants_EWR2	Olifants	B32A	C	High	B	500.63	23.8	-25.49567	29.25411
Olifants_EWR3	Klein Olifants	B12E	D	Moderate	C	81.54	27	-25.67358	29.3168
Olifants_EWR4	Wilge	B20J	C	High	B	175.5	29.9	-25.61994	28.99881

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m³)	%EWR (REC)	LatDD	LongDD
Olifants_EWR5	Olifants	B32D	C	High	C	570.98	19.1	-25.304	29.422
Olifants_EWR6	Elands	B31G	E (D)	Moderate	D	60.3	17.9	-25.116	28.9565
Olifants_EWR7	Olifants	B51G	E (D)	Moderate	D	726.52	12.7	-24.52889	29.54639
Olifants_EWR8	Olifants	B71B	E (D)	Moderate	D	813.04	15.2	-24.23889	30.08194
Olifants_EWR9	Steelpoort	B41J	D	High	D	120.17	15.2	-24.775	30.165
Olifants_EWR10	Steelpoort	B41K	D	High	D	336.63	12.1	-24.4965	30.399
Olifants_EWR11	Olifants	B71J	E (D)	High	D	1321.8	13.7	-24.30719	30.78608
Olifants_EWR12	Blyde	B60J	B	High	B	383.7	34.5	-24.40861	30.82639
Olifants_EWR13	Olifants	B72D	C	Moderate	B	1760.7	23.6	-24.12667	31.01694
Olifants_EWR14a	Ga-Selati	B72H	C	Moderate	C	52.2	31.2	-23.99139	30.68333
Olifants_EWR14b	Ga-Selati	B72K	E (D)	Moderate	D	72.74	24.8	-24.0225	31.14667
Olifants_EWR16	Olifants	B73H	C	Very high	B	1916.9	21.6	-24.05117	31.73231
TREUR	Treur	B60C	A/B	Very high	A/B	49.28	45.4	-24.70967	30.81792
DWARS	Dwars	B41H	B/C	High	B/C	31.43	25.9	-24.84392	30.09189
NPS	Noupoortspruit	B11G	C/D	Moderate	C/D	4.28	25.9	-29.7554	30.60588

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m³)	%EWR (REC)	LatDD	LongDD
OLI-EWR1	Upper Klein Olifants	B12C	C	Low	C	44.46	28.9	-25.8169	29.5904
OLI-EWR2	Upper Steelpoort	B41B	C	Moderate	C	63.46	29.8	-25.3831	29.8383
OLI-EWR3	Kranspoortspruit	B32A	B	Very high	A/B	4.71	30.5	-25.4376	29.4758
OLI-EWR4	Klip	B41F	C	Moderate	B/C	5.2	27.5	-25.2249	30.0523
OLI-EWR5	Watervals	B42G	C	Moderate	C	36.39	23.5	-24.8912	30.3105
OLI-EWR6	Upper Spekboom	B42D	C	High	B/C	28.04	28.1	-25.0094	30.5003
OLI-EWR7	Klaserie	B73A	B/C	High	B	25.54	33.1	-24.5427	31.0349
OLI-EWR8	Ohrigstad	B60H	C	Moderate	C	65.49	21.5	-24.5403	30.7223
CROC_EWR 1	Crocodile: Upstream of the Hartbeespoort Dam	A21H	D	Moderate	D	231.1	24.07	-25.8004	27.896
CROC_EWR 2	Jukskei: Heron Bridge School	A21C	E	Moderate	D	139.9	29.19	-25.9539	27.9621
CROC_EWR 3	Crocodile: Downstream of Hartbeespoort Dam in Mount Amanzi	A21J	C/D	High	C/D	143.3	25.02	-25.7168	27.8431
CROC_EWR 4	Pienaars: Downstream of Roodeplaat Dam	A23B	C	High	C	28.2	20.98	-25.4155	28.312
CROC_EWR 5	Pienaars/Moretele: Downstream of the Klipvoor Dam in Borakalalo National Park	A23J	D	High	C	113	11.82	-25.12657	27.80457
CROC_EWR 6	Hex: Upstream of Vaalkop Dam	A22J	D	Moderate	D	26.9	14.96	-25.5214	27.3749

EWR site	River	Quat catchment	PES	EIS	REC	nMAR (106m^3)	%EWR (REC)	LatDD	LongDD
CROC_EWR 7	Crocodile: Upstream of the confluence with the Bierspruit	A24C	D	Moderate	D	463.4	9.14	-24.88661	27.51743
CROC_EWR 8	Crocodile downstream the confluence with Bierspruit in Ben Alberts Nature Reserve	A24H	C	Moderate	C	559.9	14.22	-24.64476	27.32569
CROC_EWR 9	Magalies: Downstream of Malony's Eye	A21F	B	Very high	B	14.7	45.58	-26.01689	27.56581
CROC_EWR 10	Elands: Upstream Swartruggens Dam	A22A	C	High	B/C	10.1	30.48	-25.72655	26.72044
CROC_EWR 11	Sterkstroom: Upstream Buffelspoort Dam	A21K	C	High	C	14	28.41	-25.80739	27.47848
CROC_EWR 12	Buffelspruit before confluence with Plat	A23G	B/C	Moderate	B/C	3.14	35.85	-24.8304	28.2224
CROC_EWR 13	Elands downstream Lindleyspoort Dam	A22E	C	Low	C	18.77	21.9	-25.4811	26.69039
CROC_EWR 14	Waterkloofspruit downstream Rustenburg Nature Reserve	A22H	B/C	Low	B/C	5.469	28.27	-25.4811	26.69039
CROC_EWR 15	Lower Magalies before confluence with Skeerpoort	A21F	C/D	Low	C/D	21.899	21.18	-25.8969	27.5982
CROC_EWR 16	Rietvlei upstream Rietvlei Dam	A21A	C	Low	C	4.788	27.83	-26.0189	28.30442
EWR1	Elephantes below Massingir Dam	Mozambique	C	High	[$] C	ND	14.77	-23.88005	32.253306
[#] EWR2	Limpopo at Chokwe	Mozambique	C	High	[$] C	ND	14.05	-24.2983	32.81861
Estuary	Limpopo	Mozambique	C	Very high	B	ND		N/A	N/A

The aim of this report is to detail the approach followed to determine holistic e-flows for the 14 sites selected in this study, evaluate e-flow requirements and review existing e-flows from an additional 4 sites and use the PROBFLO models and site-specific hydrology to infer e-flows for 5 important tributaries of the Limpopo Catchment in Botswana and Zimbabwe. To achieve this the following important outputs are included and documented in two main reports (Report 7: "*Environmental Flow Determination for the Limpopo Basin"* (this report) and Report 8: "*Risk of altered flows to the ecosystem services of the Limpopo Basin"*:

1. Apply PROBFLO relative risk model and BNs framework for assessing e-flows in ephemeral river systems that incorporates groundwater information (See Appendix C that details the groundwater contribution).
2. The eight (8) Monograph e-flow sites upgraded with additional evidence and linked to ecosystem services. Eight additional sites added, totaling eighteen sites being evaluated in the study.
3. A description of the vision and management objectives for water flows as contained within existing governance structures (national governments and transboundary agencies, especially LIMCOM) and agreed with key stakeholders. Coupled with this, a preliminary livelihoods and socio-economic description of the users of the flow-related ecosystem services and their e-flow requirements to retain resilience in the face of altered flows.
4. Detailed assessment of the alteration of flows in the basin (including historical, present and hypothetical future) and the impact that these will have on the geomorphology and sediment regime, hydraulic habitats within the river, the water quality, and the riparian vegetation.
5. Detailed assessment of the interactions between groundwater and surface water in representative ephemeral and perennial parts of the Limpopo River. The assessment is incorporated into the E-flow conceptual model based on a synthesis of information from two key sites linked to basin-wide data.
6. Detailed documentation of the flow-ecosystem interactions. This includes the impact of flows on sediment movement and channel structure, water quality, the hydraulic habitat, the riparian vegetation, fish and invertebrates in the river.
7. The socio-ecological consequences of altered flows, the risk of developmental and climate change alterations in water flow to several ecological and social endpoints that include the requirements for sustainable agriculture. This includes a risk assessment framework and additional monitoring spreadsheets to contribute to the adaptive management process designed to improve confidence in the assessment over time.
8. Based on the risk posed to these endpoints caused by different scenarios of change, **an e-flow (volume and timing of flow) is determined that would maintain the resilience of the ecosystem and communities in their present form, that considers increasing resilience of the present days condition and also provides possible restoration options**. The final e-flows that are determined come in three main forms, all of which will be important for management of water resources in the basin:
    a. A table of expected river discharges, per month, that will allow regulators to monitor and ensure there is sufficient water (according to the preliminary vision) in the river to continue to provide the services that it should. These flows can be built into management strategies, regulations and can be used to assist with issue of permits for water abstractions.

   b. The interaction and contribution of groundwater to maintaining e-flows during the wet season, and the role groundwater plays in supporting services throughout the year and in particular when river is dry and where only pools remain. This will be documented with a focus on hotspots where such interaction is vital for river functioning.

   c. A presentation of the risks to all of the flow-related ecosystem services (endpoints) that will come about if the drivers of change (e.g. water abstraction, climate change) result in a further change to stream flow. These risks can be used in basin strategies, not only for water resource management, but also for other strategies that involve each of these endpoints, e.g. related to food security and agriculture, human settlements. NOTE that this information is provided in Report 8.

9. E-flows are determined for a range of ecological scenarios including the ecological categories as described in Kleynhans and Louw, (2008[1]) which formed the basis of the Monograph study, and consider associated socio-economic risks.

This report describes the application of all the precursor data and information that is described in reports 1-5, using the PROBFLO approach to determine the e-flows for the basin.

[1] Kleynhans, C.J. and Louw, M. D. (2008). River EcoClassification: Manual for EcoStatus determination. Report No. TT 329/08. Water Research Commission, South Africa.

2 METHODS

2.1 STUDY AREA

The Limpopo Basin falls within the borders of Botswana, Mozambique, South Africa and Zimbabwe, with the majority of the 411 000km^2 catchment located in South Africa (Aurecon, 2013a). Many of the people in the basin are linked to the flows of the Limpopo River and its associated groundwater system and depend on the ecosystem services derived from the rivers including provisioning, regulatory, supporting and cultural services. The approximate population in the Limpopo Basin is close to 20 million and is expected to grow 10% by 2040, which will increase demand for the already limited and over utilised resources (RESILIM, 2013). A large proportion of this population occurs within South Africa and the least in Botswana, while Mozambique and Zimbabwe have the largest rural populations (Aurecon, 2013b).

The economic development in the four countries is disproportionate and leads to uneven water use with South Africa being the biggest water user (RESILIM, 2013). Economic activities linked to water availability in the basin include (i) irrigation agriculture (ii) commercial forestry (iii) mining (iv) power generation (v) industry and (iv) eco-tourism. Continued economic expansion increases the risk of sustaining the e-flows of the Limpopo basin, and planned future activities in the South African sub-basins may require water transfers from other basins. Uneven economic growth in the basin may also cause inequities and stress in parts of the basin. If however the water resources are sustainably managed which includes providing e-flows, then economic transformation/diversification is possible to optimise available water resources.

The most important rivers with regards to volume contributions to the Limpopo main-stem flow are the Crocodile and Olifants Rivers in South Africa and the Umzingwane River in Zimbabwe (Aurecon, 2013a). The arid conditions within Botswana contribute relative few river channels in the western portion of the study area and within Mozambique, besides the Olifants/Elephantes, there is only one tributary, the Changane River, that contributes limited runoff to the Limpopo River but has significant associated wetlands (Aurecon, 2013a). This study undertook to sample 18 sites in the upper, middle and lower Limpopo Basin (Figure 2-1 and Table 2-1), each site was located in the lower reaches of important tributaries and within the Limpopo River main stem at selected locations to consider changes in instream habitat and consider the effect of upstream drivers of change to the ecosystems. **It must be stressed that the location of sites was based entirely on biophysical and not political criteria. The high number of sites in South Africa was determined by the greater number of perennial tributaries in that region, and because some sites had previously been assessed by the South African government and thus had readily available data.**

While the RDM approach has been implemented in various sub-basins in South Africa resulting in the Ecological Reserve or e-flows for numerous sites including the Olifants River and Letaba Rivers, sites where Reserves have been established in these rivers were included in this study so that the risk of altered flows and or consequences of present and e-flow scenarios could be considered in this study. These results allow for direct comparison with the other 12 sites selected for the case study and to improve our understanding of the flow requirements of ecosystems in the study. In addition to the 18 sites that were surveyed in the study, the PROBFLO approach was used in an E-flow framework context (Horne et al., 2017) where desktop e-flows were established for five additional seasonal tributaries, four in Botswana and one in Zimbabwe. This approach was implemented in the study to fill gaps in available e-flow data using a desktop extrapolation e-flow determination approach for sites where no field data was collected. This approach to infer ecosystem requirement data from one site to another is based on a holistic e-flows framework approach such as ELOHA (Poff et al., 2010; Horne et al., 2017). It should be noted that due to resource limitations, logistical problems including restrictions of movement and border closures, and other costs associated with the outbreak of the COVID pandemic, the focus of the study was placed on the perennial part of the system.

Figure 2-1: The Limpopo catchment and sites surveyed

Table 2-1: The rivers, site codes and description for the sites surveyed in the Limpopo River study area

River	Site Code	Description
Crocodile River	CROC-A24J-ROOIB	Crocodile River upstream of confluence with Marico River. Perennial river under natural conditions but seasonal under present conditions.
Limpopo River	LIMP-A41D-SPANW	Limpopo River at Spanwerk below confluence of Marico and Crocodile Rivers. Perennial river under natural and present conditions.
Matlabas River	MATL-A41D-WDRAAI	Site located on the Wegdraai Farm. Perennial river under natural and more seasonal under present conditions.
Lephalala River	LEPH-A50H-SEEKO	Perennial river under natural conditions but ephemeral under present conditions.
Limpopo River	LIMP-A36C-LIMPK	Limpopo River located on Limpokwena Nature Reserve. Perennial river under natural and present conditions.
Mogalakwena River	MOGA-A36D-LIMPK	Mogalakwena R. upstream of confluence with Limpopo River. Perennial river under natural and present conditions.
Shashe River	SHAS-Y20B-TULIB	Shashe river in Zimbabwe. Ephemeral under natural and present conditions.
Limpopo River	LIMP-A71L-MAPUN	Site just upstream of poacher's corner in Mapungubwe National Park. Perennial river under natural and present conditions.
Umzingwani River	UMZI-Y20C-BEITB	Umzingwani river in Zimbabwe. Ephemeral under natural and present conditions.

River	Site Code	Description
Sand River	SAND-A71K-R508B	Sand River upstream of R508B bridge from Messina to Tsipise. Ephemeral under natural and present conditions.
Luvuvhu River	LUVU-A91K-OUTPO	Luvuvhu River in Kruger National Park below Outpost private lodge. Perennial river under natural and present conditions.
Mwenedzi River	MWEN-Y20H-MALAP	Ephemeral under natural and present conditions.
Limpopo River	LIMP-Y30D-PAFUR	Perennial river under natural and present conditions.
Shingwedzi River	SHIN-B90H-POACH	Shingwedzi River within Kruger National Park at Poachers Corner. Seasonal river under natural and present conditions.
Groot Letaba River	GLET-B81J-LRANC	Groot-Letaba River, Letaba Ranch upstream of confluence with Klein Letaba River. Perennial river under natural and more seasonal under present conditions.
Letaba River	LETA-B83A-LONEB	Letaba River upstream of the Letaba Rest Camp in the Kruger National Park, South Africa. Perennial river under natural and present conditions.
Olifants River	OLIF-B73H-BALUL	Olifants River within the Kruger National Park, South Africa at the Balule Weir, below the Olifants River rest camp. Perennial river under natural and present conditions.
Elephantes River	ELEP-Y30C-SINGU	Elephantes river downstream of Lake Massingir. Perennial river under natural and present conditions.
Limpopo River	LIMP-Y30F-CHOKW	Limpopo river close to Chokwe in Mozambique. Perennial river under natural and present conditions.
Inferred sites (for rapid e-flow assessment)		
Ngotwane River	NA	Lower reaches of the Ngotwane River, seasonal river under natural and more ephemeral under present conditions. Requirements inferred from Matlabas/ Sand River.
Bonwapitse River	NA	Lower reaches of the Bonwapitse River, ephemeral river. Requirements inferred from Sand River.
Lotsane River	NA	Lower reaches of the Lotsane River, ephemeral river. Requirements inferred from Sand River.
Motloutse River	NA	Lower reaches of the Motloutse River, ephemeral river. Requirements inferred from Sand River.
Bubye River	NA	Lower reaches of the Bubye River, ephemeral river. Requirements inferred from Sand River.

2.2 E-FLOWS ASSESSMENT

In this study, the PROBFLO holistic e-flow determination and framework approach (O'Brien et al, 2018), was implemented to establish e-flows for 14 sites in the Limpopo Basin, while the results from 4 previously determined e-flow sites on the Letaba and Olifants River were reviewed, and e-flows for an additional 5 sites were inferred (Ngotwane, Bonwapitse, Lotsana, Motloutse and Bubye Rivers). PROBFLO combines Relative-Risk Modelling (RRM) and the use of BNs in a BN-RRM approach to:

1. determine the flow requirements of selected indicators components of ecosystems,
2. evaluate the synergistic effects of e-flow scenarios to ensure they are suitable in a holistic context
3. and characterise and evaluate the relative risk of flow and non-flow stressors to social and ecological water resources on regional scales to contribute to water resource sustainability management.

In this report the first two components of the PROBFLO approach to determine holistic e-flows are reported. As e-flows take into consideration the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems only supporting and regulatory ecosystem services that represent a healthy functioning ecosystem (maintain fish, vegetation and invertebrate communities) are considered in e-flow determinations, while the balance of ecosystem services will be considered in the

Risk Report (7). In a PROBFLO assessment, after e-flows are established using ecosystem information, the social consequences of altered flow scenarios, including e-flow scenarios, are addressed. The outcomes of this component of a PROBFLO assessment allows stakeholders to consider the socio-ecological consequences of multiple scenarios including trade-off implications associated with difference scenarios and opportunities to attain a sustainable balance between the use and protection of water resources (e-flows) while maintaining critical provisioning and cultural ecosystem services.

In the following section we provide a summary of the PROBFLO approach implemented in this study to determine holistic e-flows required to maintain sustainable ecosystems in multiple reaches of a regional water resource, the Limpopo River.

Step 1: Identification and selection of sites

Step 1 in this study was to identify and select sites representative of the rivers reaches in the basin. These sites are listed in Table 2-1 and presented in Figure 2-1. In Figure 2-2 a schematic representation of the rivers and associated sites selected in the study to represent the Limpopo Basin is provided. These sites are located in the lower reaches of major systems to represent the effects of altered flows in the upstream catchment. The first step of the e-flow determination process is to identify a suitable reach of river, and associated ecosystems that can be used to determine the e-flows for a wider reach of the Limpopo River or an important tributary (Figure 2-3). Criteria for site selection for the collection of data are normally based on biophysical characteristics, however this was varied and included representativeness of the reach considered, access to the site for bio-physical surveys, existing data especially hydrological, and local and regional land use or resource development scenarios (as noted above, site selection was done only using ecological and practical considerations and ignored political boundaries). Data form all of these sites is needed so that flow-ecosystem and non-flow stressor and ecosystem relationships can be determined. At this stage the vision for each river reach in terms of its protection vs. use/development must be considered.

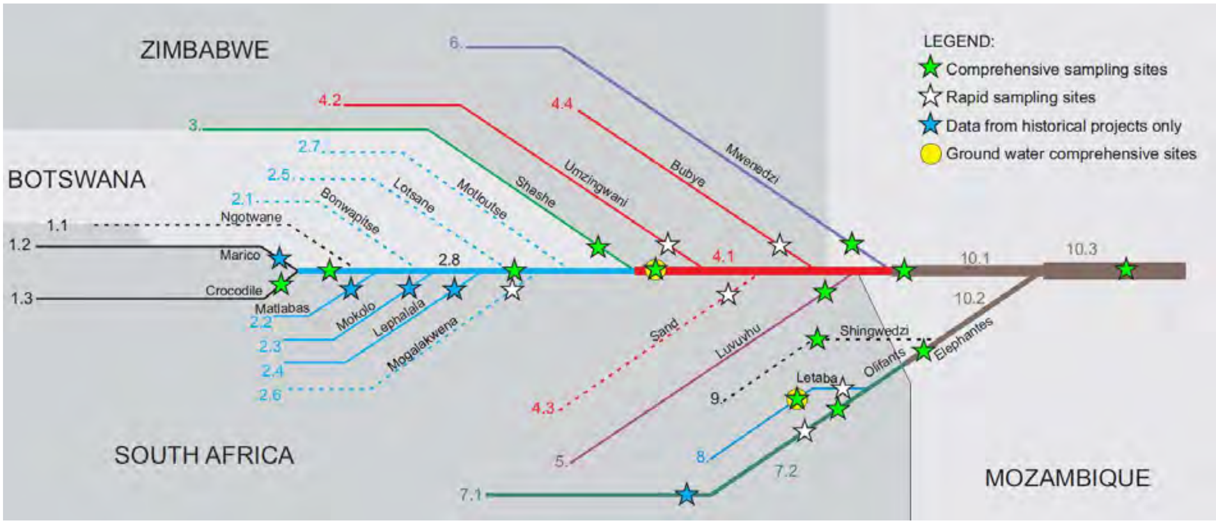

Figure 2-2: Schematic representation of the rivers and associated sites selected in the study to represent the Limpopo Basin.

Figure 2-3: Step 1 of PROBFLO integrated e-flow determination approach. Identification of representative reach of the water resource in the landscape for e-flow determination.

Step 2: Consideration of the physico-chemical dynamics of the ecosystem

In Step 2 of the e-flow determination process the physico-chemical dynamics of the ecosystem for a holistic e-flow assessment are considered for each reach of river (Figure 2-3). Here available flow gauging data and rainfall information is used to establish hydrological statistics for the resource being evaluated. Statistics representing natural and present conditions including the durations, volumes, timing and frequencies of flow are determined. These statistics are summarised into different formats including flow exceedance tables that are foundational to scenario evaluations in PROBFLO.

The flow dynamics of each river reach are described to represent the habitat dynamics which can be achieved through hydraulic modelling. In holistic e-flow determination assessments, at least a cross section (1d), or multiple cross sections (multiple 1d sections) or best of all, an integrated model at a reach scale (2d), are used for the hydraulic modelling. These models facilitate the evaluation of changes in flows as related to habitat characteristics including depths, levels, wetted area, velocities and turbulence of flow within the water column. Hydraulic models and associated hydro-dynamic or fluid-mechanics information is used to describe the availability and or condition of instream and riparian habitat/s through association with flow variability and geomorphological processes. These models can also be used to evaluate future habitat characteristics that could result from predicted e-flow scenarios.

Historical and natural water quality variability of the water resource being considered is also required as foundational information in an e-flow assessment. The data is usually based on available historical vs. present trends in the ionic concentrations of salt, nutrient and toxicants of interest in the study area due to natural geological features of the resource, including naturally high salinities and serpentine soils for example, and anthropogenic activities resulting in water quality stressors. In holistic e-flow determination studies the relationships between river flows and water quality constituents through for example dilution flows required to provide suitable ecosystem conditions is required. Summer freshet flows can also be considered to flush nuisance water quality constituents or maintain the quality of refuge pools in rivers during dry, low flow conditions.

River flows also support groundwater recharge which in-turn will result in groundwater linked pools in rivers during dry periods or reduce groundwater intrusion if the quality of that aquifer is undesirable. Understanding the contribution of groundwater is of particular importance in the Limpopo Basin where so many of the river reaches are dominated by alluvial sand and where surface flows stop for extended periods every year. Groundwater flows contributing to baseflow or sustaining pools during the dry season are thus particularly important aspects. All this physico-chemical information is used to represent the physical dynamics of the habitats of a water resource being considered in an e-flow study and are presented in great detail in Report 4 "*Drivers of Ecosystem Change*".

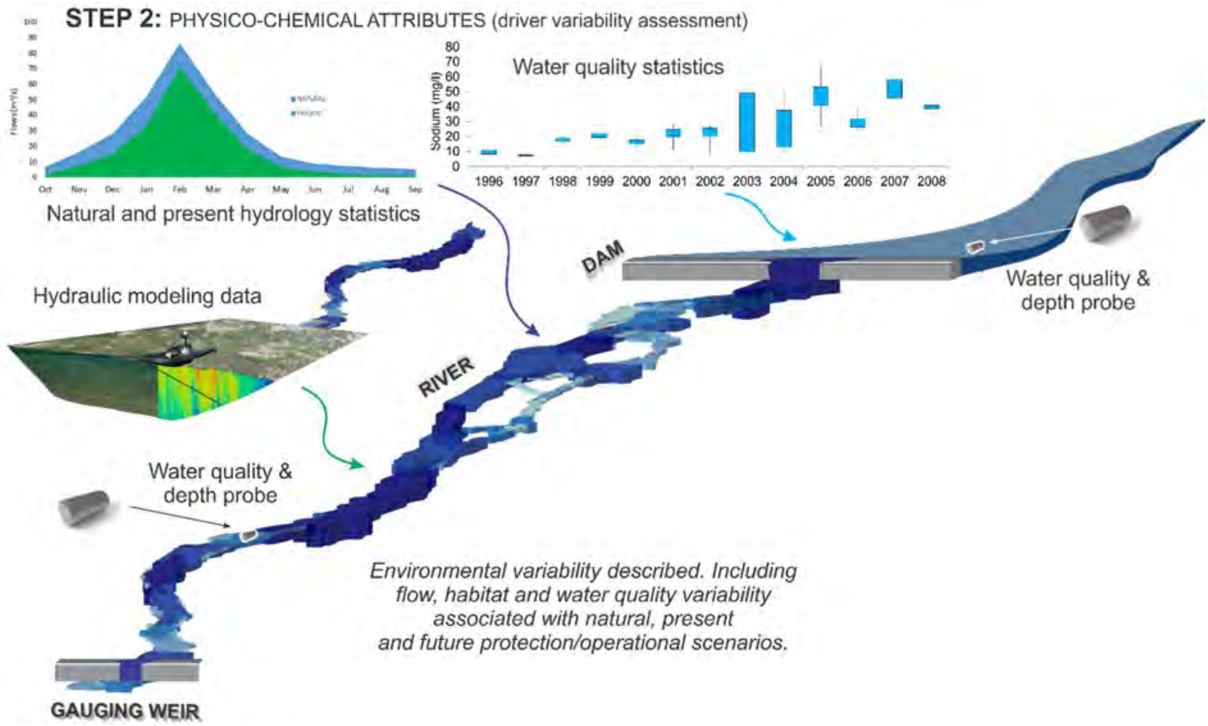

Figure 2-4: Steps 2 of PROBFLO integrated e-flow determination approach. Characterisation of physico-chemical dynamics of ecosystem for holistic e-flow assessment associated with each reach of the system considered.

Step 3: Determine flow-ecosystem relationships

With a good understanding of the habitat characteristics of a river reach, floodplain, lake and or estuarine resource being considered in a PROBFLO assessment, holistic flow-ecosystem relationships that characterise a sustainable ecosystem are determined in Step 3. Here a range of ecosystem lines of evidence (LoEs) are used to identify species, populations and community indicators that represent the ecosystem and their preferences for the volume, timing, duration and frequencies of flows. In this study on the Limpopo Basin, fish, macroinvertebrates and aquatic and riparian vegetation were selected to represent the riverine ecosystems. Holistic e-flow assessments have previously established these ecosystem components as foundational components to consider in e-flow assessments. For specific case studies, amphibians, microbes and or regulator ecosystem services can be included in e-flow assessments to represent functioning sustainable ecosystems.

In this study the detailed information on the flow relationships of the fish, macroinvertebrates and aquatic and riparian vegetation are provided in Report 6: "*Ecological Responses to Change*". A further list of indicators that are included in the BN model is summarised in Appendix A of this report. The use of these indicators has also been summarised in the following section on “Biological Data”, refer to Section 2.2.2.2. The application of these indicators results in a range of flow-ecosystem relationships which in the PROBFLO process are presented as rule or conditional probability tables. In order to represent the flow-ecosystem relationships graphically, the rule and conditional probability relationships are represented in stacked area charts that represent the ecological components as areas stacked in relation to discharge. The stacked area charts used to represent the relationships are cumulative areas and always represents 100%. These are divided into ranks that relate, for example, to ideal or pristine (synonymous with zero risk rank), sustainable or suitable (synonymous with low-risk rank), threshold of potential concern (synonymous with moderate-risk rank) and unsustainable or unsuitable conditions (synonymous with high-risk rank) in the graphs (see Figure 2-5).

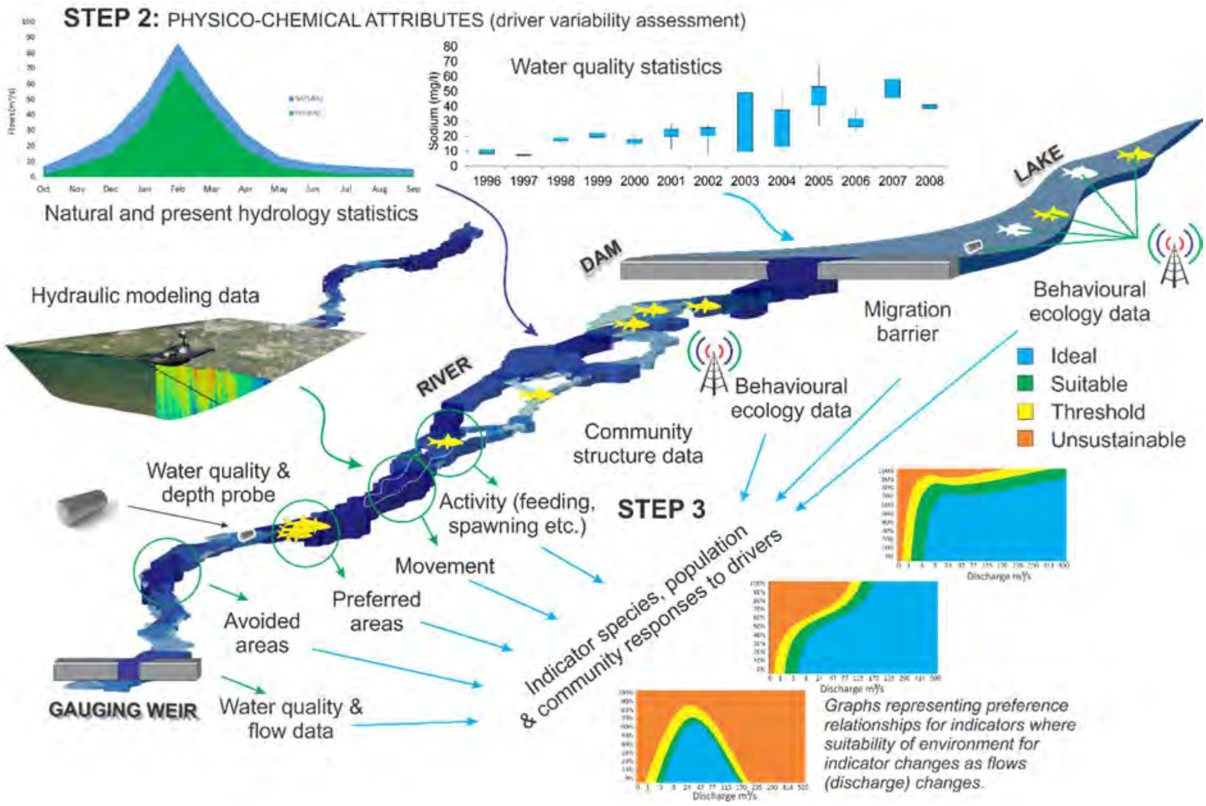

Figure 2-5: Step 3 of PROBFLO integrated e-flow determination approach. Indicator species, populations and community responses to drivers representing flow-ecosystem relationships for holistic e-flow determination. Note: flow-ecosystem stacked area graphs include ideal or pristine, sustainable or suitable, threshold of potential concern and unsustainable or unsuitable conditions in the graphs.

The flow-ecosystem relationship data includes species, populations and community requirement/preference information for the volume, duration, frequency and timing (e.g. seasonality) of flows. In a PROBFLO assessment habitat depth and velocity requirements are generated to:

- maintain refuge areas for species,
- provide access for migration, spawning and recruitment,
- optimise water quality conditions of instream habitats, and
- optimise levels required to inundate cover features
- facilitate recruitment of indicator riparian plants.

Additional data pertaining to sediment flows, habitat conditions and the movement and deposition of sediments is considered. These relationships can also consider the timing and duration of flows to ensure that they are aligned to seasonal life-cycle activities of indicator species. With this evidence of the requirements or preferences of ecosystem indicators, and knowledge of the use or protection focus of the vision for the resource, multiple ecosystem requirements can be generated to contribute to the determination of e-flows. These indicator requirements often pertain to life-cycle processes of indicator species including for example the habitat for indicator species to spawn in, recruit from, grow in and or migrate between. These habitats associated with the timing of life-cycle attributes results in the volume, timing, duration, and frequency of flows to maintain these indicators.

For the e-flow determination, the state of the indicators is extracted to generate the flow requirements and the ranking scheme established for the study corresponds to the state of the indicators as described in Table 2-5 or Section 2.2.4. If the vision for the resource is use focused the requirements associated with the moderate risk rank range is used while if the vision is protection focused, then the low rank range is usually considered to generate flow requirements for each indicator. In these assessments a range of requirements generated from indicator species, populations and communities is summarised to represent the drought, base low, base high, freshet and flood requirements for each site. The hydrologist thus obtains indicator requirements pertaining to the volume, timing, duration, and frequency of flows for each site associated with drought, base low and high flows, freshets and floods.

Step 4: Generation of flow scenarios

In Step 4 (see Figure 2-6) the information obtained in Step 3 is used as controls to generate a flow scenario that meets these isolated requirements provided. Consider however that these requirements are generated independently and only integrated by the hydrologist to represent an initial e-flow requirement. Consideration of the potential synergistic effects of altered flows and combinations of the independent requirements still needs to be considered. The PROBFLO approach is a holistic assessment that then considers the integrated requirements, or synergistic effects of the indictor e-flow requirements using the RRM and BN approach described now in Steps 5-8 (see Figure 2-7 to Figure 2-9).

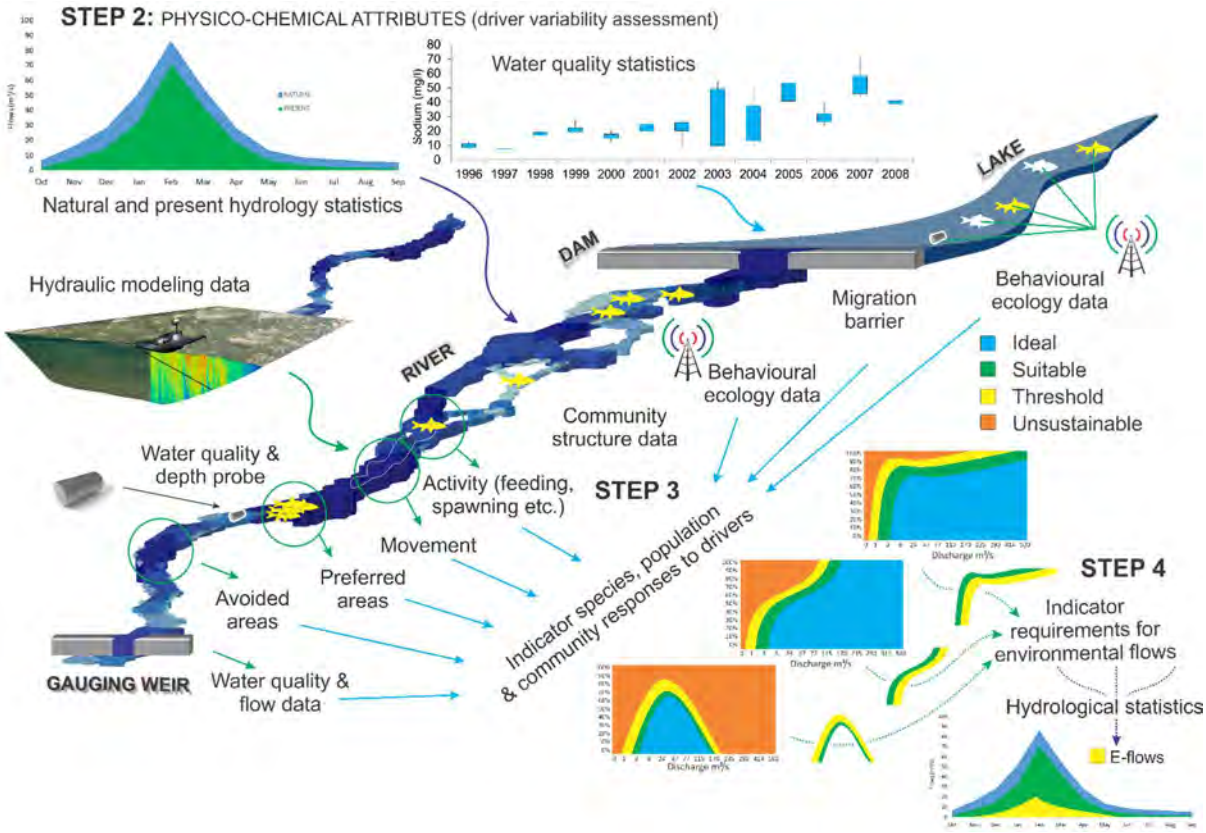

Figure 2-6: Step 4 of PROBFLO integrated e-flow determination approach. Flow-ecosystem relationships for indicators provided to the hydrologist as requirements for indicators to establish preliminary (indicator based) e-flow scenario.

Step 5: Evaluation of the integrated risk of preliminary e-flow requirements

In Step 5 (Figure 2-7) the knowledge of the socio-ecological system representing each reach of river in the case study and links between sites to represent upstream and downstream relationships is used to evaluate the integrated risk of preliminary e-flow requirements, to ensure that they meet the integrated ecosystem requirements. This is achieved using BN probabilistic modelling methods using the Norsys Netica tool. This holistic probability modelling approach is used here to evaluate the integrated risk associated with the preliminary e-flow requirements to provide for maintaining supporting service endpoints (fish, vegetation and invertebrates) or the ecosystem part of this assessment to meet the definition of the e-flow and later in the study where additional, particularly cultural and provisioning or social endpoints and other regulatory (additional ecosystem endpoints) were included in Report 8 "*Risk of altered flows to the ecosystem services of the Limpopo Basin*".

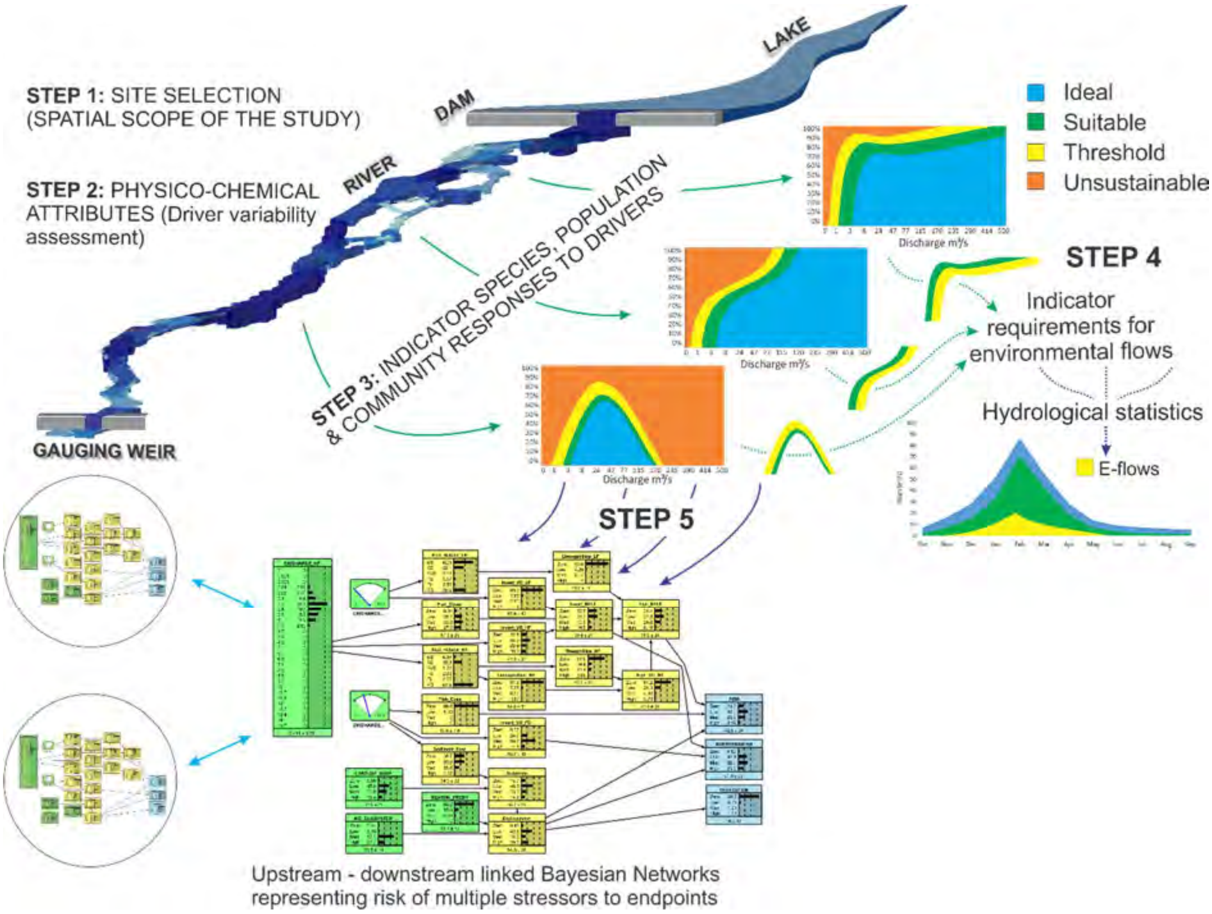

Figure 2-7: Step 5 of PROBFLO integrated e-flow determination approach. Use of flow-ecosystem relationships and non-flow ecosystem relationships to establish Bayesian Network probabilistic models for reach/multiple-reaches of ecosystems represented through connected models for holistic e-flow determination.

Step 6: Determining probable risk

In Step 6 (Figure 2-8) all the flow indicator components of the ecosystem used to establish preliminary e-flow requirements are integrated into the BN. The same rules or conditional probability tables (represented as stacked area graphs) are integrated into the model and combined to represent ecosystem components using additional conditional probability tables. The risk projections using the same ranking system (ideal to unsustainable) are used to represent the outputs of the models.

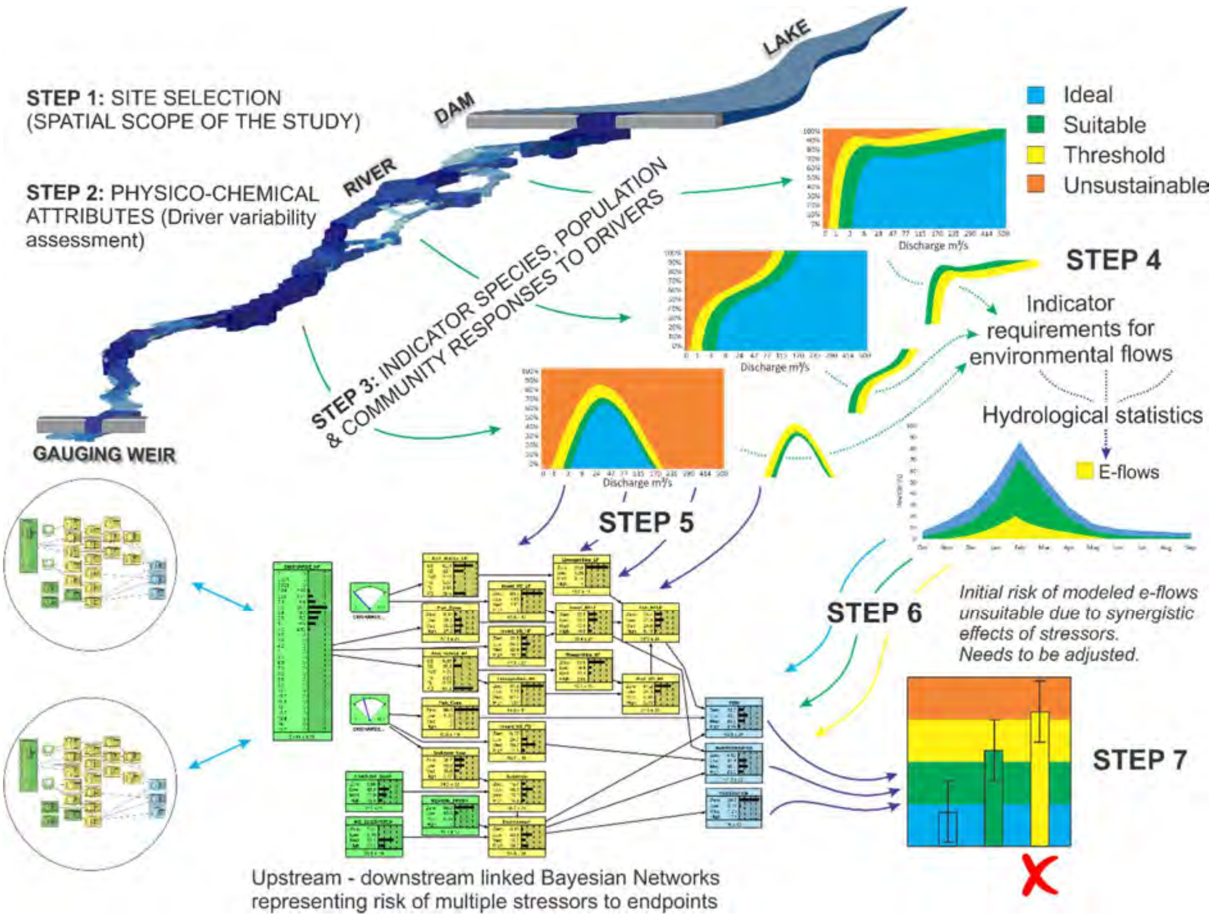

Figure 2-8: Step 6&7 of PROBFLO integrated e-flow determination approach. Bayesian Networks applied to determine probable risk of multiple flow and non-flow stressors to model endpoints that represent the ecosystem in an acceptable condition. Relative risk of natural, present day and preliminary (indicator based) e-flow scenarios evaluated.

Step 7 & 8: Evaluation of integrated risk

In step 7 (Figure 2-8) the integrated risk to the ecological endpoints determined in Step 6 are evaluated. This allows for the consideration of the suitability of the indicator requirements used in Step 4 to determine the preliminary e-flows. If the integrated risk is suitable and aligns to the vision for the reach of river considered these e-flows are accepted as suitable integrated e-flow requirements for the site. If the evaluation of the preliminary risk results in a risk score that is too high, then in Step 8 an iterative process is followed to amend the flow requirements provided (step 4) into the hydrological statistical model to update the preliminary e-flows which can be re-evaluated in step 8. Here any potential discrepancies between preliminary e-flows where indicators are considered independently, compared to the holistic, integrated model results, need to be addressed. During this process new flow requirements can be generated and tested resulting in an acceptable, evidence-based risk profile that can meet the vision for the resource considered and from which suitable e-flows are determined. Take note, that while the uncertainty associated with isolated indicator requirements may be low-to moderate and uncertainty can increase through the use of the integrated probabilistic model, this can be mitigated/reduced through monitoring and testing and improved through iterative or adaptive modelling processes. This integrated approach meets good international, holistic e-flow determination considerations and conforms to the precautionary approach to water resources management.

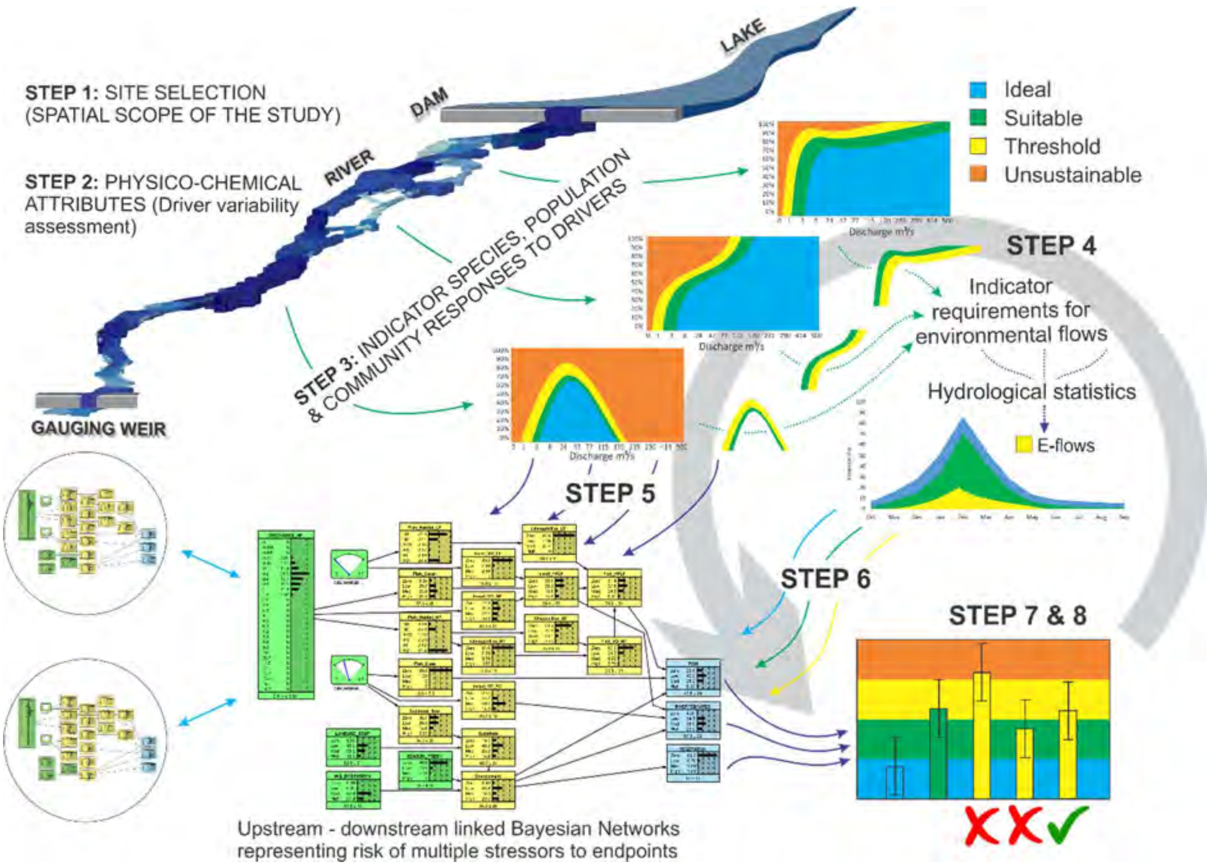

Figure 2-9: Step 8 of PROBFLO integrated e-flow determination approach. Bayesian Networks evaluation of risk of multiple stressors to preliminary (indicator based) e-flow requirements and revise to establish "integrated, holistic" e-flow requirements. This adaptive process can be applied through multiple iterations to result in a suitable "integrated, holistic" e-flow for each reach which is also integrated/synchronised between sites/reaches.

This PROBFLO approach was applied to 18 sites in the basin, where 4 of these 18 sites (Olifants and Letaba River) have existing e-flows established and gazetted (written into law) and thus cannot be changed. We have used the information generated to query the suitability of the existing e-flow requirements. We have also used the data from these 4 sites, together with the remaining 14 sites, to evaluate the socio-ecological consequences of the e-flows and alternative flow and non-flow scenarios in the basin (see Report 8: "*Risk of altered flows to the ecosystems services of the Limpopo Basin*").

To fill in some important gaps where there was no field data available for an additional 5 tributaries in Botswana and Zimbabwe, we applied the PROBFLO approach in an e-flows framework context (Poff et al., 2010) and used available hydrology data to determine low confidence e-flow requirements, which are included in this overall assessment. For these 5 reaches of river that represent the Ngotwane, Bonwapitse, Lotsane and Motloutse Rivers in Botswana and the Bubye River in Zimbabwe, available hydrological monitoring data was used to model natural and present flows and then the e-flow requirements of comparable rivers in the same eco-region in close proximity. This data was used as a function, relative to the flow in their own basins, to propose preliminary e-flows and evaluate integrated e-flow requirements. The results of this process have been included in this study so that the entire basin is included in the study.

2.2.1 Vision and endpoints

E-flows represent the target or condition of a river which needs to be aligned to the desired balance between the use and protection of water resources, or the "vision" of the resource. On a regional scale, to achieve an overall sustainable balance between the use and protection of water resources some areas may be allocated for "high but sustainable" use and other areas may be assigned a "low use and protect" scenario, where together they at a regional scale allow sufficient protection of the resource for regional sustainability. In this context, the ecological classification of ecological category (A=pristine to F=critically modified) system is used (see Kleynhans and Louw, 2008). This classification is required to align the e-flow requirements to maintain a reach of a river in a particular sustainable condition (A=pristine to D=largely modified but sustainable). The requirements to maintain a reach of river in a protected area such as in the Kruger National Park for example, where the emphasis is on conservation, would be considerably greater than a river allocated to be heavily but sustainably used (largely modified or Class D for example).

The vision information exists in different formats for the different parts of the basin as part of policies, strategies and resource objectives within riparian governments and LIMCOM have completed a study on the vision for the basin. The detailed methods and outcomes of the visioning exercise for this study are documented in the *"Reports 2&3: E-flows for the Limpopo River Basin – Basin Report and From Vision to Management"*.

The e-flows that are to be determined for the Limpopo Basin, need to meet user and environmental water requirements so that the system can continue providing the following ecosystem services and associated endpoints (Table 2-2). As described earlier (Section E-FLOWS ASSESSMENT2.2), to conform to the e-flow definition where the requirement is to maintain a sustainable ecosystem, the supporting services including "maintain fish, vegetation and invertebrate communities" are used (Table 2-2).

2.2.2 Data analysis

2.2.2.1 Hydrology

The data used for the hydrology was mainly based on the results from the hydrological study (Volume C – hydrological assessment, 2013) from the Limpopo Monograph study, data from the Limpopo Reconciliation study (DWS, 2015) and for the existing gazetted e-flow sites in Olifants and Letaba Rivers, the hydrology from the 2017 Implementation of the Reserve study. The Monograph study undertook a detailed assembly and processing of the hydro-meteorological data, historical water use collation and the generation of long-term natural and present-day streamflow time series for the period 1920 to 2010 through calibration of the WRSM2000 model at selected river gauging weirs in the four basin countries.

Flow statistics (mean, percentage zero flows, minimum and maximum flows per month as well as various percentiles) have been calculated for each of the major tributaries. As variability is very high for most of the rivers in the Limpopo Basin, the median was also calculated to give an indication of the characteristics of the rivers. Baseflow separation was undertaken using the approach developed by Smakhtin, 2001. This provides an indication of the groundwater contribution to surface flows without the influence of high flows (freshets and floods) and assist the ecologists with the setting of baseflows (maintenance low) flows for the rivers. Where detailed information was available from the groundwater component of this study, the baseflows have been adjusted with the groundwater information.

A flow variability index (CV_Index) was also calculated for each of the major tributaries to get an indication of the seasonal, perennial or ephemeral character of the river. This index was calculated for both the natural (NAT) and present day (PRS) flows to give an indication if the nature of the rivers has changed from natural to present day due to catchment developments. This index summarises the variability within the wet and dry seasons and is based on the average coefficient of variation for the three main wet and dry months (excluding zero flow months). Table 2-3 presents the natural and present day mean annual runoff (MAR) from the Limpopo Monograph study and the calculated CV_Index for each of the major tributaries. A CV_Index between 1 and 4 indicates a perennial system, 5 a seasonal and >6 an ephemeral system. It can be seen from the table that several systems are naturally ephemeral, especially those in Botswana. It should be noted that this index was calculated for the flows at the outlets of the tributaries. Thus, some systems might still be perennial or seasonal in the upper reaches. A number of systems have been changed from perennial to seasonal or even ephemeral with water uses in the upper catchments, especially those from South Africa.

Table 2-2: Endpoints selected for the Limpopo e-flow determination and socio-ecological consequences of altered flows study.

Ecological Service	Endpoint
Provisioning services	Maintaining fisheries for livelihoods
	Maintain plants for livelihoods
	Maintain plants for domestic livestock
	Maintain water for domestic use
Regulatory services	Flood attenuation services
	River assimilation capacity
	Maintain water borne diseases
	Resource resilience
Supporting services	**Maintain fish communities***
	Maintain vegetation communities*
	Maintain invertebrate communities*
Cultural services	Maintain recreation and spiritual act.
	Maintain tourism

Note (*) highlights the endpoints used to establish e-flows in the study as they represent the aquatic ecosystem that will be affected by the quantity, timing, and quality of freshwater flows. Other ecosystem services are used to assess risk to people.

The percentage zero flows per month for the natural and present-day flows have been determined to give an indication if the systems have more or less zero flows (Table 2-4). The results indicate that the mainstem Limpopo River still has only a few zero flow months, even with present day flows, with the sites at Spanwerk and Combumune at a higher percentage of zero flows for present day. This is due to the very high percentage of zero flows for the Marico and Ngotwane Rivers that contribute to the flows at Spanwerk. Combumune is towards the lower reaches of the Limpopo River before the confluence of the Elephantes River with more constant present day flows due to the releases from Massinger Dam. Most of the tributaries show an increase in zero flows for present day due to upstream developments. The Lephalale, Mogalakwena and Nzhelele Rivers show a large shift from almost no zero flows for natural to almost 100% zero flows for present day. It seems as if the operation of the Mwanedzi River resulted in less zero flows for present day.

Table 2-3 Summary of the main statistics per tributary in the Limpopo Basin (1-4=perennial; 5=seasonal; >6 seasonal)

Rivers	E-flow site	MAR (10^6m^3)		CV_Index	
		Natural	Present day	Natural	Present day
Ngotwane	Lim_EF01	92	62	5	10
Marico	Lim_EF02	154	24	2	6
Crocodile (West)	Lim_EF03	596	399	2	5
Bonwapitse	Lim_EF04	81	81	11	11
Matlabas	Lim_EF05	40	39	3	3
Mokolo	Lim_EF06	182	144	5	10
Lephalale	Lim_EF07	142	82	2	7
Lotsane	Lim_EF08	35	22	10	10
Mogalakwena	Lim_EF09	243	125	2	4
Motloutse	Lim_EF10	125	86	8	8
Limpopo to Lotsane confluence	Lim_EF11	591	373	2	3
Limpopo – Lotsane to Shashe	Lim_EF12	801	523	2	2
Shashe	Lim_EF13	687	513	9	9
Limpopo – Shashe to Mzingwani	Lim_EF14	1684	1201	2	4
Mzingwani	Lim_EF15	438	261	7	7
Sand	Lim_EF16	74	40	7	14
Bubye	Lim_EF17	200	187	11	12
Luvuvhu	Lim_EF18	560	455	2	2
Mwanedzi	Lim_EF19	412	332	11	11
Olifants – to Blyde	Lim_EF20	1322	568	2	2
Olifants – to Letaba	Lim_EF21	1918	947	2	3
Letaba – to Little Letaba	Lim_EF22	441	196	2	4
Letaba – to Olifants	Lim_EF23	642	371	3	3
Shingwedzi	Lim_EF24	87	84	5	5
Limpopo – Mzingwani to Mwanedzi	Lim_EF25	2792	1970	3	3

Rivers	E-flow site	MAR ($10^6 m^3$)		CV_Index	
		Natural	Present day	Natural	Present day
Elephantes	Lim_EF26	2552	1236	2	2
Limpopo – to estuary	Lim_EF27	5572	3325	3	2

Table 2-4: Percentage zero flows per month per tributary in the Limpopo Basin (Natural and Present-day)

MAJOR TRIBUTARIES	PERCENTAGE ZERO FLOWS PER MONTH												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Marico	NAT	4	3	0	0	1	2	3	3	3	4	4	4
	PRS	76	55	30	25	34	40	51	68	76	77	80	81
Crocodile (West)	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	0	0	0	0	0	0	0	0	0	0	0	0
Ngotwane	NAT	33	5	0	0	0	0	0	0	1	8	14	33
	PRS	64	29	15	13	29	36	62	90	97	99	100	91
Limpopo @ LmEWR01	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	13	7	8	4	2	4	2	5	7	8	12	14
Matlabas	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	12	2	1	0	0	0	0	2	8	9	9	16
Mokolo	NAT	87	77	56	40	25	23	23	18	18	18	30	65
	PRS	100	95	87	71	58	53	49	49	60	70	98	99
Lephalale	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	99	89	65	51	55	48	44	69	87	95	99	100
Mogalakwena	NAT	4	1	0	0	0	0	0	0	0	0	0	0
	PRS	93	75	60	42	37	44	46	62	69	77	92	92
Bonwapitse	NAT	66	36	18	16	33	42	69	96	98	99	100	96
	PRS	66	36	18	16	33	42	69	96	98	99	100	96
Mhalatswe	NAT	74	31	10	10	15	27	49	85	98	100	100	100
	PRS	74	31	10	10	15	27	49	85	98	100	100	100
Lotsane	NAT	78	32	16	13	12	27	43	86	97	99	99	99
	PRS	92	47	31	23	34	42	62	91	99	100	100	99
Motloutse	NAT	31	2	0	0	0	1	15	47	80	92	97	88
	PRS	36	3	0	0	0	3	16	56	87	95	99	91
Shashe	NAT	34	2	0	0	0	1	9	45	85	93	100	87
	PRS	76	13	0	1	4	11	27	69	95	98	100	98
Mzingwani	NAT	80	25	15	7	11	24	41	66	86	95	100	97
	PRS	90	42	24	13	27	42	54	81	92	97	100	100
Sand	NAT	52	21	9	12	13	15	16	30	38	51	56	60
	PRS	96	79	64	58	59	71	86	97	97	97	98	99
Bubye	NAT	87	36	18	9	13	23	42	75	92	98	99	97
	PRS	91	44	20	14	16	25	45	77	92	98	99	97

MAJOR TRIBUTARIES	PERCENTAGE ZERO FLOWS PER MONTH												
Nzhelele	NAT	24	15	8	3	2	0	0	4	7	9	11	22
	PRS	99	87	71	53	43	40	40	60	80	95	99	100
Limpopo @ LmEWR02	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	18	2	0	0	0	0	1	2	2	3	4	4
Luvuvhu	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	0	0	0	0	0	0	0	0	0	0	0	0
Limpopo @ LmEWR04	NAT	0	0	0	0	0	0	0	0	0	1	1	2
	PRS	4	0	0	0	0	0	0	1	0	2	2	4
Mwanedzi	NAT	76	23	14	4	14	16	38	76	91	98	99	97
	PRS	70	21	7	3	11	12	0	69	89	97	97	95
Olifants	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	7	12	4	1	0	0	0	0	0	0	0	1
Letaba	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	0	0	0	0	0	0	0	0	0	0	0	0
Shingwedzi	NAT	82	38	20	12	12	29	55	76	86	91	93	92
	PRS	86	41	20	12	13	29	55	77	87	93	95	93
Elephantes	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	0	0	0	0	0	0	0	0	0	0	0	0
Limpopo @ LmEWR05	NAT	19	3	1	0	0	0	1	2	4	11	16	22
	PRS	35	12	4	4	2	1	2	4	11	23	41	48
Limpopo @ LmEWR07	NAT	0	0	0	0	0	0	0	0	0	0	0	0
	PRS	0	0	0	0	0	0	0	0	0	0	0	0

2.2.2.2 Biological data

In this study all four ecosystem service categories (provisioning, regulating supporting and cultural services) have been considered as they represent the socio-ecological system we care about and want to sustainably manage in water resources management. The e-flow component represents the ecological wellbeing of the ecosystem, which is included in the ecosystem service categories, particularly supporting services. These services represent how well the ecosystem is being protected compared to how much use is occurring. The establishment thus of e-flows in this study represents the flow required to sustain aquatic ecosystems in part 1 and 2 of the PROBFLO assessment to establish holistic e-flows for the system. These flows will contribute to human livelihoods and other ecosystem services which represents equitable, sustainable use of water resources and sustainable management of flows in part 3 of the PROBFLO assessment which will be presented in detail in the Report 8: "*Risk of altered flows to the ecosystem services of the Limpopo Basin*".

In this part of the PROBFLO assessment for the Limpopo River, the wellbeing of fish, macroinvertebrates and riverine vegetation has been included to establish suitable, integrated e-flows for the 14 new sites considered, existing gazetted e-flows from South Africa and five sites where rapid e-flow determination has been undertaken using inferred requirements from sites assessed in this study (Table 2-1). Detailed reports of the field surveys that were undertaken and on the present ecological condition are available (Report 6: "*Present Ecological State of the Limpopo River: Ecological Responses to Change*"). Here a summary of the data available for each component, data collected and how it has been used in this assessment is provided.

2.2.2.2.1 Fish as ecological indicators of altered flows and associated non-flow variables in the Limpopo Basin

Fish are highly mobile, and relatively long lived, charismatic and targeted by human communities for food. Fish are relatively easy to sample and identify and are used extensively as indicator organisms so a lot of biological and ecological information is known about how fishes can be used in e-flow assessments. There are 77 species of fishes that are known to occur in the Limpopo Basin. The species list is growing with new genetically unique species being described. Within this species flock the Mochokidae, Cyprinids, Siluriformes and Characan families include species that have preferences for flow-related habitats, depths and cover features and or have a need to migrate. Many of these fishes are also known to require flow related ecological cues and have been used extensively in the evaluation of e-flow requirements in the region and on the continent. Extensive historical data representing the natural distributions of population of fishes in the basin are available from the South African Atlas of Freshwater Fishes (using museum records, Scott et al., 2006) and from more recent DWS PES&EIS data (DWA, 2012). Changes in the distributions of population associated with water resource use and or development is available from monitoring data including river health monitoring, published data and from the extensive sampling undertaken from LIMCOM (2012) and in this study (Report 6:"*Present Ecological State of the Limpopo River: Ecological Responses to Change"*). For this study, changes in the distributions of species/populations were considered to contribute to the determination of the present ecological condition of fish communities in the basin. This data was integrated with other ecological components to determine the present ecological state of the reaches of rivers considered and these results were compared with the vision requirements to represent a sustainable balance between the use and protection of resources in the basin. If the present ecological condition of the fish communities matched the desired ecological state of the river from the vision exercise, the real data related to how the communities of the rivers have responded to flow and non-flow changes was used to provide indicator-based e-flow recommendations. Care was given to ensure that rheophilic or flow requiring species were included in the assessment. If the present state was better or worse than the vision, then adjustments were proposed based on available information to ensure that the vision was met.

The occurrence of many species in the basin and their recruitment, maintenance and reproduction requirements were unpacked in this study and used to establish flow indicator relationships. This included for example the flows required to provide suitable access for spawning migrations of large (>300mm) growing anguillid eels (Anquilla spp.), barbs (*Enteromius spp.*) labeos (*Labeo spp.),* yellowfish (*Labeobarbus spp.*), catfish (*Clarius gariepinus*) and lateral migrations onto and from floodplains by species such as the cichlids (*Oreochromis spp.*, *Tilapia spp.* and *Coptodon spp.*). Thereafter seasonal spawning requirements including the correct timing of increased flows, and the volumes to provide suitable depths, velocities, cover (inundation of marginal vegetation) and substrates for habitats were considered. The duration of flows to ensure that species successfully recruit were included. In addition to the requirements for migrations and successful recruitment of fishes, the provision of refuge areas for species to over winter and habitats for species to establish themselves in summer were included. All the indicators considered in the study are presented in the Appendix A. In this study the indicators considered included: barriers affecting migrations (FISH_ECO_BAR), sediment supply for instream habitats (FISH_ECO_SSUP), water quality preferences (FISH_ECO_WQ), flows to mobilise or remove sediments (FISH_ECO_SFLO), velocity/depth habitat characteristics (FISH_ECO_VD), cover characteristics for instream habitats (FISH_ECO_COV), ecological cues for life cycle processes (FISH_ECO_CUEQ) and the effects of alien species (FISH_ECO_ALI) and human activity associated disturbance to wildlife (FISH_ECO_DTW) impacts were considered in the study. Flow-ecosystem or in this case flow-fish response relationships were generated to represent these requirements of the fish from each site. This data was used to generate critical low flows, base low and high flows and freshet and flood flow requirements for each site. This data was provided to the hydrologist to establish preliminary indicator-based e-flow requirements for each site.

The results of the preliminary e-flow requirements were tested using the probabilistic BN models for the study to determine integrated e-flows for each site. Uncertainty associated with the fish component in the study includes the limited time available to comprehensively evaluate fish communities at each site and limited site-specific knowledge of how resilient and or adaptable fishes are to flow variability and or non-flow variability. There is also limited information to represent how populations of fishes may be vulnerable to inter- and intra-species competition and or disease for example. The outcomes of this study are evidence based but should also be considered in an adaptive management context and new information should be incorporated into the study.

2.2.2.2.2 Macroinvertebrates as ecological indicators of altered flows and associated non-flow variables in the Limpopo Basin

All species and species assemblages provide insight into environmental conditions. Species have adapted over millennia to tolerate limited ranges of chemical, physical, and biological conditions (Genner & Hawkins 2016). The distribution and ecological success of aquatic biota in lotic systems are affected by sediment load, stream bed movement-transport, turbulence (affected by substrate-slope), velocity profile, and substrate composition (Gore et al. 2001). Knowledge of which taxa (preferably species) are in a stream when and where, and their presence or absence, can therefore provide valuable insights into changes within these systems, whether natural or anthropogenic. The limitation to interpreting responses to change is what is known about the life traits of a species throughout all its life stages, e.g., egg, pupae, larvae/nymph, imago. Stream flow duration and frequency of high and low flow affect variability between streams (e.g., temporal, and spatial variation) and within streams (e.g., in response to biotic interactions, abiotic factors, habitat differences, and other environmental influences). Stream flow duration therefore also affects the respiration, reproduction, locomotion, development rates, and dispersal capacity for individuals.

In this e-flows study, all accessible biological data from the Freshwater Biodiversity Information System (FBIS), the LIMCOM 2012 low flow survey report (Dickens et al. 2013), and various publications from work within the Limpopo basin were summarized to determine background information. During the April-May and June 2021 field surveys, quantitative biotic and abiotic data were collected in 40x40 cm flowing and stagnant habitats at different depth and velocities. A Surber sampler was used to collect biota in flowing waters, and a SASS net (40 x 40 cm area) in vegetation and sand-silt-mud-gravel biotopes.

The MIRAI (Macroinvertebrate Response Assessment Index) model by Thirion (2007) was applied to the historical data and the data collected in 2021 to determine likely Present Ecological State of the macroinvertebrate community at each site. The MIRAI is a rule-based model developed by DWS in South Africa and considers the knowledge of water quality, flow preference, and habitat requirements of the invertebrates at family level. The method integrates the currently known ecological requirements of the invertebrate taxa at a family level to their responses to modified habitat conditions. Taxa strongly associated with fast to moderate flows are compared to those strongly associated with slow flowing to stagnant waters. Responses to water quality and availability of instream habitat (habitat heterogeneity) was also considered.

For the risk assessment using the BN Probabilistic Model, environmental conditions (INV_ECO_ENV), the instream environment (INV_ECO_INS), physical habitat (INV_ECO_HAB), geomorphological substrate (INV_ECO_GEO) for invertebrates were considered. For the maintenance of invertebrate communities' environmental potential (INV_ENV_POT), migration barriers (INV_ENV_BAR), sediment supply (INV_ECO_SSUP), sediment removal (INV_ENV_SFLO), velocity-depth categories (INV_ECO_VD), and cover (INV_ECO_COV) were considered. All these considerations were linked to the different historical hydrological regimes supplied by the hydrologist plotted on lateral profile by the geomorphologist.

2.2.2.2.3 Vegetation as ecological indicators of altered flows and associated non-flow variables in the Limpopo Basin

The riparian zone is the interface between terrestrial and aquatic ecosystems. Plant communities along river margins are called riparian and are characterized by hydrophilic plants to greater or lesser degrees. Riparian zones are significant in ecology, environmental management, and civil engineering because of their role in soil conservation, biodiversity (both intrinsic and supportive of overall biodiversity), and the influence they have on aquatic ecosystems. Riparian zones have frequently been referred to as interfaces or ecotones, which possess specific physical and chemical attributes, biotic properties, and energy and material flow processes, and are unique in their interactions with adjacent ecological systems (Naiman et al, 1988; Risser, 1993; Naiman & D´ecamps, 1997). They operate as both ecosystem drivers (flood attenuation, sediment dynamics, instream and riparian habitat provision) and biotic responders.

During April and May of 2021, 14 sites were surveyed and sampled along the main channel of the Limpopo River and some of its tributaries within South Africa. In June 2021 two assessments were conducted in Mozambique, the Limpopo River and the Elefantes, and the Sashe River in Zimbabwe was assessed during July of 2021. The biophysical survey for riparian vegetation at each site consisted of site and riparian zone delineation, determination of the present ecological status (PES) for riparian vegetation using VEGRAI (Kleynhans *et al.*, 2007), and determination of indicator / environment links to determine Environmental Flows for riparian vegetation and definition and parameterisation of endpoints for inclusion in risk analyses using PROBFLO.

In situ data collection was conducted with the use of cross-section transects perpendicular to flow. As far as possible, sites were placed across single or less complicated channels, perpendicular to flow and included vegetation species that represented flow-dependent community compositions (woody and non-woody) as well as flow-sensitive species such as rheophytics (e.g. *Breonadia salicina, Gomphostigma virgatum*). The basis for determining the e-flows for riparian vegetation is to survey key riparian indicator sub-populations to enable accurate placement of the upper and lower limits of chosen sub-populations onto the profile and then with use of the rating curve or look-up tables for each transect to determine the flows at which sub-populations become activated (activation discharge - water level is at the lower limit of the sub-population, inundation at 0%) or inundated, or to calculate proportions of sub-population inundation. Similarly, this can be done for sub-zones or features within the riparian zone. This approach takes its roots from the Building Block Methodology (BBM, King and Louw, 1998), which is a holistic approach that requires identification of a single predetermined condition, usually the present state. A single flow regime is then determined to facilitate the maintenance of the present state.

The flow regime that is determined consists of different components i.e. base flows (discharge and seasonality) and floods (seasonality, frequency, timing, duration, magnitude). Indicator sub-populations (that are surveyed onto the profile), together with hydraulics are used to determine base flow requirements for the wet and dry season. As a general guide, the dry season base flow should facilitate survival of marginal and lower zone vegetation while the wet season base flow should facilitate growth, reproduction and recruitment. For high flows and floods there are multiple functions for different flows. Different class floods (usually class 1 to 5 but could be more or less) are determined and defined according to each of the sub-population requirements, and for the riparian zone as a whole. General flood functions are applied to each sub-population with specific considerations.

The data collected in this study were used to establish flow indicator relationships that were used in a BN modelling environment to assess risk to pre-defined endpoints. The ecosystem endpoints relate to the most vital vegetation habitats with the aim to maintain habitats and ecosystem processes for critical indicator macrophytes and riparian/wetland vegetation and social benefits (ecosystem services). In this study the end points were SUB-VEG (the maintenance of riparian vegetation for the purposes of subsistence use by local communities), LIV-VEG (the maintenance of riparian vegetation for the purposes of use by livestock) and VEG-ECO (the maintenance of riparian vegetation for the purposes of ecological functionality). More specifically, the outcomes of these endpoint dynamics were linked to relevant riparian indicators and in turn their relation to flow and flow dependent variable such as sediment dynamics.

2.2.3 Conceptual model

A conceptual model was developed that represents hypothesised cause-effect relationships between stressors and receptors that represent the ecosystem services and endpoints. The basic conceptual model that is used is shown in Figure 2-10, showing how the SOURCES of change (dam development etc) lead to STRESSORS on the river (altered timing of flows, volumes of water etc). These in turn affect either the instream, riparian or floodplain HABITATS, where most of the RECEPTORS (Instream biota, etc) will be impacted. These in turn impact on socio-ecological ENDPOINTS (supply of water for agriculture, biodiversity etc).

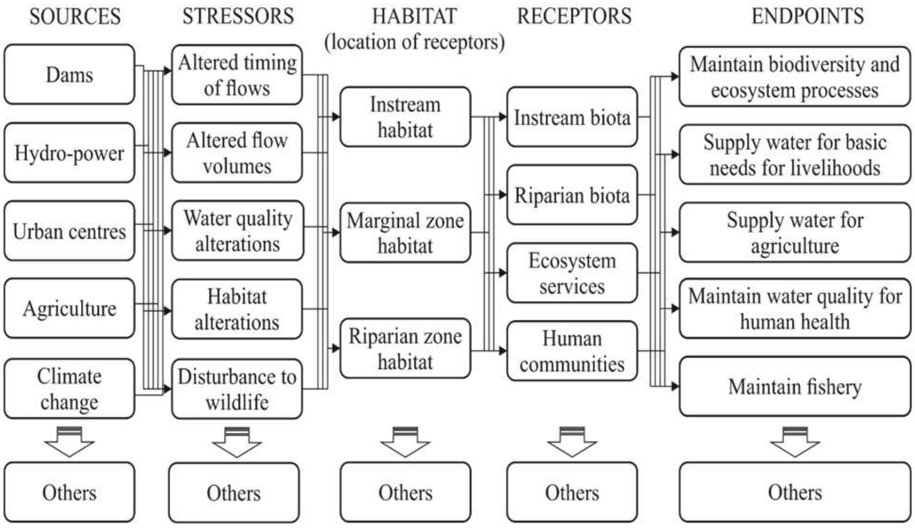

Figure 2-10: Basic conceptual model of the socio-ecological system for the Limpopo e-flow study

The basic conceptual model was expanded upon to generate a more detailed model for the project during a workshop held with the specialist team in August 2021. Due to COVID restrictions, the workshop was held on-line and spanned two days. The first day was dedicated to specialists providing an overview of the data obtained from the field surveys and the second day to the development of the conceptual model of the socio-ecological system in a mind map format (Figure 2-11). The conceptual model addressed the requirements of the PROBFLO approach by:

1. the selection of socio-ecological endpoints, to direct the hydrologic foundations for the study including the selection of hydrological statistics required,
2. to classify ecosystem types based on geomorphic, water quality, quantity and ecoregion considerations, and with this data,

3. to incorporate evidence based flow-ecosystem relationships and flow-ecosystem service relationships, with relevant non-flow variable relationships upon which the assessment is based.

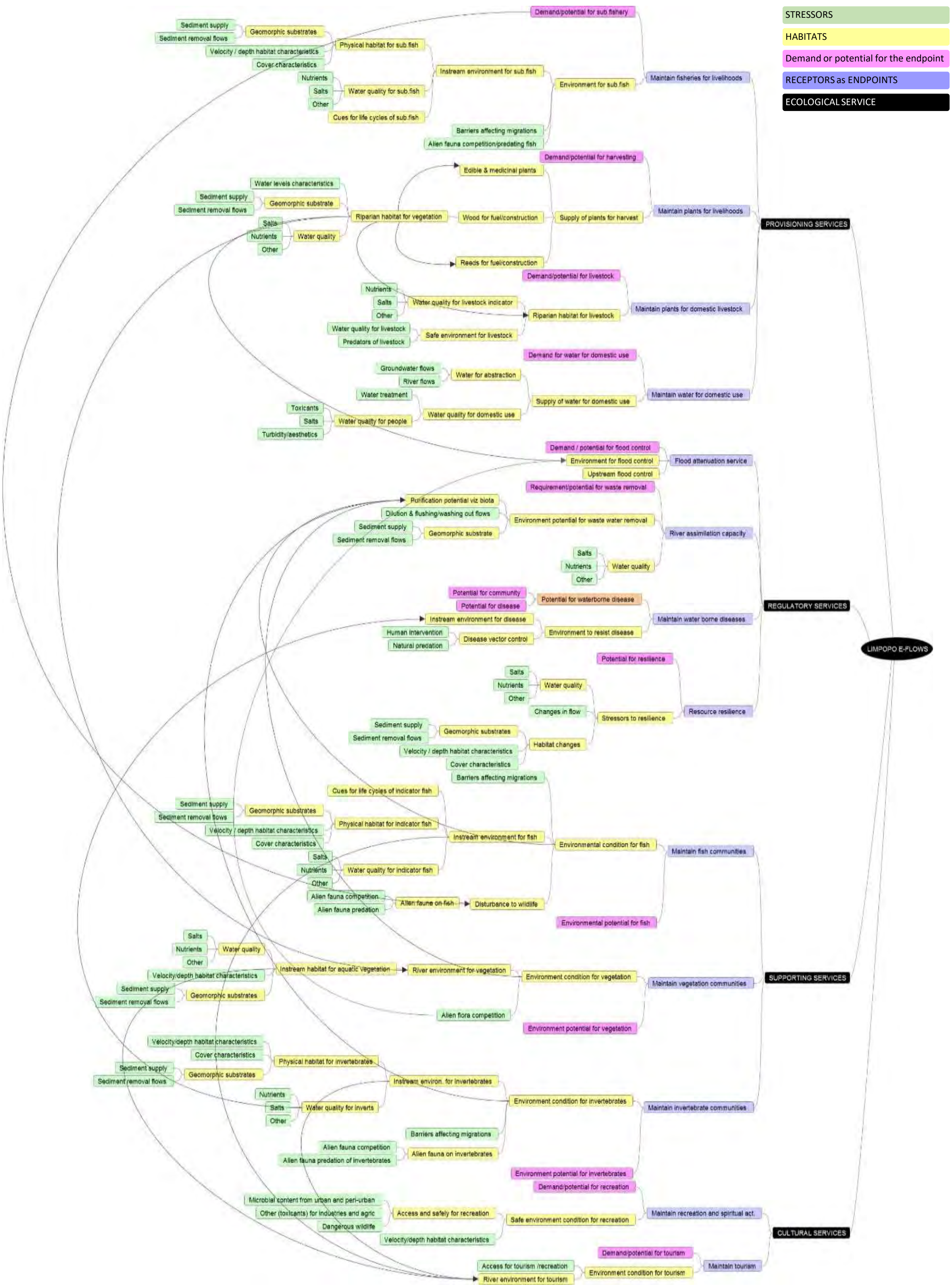

Figure 2-11: Conceptual model "mind map" of the socio-ecological system for the Limpopo e-flow study

Explanation of the Conceptual Model

To explain the model in Figure 2-11 it is necessary to start from the right-hand side of the Conceptual Model, with the determination of the risk of multiple flow (and non-flow) stressors to the ecosystem services endpoints (see the detail shown in Figure 2-12). The links between variables indicate that one variable is conditionally dependant on the other. These relationships are documented in detail in Figure 3-7 and Figure 3-8. The final model (Figure 2-11) is an overview that is they subsequently used as the basis for the development of the BN (Annexure D) using the Netica software.

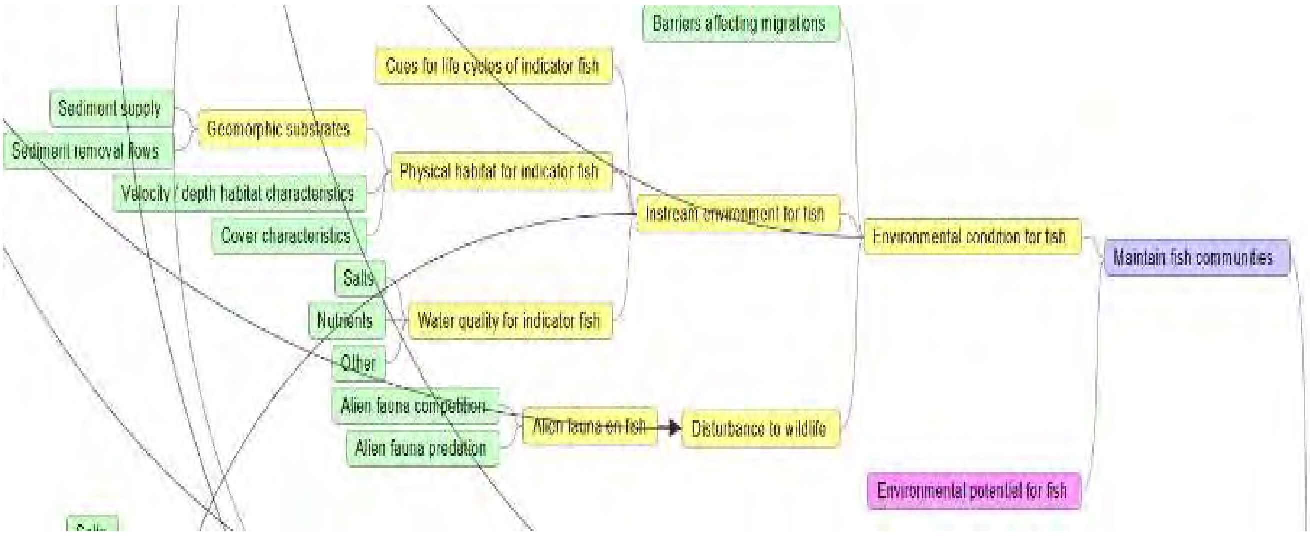

Figure 2-12 Extract from the complete Conceptual Model provided in Figure 2-11

For explanation of how the Conceptual Model works, here is an example (explaining Figure 2-12):

- The risk to the fish endpoint (MAINTAIN FISH COMMUNITY NODE) is a function of the environmental conditions that support or pose a threat to fish (ENVIRONMENTAL CONDITION FOR FISH NODE) and the potential diversity and sensitivity of fishes that may occur at the site (ENVIRONMENTAL POTENTIAL FOR FISH NODE). The data available to represent the potential for fish is available from historical data and survey results to the study area.

- The ENVIRONMENTAL CONDITIONS node is a function of the presence of, and potential for, barriers to affect river connectivity and fish migrations (BARRIERS AFFECTING FISH MIGRATION NODE), INSTREAM ENVIRONMENT FOR FISH and DISTURBANCE TO WILDLIFE potential which is in itself a function of alien fauna (ALIEN FAUNA ON FISH).

- The Data required for barriers to fish movement has been derived from a dam database, while the instream environment for fish itself is a function of CUES FOR LIFE CYCLE ACTIVITIES for fish, the PHYSICAL HABITAT FOR INDICATOR FISH and WATER QUALITY REQUIREMENTS FOR FISH. The cue node represents our knowledge of the flow requirement of migratory and summer (high flow) spawning fishes and the instream habitat characteristics of the river for these cues based on the volume and timing of flows. Available and new information obtained in this study that represents the timing and volume of water required for these indicator fish, has been used to establish a flow-ecosystem relationship that will query available flow data and represent the suitability of flows for those species. The data and how the data is used to query the suitability of flow data will be provided in the Bayesian Network report.

- The PHYSICAL HABITAT FOR INDICATOR FISH node is a function of the geomorphic substrate (NODE) characteristics, velocity/depth habitat characteristics (NODE) of indicator fishes and cover characteristics (NODE) for indicator fishes. The WATER QUALITY INDICATOR FOR FISH node represents the overall condition of water quality including consideration of the salts, nutrients and other (system variables and toxicants).

All input nodes are evidence based and use existing or collected (in this study) and modelled data to represent a flow (or non-flow for water quality and geomorphology characteristics) relationship with ecological variables. All of the daughter nodes are conditional to the parent nodes and integrate response relationship distributions in the form parent nodes using Conditional Probability Tables or rules that represent how the data is integrated. These relationships will also all be presented as evidence for the model. These relationships are then represented in a BN model. We have selected Norys Netica as the software model. The structure incorporates the ecological risk assessment framework where the risk exposure is represented by the input green and yellow nodes. This represents how the ecosystem is threatened by flow and non-flow stressors. The pink nodes introduce risk region or site dynamics which represents the exposure pathways of the risk framework.

2.2.4 Ranking scheme

The ranking scheme allows for the calculation of relative risk for each endpoint and represent the range of well-being conditions, levels of impacts and management ideals as detailed in Table 2-5 (O'Brien et al, 2018; Wade et al, 2020). These ranks are based on the four states traditionally used in RRM, namely zero, low, moderate and high (Colnar & Landis, 2007; O'Brien and Wepener, 2012; Hines & Landis 2014). Zero risk usually represent a reference state with low-risk states representing management targets with little impact. Moderate-risk states represent partially suitable ecosystem conditions that usually warrant management/mitigation measures to avoid high-risk conditions that are deemed unacceptable. The incorporation of BN modelling into PROBFLO, allows the approach to incorporate the variability between ranks as a percentage for each rank. Indicator flow and non-flow variables are selected (linked to endpoints), and unique measures and units of measurement are converted into and represented by ranks for integration in BN assessments (O'Brien et al, 2018).

Table 2-5: Ranking scheme selected for the Limpopo e-flow study (O'Brien et al, 2018)

State and score	Description
Zero (0-0.25)	Pristine/baseline/reference state with no impact or risk compared to the pre-anthropogenic source establishment
Low (0.26-0.5)	Largely natural state with low impact /risk, ideal range of sustainable ecosystem use
Medium (0.51-0.75)	Moderate use/risk/impact or modified state representing a threshold of potential concern and possible failure threshold
High (0.76 -1)	Significantly altered/impaired state with unacceptably high impact/risk

2.2.5 Bayesian network model development

Bayesian risk methods that evaluate the magnitudes and probabilities of multiple stressors associated with anthropogenic activities, or hazards, that affect the social and or ecological attributes of water resources have been established globally (Ayre and Landis., 2011; O'Brien et al., 2019a). These methods incorporate Bayesian statistics that evaluate a hypothesis based on given evidence, which differs from classical, or frequentist statistics that evaluate the probability of the evidence given a hypothesis (Ayre and Landis., 2011). BNs incorporate Bayesian statistics in graphical, hierarchical, probabilistic models of multiple stressors that use conditional probability distributions to describe relationships between the variables of the model (Ayre and Landis., 2011; O'Brien et al., 2019). BN models have been used to represent knowledge of how multiple stressors interact to evaluate the cumulative or synergistic effects of these stressors to socio-ecological endpoints of water resources (Lee 2000; Marcot et al. 2001; Rowland et al. 2003; Borsuk et al. 2004; Marcot et al. 2006a; Pollino et al. 2007a; Ayre and Landis., 2011; O'Brien et al., 2019a; 2020; 2021).

The causal BN model developed for this assessment includes a range of nodes that represent indicator components of the socio-ecological system, linked by arrows that demonstrate causal relationships between variables. The models are causal and from the left-hand side to the right-hand side input environmental variability is interpreted and integrated to represent how the endpoints respond to changes (Annexure D). The BNs provided in Annexure D provides a graphical representation of the final BN using the Norys Netica software, to determine the risk to the endpoints (blue nodes) for every site. This structure incorporates the ecological risk assessment framework where the risk exposure is represented by the input green and yellow nodes. This represents how the ecosystem is threatened by flow and non-flow stressors. The pink nodes introduce risk region or site dynamics which represents the exposure pathways of the risk framework. All input nodes are evidence based and use existing, or collected (in this study), and modelled data to represent a flow (or non-flow for water quality and geomorphology characteristics) relationship with ecological variables. All of the child nodes are conditional to the parent nodes and integrate response relationship distributions in the form of parent nodes using conditional probability tables (CPT) or rules that represent how the data is integrated. The CPTs combine the causal relationships between nodes and describe the conditional probabilities between the occurrence of states in the parent exposure nodes and the resulting probabilities of states in the child exposure node.

The complete list of endpoints selected for the study includes both social and ecological (supporting service) endpoints that are supported by e-flows (Table 2-6). These are used for part 2 of the PROBFLO assessment and are reported in Report 8: "*Risk of altered flows to the ecosystem services of the Limpopo Basin"*. All of these endpoints are included in the BN-RRM assessment to evaluate the socio-ecological affectes of altered flows in the study to support the implementation of e-flows and consideration of trade-offs between the use and protection of water resources in the basin. Only the Supporting services are used directly for estimation of e-flows as these are the flows that support the ecosystem directly.

Table 2-6: E-flow supported Endpoints selected for the Limpopo risk assessment

Ecological Service	Endpoint	Code in the BN
Provisioning services	Maintaining fisheries for livelihoods	SUB-FISH-END
	Maintain plants for livelihoods	SUB-VEG-END
	Maintain plants for domestic livestock	LIV-VEG-END
	Maintain water for domestic use	DOM-WAT-END
Regulatory services	Flood attenuation services	FLO-ATT-END
	River assimilation capacity	RIV-ASS-END
	Maintain water borne diseases	WAT-DIS-END
	Resource resilience	RES-RES-END
Supporting services	Maintain fish communities	FISH-ECO-END
	Maintain vegetation communities	VEG-ECO-END
	Maintain invertebrate communities	INV-ECO-END
Cultural services	Maintain recreation and spiritual act.	REC-SPIR-END
	Maintain tourism	TOURISM-END

3 RESULTS

3.1 Hydrology

The e-flow sites selected for the study were based on new selected and surveyed e-flow sites or existing e-flow sites from previous studies that were re-surveyed or information from previous studies where no new surveys were undertaken (Table 3-1). Figure 3-1 provides a comparison of the nMAR for each site, and shows increases in the nMAR in the lower portions of the basin. The natural, present day and natural base flow separation hydrological data that was characterised for this study to determine the e-flows is graphically summarised and provided in Appendix B with detailed data provided for the different scenarios in the Appendix D. Figure 3-2 and Figure 3-3 provide an example of freshets and floods have been removed from the present hydrology while baseflows are somewhat comparable with natural flows. Figure 3-4 and Figure 3-5 are an example of primarily removing base flows and demonstrating how the river has changed from a perennial river into a seasonal river. *Refer to the hydrology specialist report for more detail and discussion of findings (Report 5: Present Ecological State of the Limpopo River: Drivers of Ecosystem Change).*

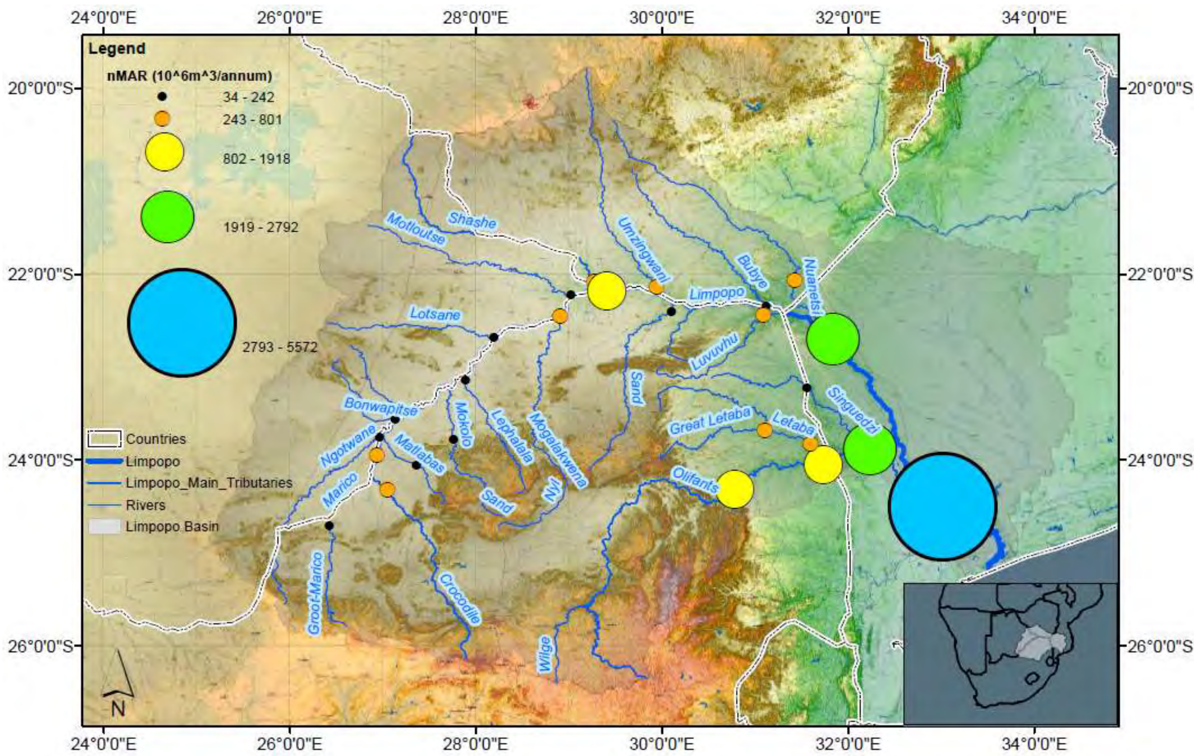

Figure 3-1: **Scaled dots illustrating the mean annual runoff for the sites assessed within the Limpopo Basin.**

Table 3-1: Summary of selected E-flow sites per risk region and hydrological aspects in the Limpopo River Basin

RIVER	Hydrology SITE NUMBER	OLD NUMBER	COORDINATES	nMAR ($10^6 m^3$)	GAUGING WEIR	COMMENTS
Ngotwane	Lim_EF01		Confluence with Limpopo	91.99		Use LIMCOM, 2013 hydrology (1920-2010)
Marico	Lim_EF02	MAR_EWR4	-24.7060; 26.4240	153.71	A3H007	Use intermediate Reserve, 2013 hydrology (1920-2006)
Crocodile (West)	Lim_EF03		-24.3142; 27.0461	595.85	A2H128	Use LIMCOM, 2013 hydrology (1920-2010) adjusted to e-flow site
Bonwapitse	Lim_EF04		Confluence with Limpopo	80.68		Use LIMCOM, 2013 hydrology (1920-2010)
Matlabas	Lim_EF05		-24.0519; 27.3596	35.28	A4H004	Use LIMCOM, 2013 hydrology (1920-2010) adjusted to e-flow site
Mokolo	Lim_EF06	MOK_EWR4	-23.7712; 27.7553	182.22	A4H013	Use LIMCOM, 2013 hydrology (1920-2010) adjusted to e-flow site
Lephalale	Lim_EF07		-23.1413; 27.8850	142.23	A5H008	Use Recon strategy, 2015 hydrology (1920-2010) adjusted to e-flow site
Lotsane	Lim_EF08		Confluence with Limpopo	34.80	Gauge 3321	Use LIMCOM, 2013 hydrology (1920-2010)
Mogalakwena	Lim_EF09		-22.4734; 28.9195	242.55	A6H035	Use Recon strategy, 2015 hydrology (1920-2010) adjusted to e-flow site
Motloutse	Lim_EF10		Confluence with Limpopo	125.46		Use LIMCOM, 2013 hydrology (1920-2010)
Limpopo to Lotsane confluence	Lim_EF11	LmEWR01 (Spanwerk)	-23.9456; 26.9320	591.49		Use LIMCOM, 2013 hydrology (1920-2010)
Limpopo – Lotsane to Shashe	Lim_EF12	Limpokwena	-22.4552; 28.9018	801.39		Use LIMCOM, 2013 hydrology (1920-2010)
Shashe	Lim_EF13		-22.0805; 29.2676	686.79	Gauge B85	Use LIMCOM, 2013 hydrology (1920-2010) adjusted to e-flow site

RIVER	Hydrology SITE NUMBER	OLD NUMBER	COORDINATES	nMAR (10^6m^3)	GAUGING WEIR	COMMENTS
Limpopo – Shashe to Mzingwani	Lim_EF14	Lm_EWR02 (Mapungubwe)	-22.1838; 29.4052	1683.98	A7H004/ A7H008	Use LIMCOM, 2013 hydrology (1920-2010)
Mmzingwani	Lim_EF15		-22.1408; 29.9384	437.81		Use LIMCOM, 2013 hydrology (1920-2010) adjusted to e-flow site
Sand	Lim_EF16		-22.3993; 30.0994	74.19	A7H010	Use LIMCOM, 2013 hydrology (1920-2010) adjusted to e-flow site
Bubye	Lim_EF17		Confluence with Limpopo	200.30		Use LIMCOM, 2013 hydrology (1920-2010)
Luvuvhu	Lim_EF18		-22.4444; 31.0834	559.85	A9H013 & A9H012	Use LIMCOM, 2013 hydrology (1920-2010)
Mwanedzi	Lim_EF19	LmEWR03 (Malapati)	-22.0639; 31.4231	411.61	Gauge B37	Use LIMCOM, 2013 hydrology (1920-2010)
Olifants – to Blyde	Lim_EF20	Olifants_EWR11	-24.3076; 30.7857	1321.92	B7H009	Use DWS, 2017 Implementation of Reserve hydrology (1920-2004)
Olifants – to Letaba	Lim_EF21	Olifants_EWR16 (Balule)	-24.0521; 31.7288	1918.3	B7H017	Use DWS, 2017 Implementation of Reserve hydrology (1920-2004)
Letaba – to Little Letaba	Lim_EF22	Letaba_EWR4 (Letaba Ranch)	-23.6771; 31.0983	441.39	B8H008	Use DWS, 2017 Implementation of Reserve hydrology (1920-2009)
Letaba – Little Letaba to Olifants	Lim_EF23	LET2	-23.8268; 31.5906	641.62	B8H018	Use DWS, 2017 Implementation of Reserve hydrology (1920-2009)
Shingwedzi	Lim_EF24		-23.2219; 31.5549	86.62	B9H003	Use DWS, 2017 Implementation of Reserve hydrology (1920-2010) adjusted to e-flow site
Limpopo – Mzingwani to Mwanedzi	Lim_EF25	LmEWR04 (Pafuri)	-22.6953; 31.8336	2792.13		Use LIMCOM, 2013 hydrology (1920-2010)
Elephantes	Lim_EF26		-23.8751; 32.2262	2552.036		Use LIMCOM, 2013 hydrology (1920-2010) adjusted to e-flow site
Limpopo – to estuary	Lim_EF27	LmEWR07 (Chokwe)	-24.5002; 33.0104	5572.09		Use LIMCOM, 2013 hydrology (1920-2010)

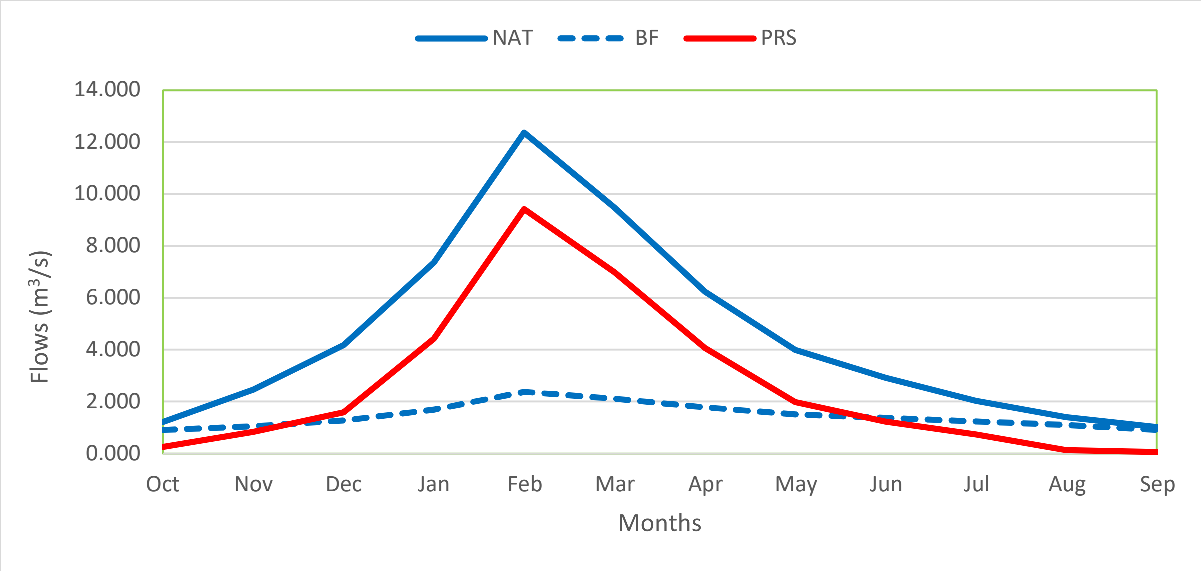

Figure 3-2: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Lephalala River (LEPH-A50H-SEEKO).

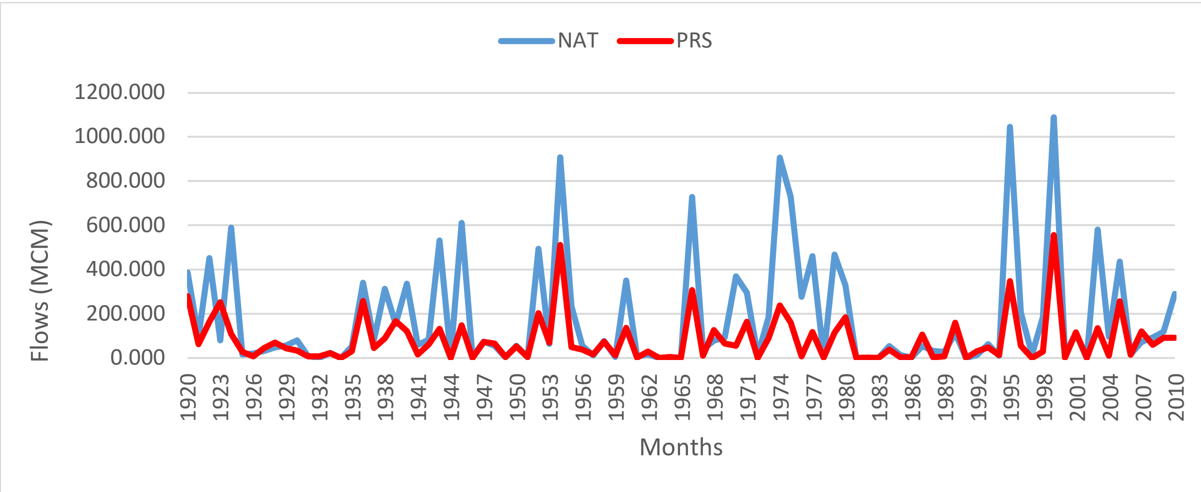

Figure 3-3: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Lephalala River (LEPH-A50H-SEEKO).

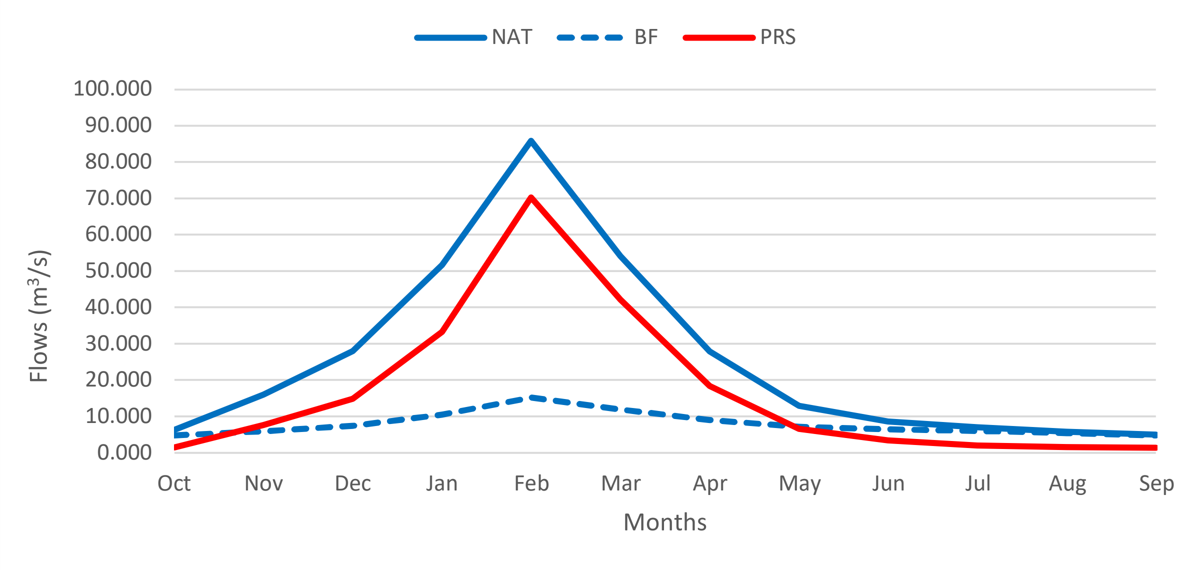

Figure 3-4: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Limpopo River at Limpokwena (LIMP-A36C-LIMPK).

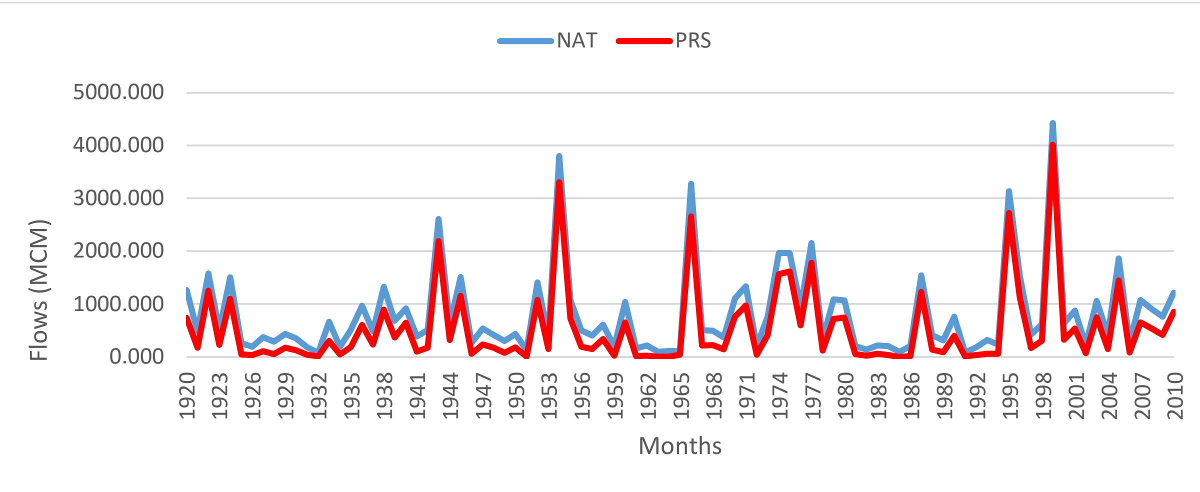

Figure 3-5: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Limpopo River at Limpokwena (LIMP-A36C-LIMPK).

3.2 Biological requirements for preliminary e-flow determination

Following the characterisation of the driver components (hydrology, water quality, geomorphology and hydraulics) for each site considered in the study, and determination of the present ecological state of each ecological component was considered (Table 3-2 and Figure 3-6), the indicator species, populations and communities identified to represent the ecosystem were used to determine preliminary e-flow requirements. The complete list of indicator components considered in the study that were established to provide preliminary e-flows and then integrated using BNs to generate integrated e-flows are provided in Appendix A. Some examples of the flow-ecosystem relationships used to generate ecosystem requirements for the LIMP-A41D-SPANW site are presented in Figure 3-7 to Figure 3-15.

Table 3-2: Summary of the present ecological state for biological components considered in the study aligned to the target ecological state for each component using A-F ecological categories where A = Natural, B= largely Natural, C = moderate modified, D = largely modified but still sustainable and F = critically modified and unsustainable.

Site	River	Invertebrates		Fish		Vegetation	
		Present state	Target	Present state	Target	Present state	Target
CROC-A24J-ROOIB	Crocodile River	C/D	C	C/D	C	C	C
LIMP-A41D-SPANW	Limpopo River	C	C	C	C	C/D	C
MATL-A41D-WDRAAI	Matlabas River	C	C	B/C	C	C	C
LEPH-A50H-SEEKO	Lephalala River	C/D	C	D	C	C	C
LIMP-A36C-LIMPK	Limpopo River	C	C	D	C	C	C
MOGA-A36D-LIMPK	Mogalakwena River	D	D	D	D	C	C
SHAS-Y20B-TULIB	Shashe River	C	C	D	C	D	C
LIMP-A71L-MAPUN	Limpopo River	C	C	C/D	C	C	C
UMZI-Y20C-BEITB	Umzingwani River	C	C	No fish	C	D	C
SAND-A71K-R508B	Sand River	C	C	C/D	C	B/C	C
LUVU-A91K-OUTPO	Luvuvhu River	C	C	C	C	B	C
MWEN-Y20H-MALAP	Mwenedzi River	C	C	C	C	NA	C
LIMP-Y30D-PAFUR	Limpopo River	C	C	C	C	D	C
SHIN-B90H-POACH	Shingwedzi River	B/C	C	D	C	B	C
GLET-B81J-LRANC	Groot Letaba River	C	D	D	D	B	C
LETA-B83A-LONEB	Letaba River	C	C	C/D	C	B	C
OLIF-B73H-BALUL	Olifants River	C	C	C	C	B	C
ELEP-Y30C-SINGU	Elefantes River	C	D	D	D	C/D	C
LIMP-Y30F-CHOKW	Limpopo River	C	D	C	D	D	D

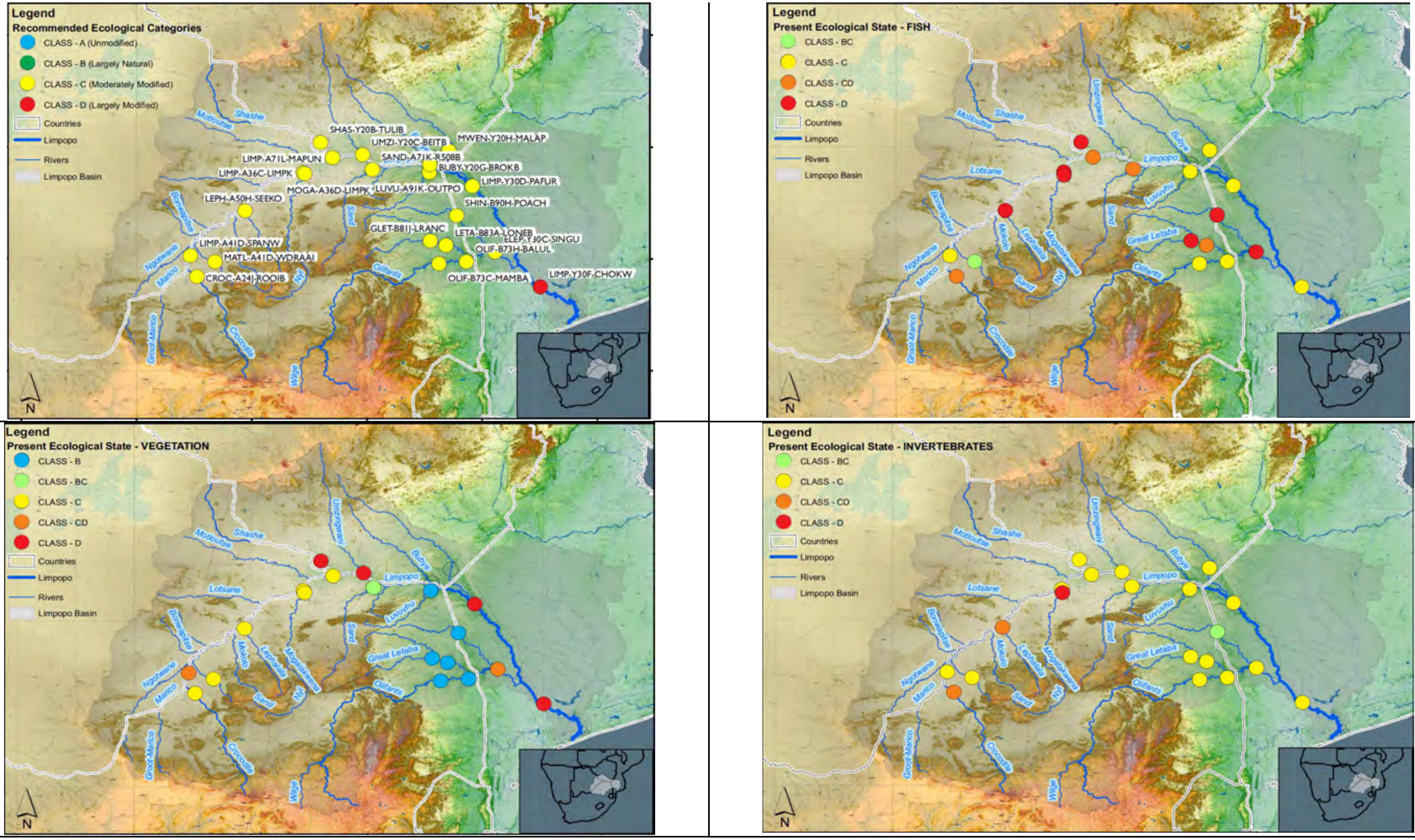

Figure 3-6: Present ecological state classification using A-F EcoClassification classification range for the recommended ecological category representing the vision for the sustainable use and protection of water resources in the Limpopo Basin, and for fish, invertebrates and vegetation.

The examples provided below are extracted from the "driver" and "response" reports (**Reports 4&5**) and are used to populate the BN models. In these examples, flow-ecosystem relationships used to represent conditional probability relationships between nodes or variables in the Bayesian Networks (as Conditional Probability Tables) are demonstrated. Here frequency distributions incorporating the zero, low, moderate and high ranks are provided. The conditional relationship has been interpreted into the zero, low, moderate and high risk ranks that are tabulated and presented graphically. In this example the relationships represents evidence used to describe the probable frequency distribution of the daughter variable in relation to discharge. These distributions are used directly to provide indicator requirement information for e-flows in the study and are then used as rules or conditional probability tables in the BN models to represent the flow-ecosystem relationships in the integrated assessments (See Appendix A). The relationships have unique shapes and distributions associated with the same hydrology (discharge) axis to represent the known evidence pertaining to each relationship. These relationships are evidence based and incorporate uncertainty due to knowledge gaps which can be mitigated through adaptive iterations.

FISH_ECO_VD				
m^3/s	Zero	Low	Med	High
0	0	0	1	99
0.8	0	0	30	70
1.6	1	10	39	50
2.4	1	34	45	20
3.2	1	63	31	5
3.9	20	53	26	1
8.8	50	48	1	1
15.5	85	14	1	0
24.2	95	5	0	0
34.7	90	9	1	0
47.1	85	10	5	0
61.3	75	20	5	0
77.4	65	30	5	0
95.3	65	30	5	0
115.1	65	30	5	0
136.8	65	30	5	0

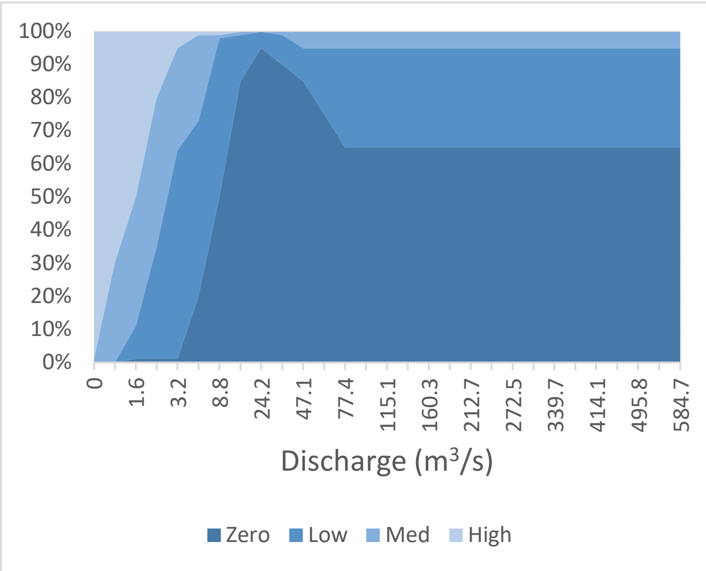

Figure 3-7: Flow-ecosystem relationship established in the study to represent the suitability of velocity-depth habitat characteristics for rheophilic indicator fishes (Labeo spp.), associated with discharge based on hydraulic relationships between flows and velocity-depth habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

FISH_ECO_COV				
m^3/s	Zero	Low	Med	High
0	0	0	5	95
0.8	0	0	5	95
1.6	0	0	5	95
2.4	0	0	5	95
3.2	1	15	45	39
3.9	10	25	40	25
8.8	55	35	9	1
15.5	70	25	5	0
24.2	95	5	0	0
34.7	95	5	0	0
47.1	95	5	0	0
61.3	95	5	0	0
77.4	95	5	0	0
95.3	95	5	0	0
115.1	95	5	0	0
136.8	95	5	0	0

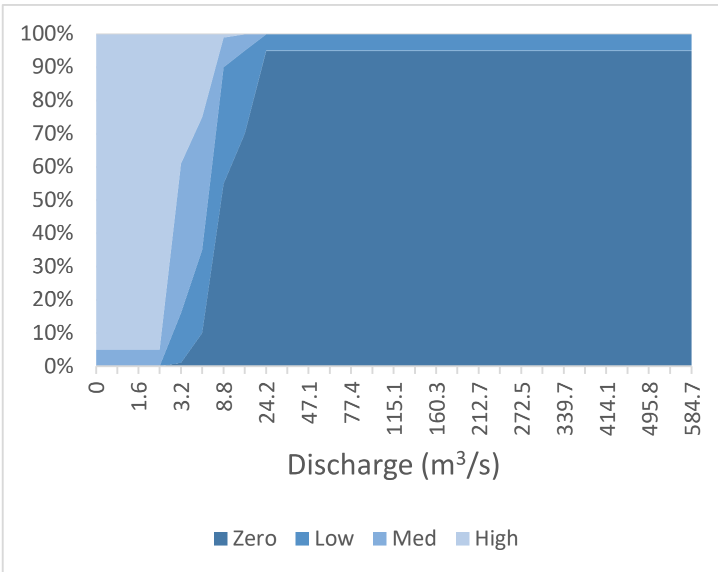

Figure 3-8: Flow-ecosystem relationship established in the study to represent the suitability of cover for the recruitment of cyprinids and cichlids as indicator fishes, associated with discharge based on hydraulic relationships between flows and levels of the channel where marginal vegetation occurs. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

FISH_ECO_SFLO				
m^3/s	Zero	Low	Med	High
0	0	0	1	99
0.8	0	0	1	99
1.6	0	1	5	94
2.4	0	1	5	94
3.2	0	1	5	94
3.9	0	1	5	94
8.8	0	5	10	85
15.5	0	10	50	40
24.2	0	20	50	30
34.7	25	50	20	5
47.1	50	40	9	1
61.3	75	20	5	0
77.4	75	20	5	0
95.3	75	20	5	0
115.1	75	20	5	0
136.8	75	20	5	0
160.3	75	20	5	0
185.6	75	20	5	0
212.7	75	20	5	0
241.7	75	20	5	0
272.5	75	20	5	0
305.2	45	45	9	1
339.7	45	45	9	1
375.9	45	45	9	1
414.1	45	45	9	1
454	45	45	9	1
495.8	20	50	25	5
539.3	20	50	25	5
584.7	20	50	25	5

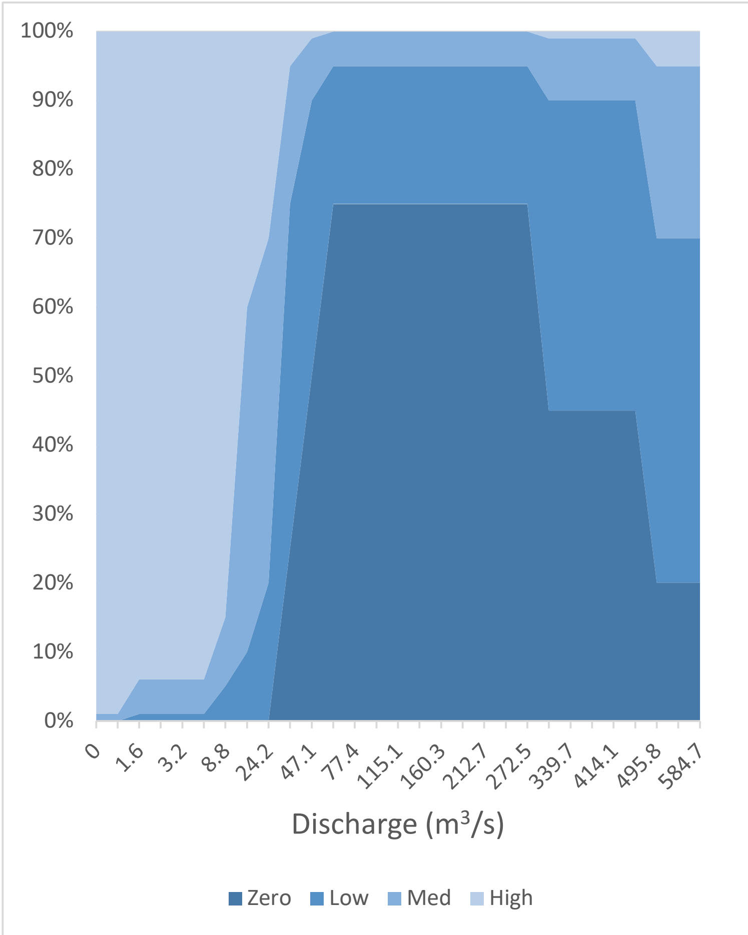

Figure 3-9: Flow-ecosystem relationship established in the study to represent the suitability of instream substrates required for the successful reproduction (spawning) and recruitment of indicator migratory fishes cyprinids, associated with discharge based on hydraulic relationships between flows and sheer velocities in the water to mobilise gravel substrates so that gravel bars can be formed. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

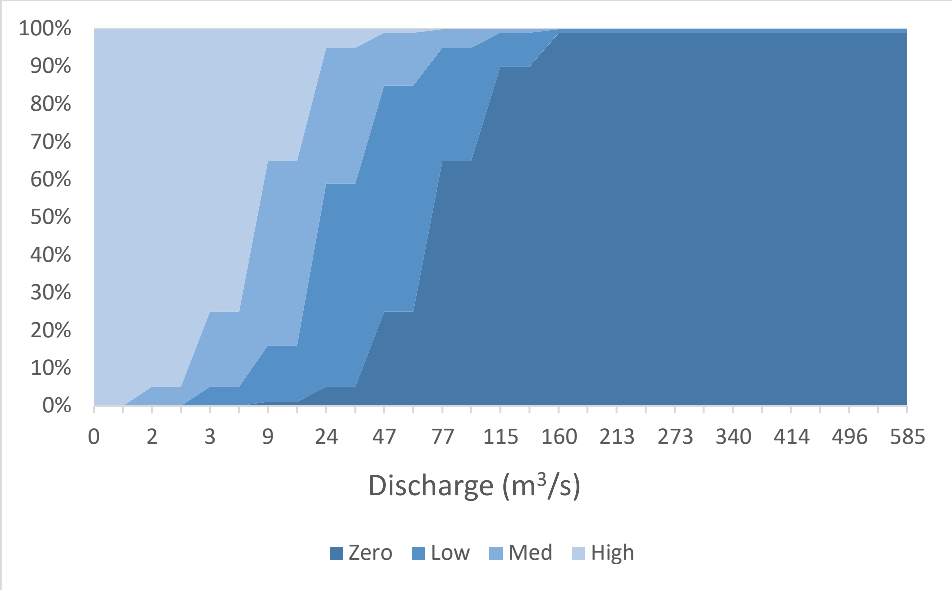

Figure 3-10: Flow-ecosystem relationship established in the study to represent the seasonal flows required for ecological cues to stimulate and facilitate the migrations and spawning of migratory fishes (cyprinids) considered in the study. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

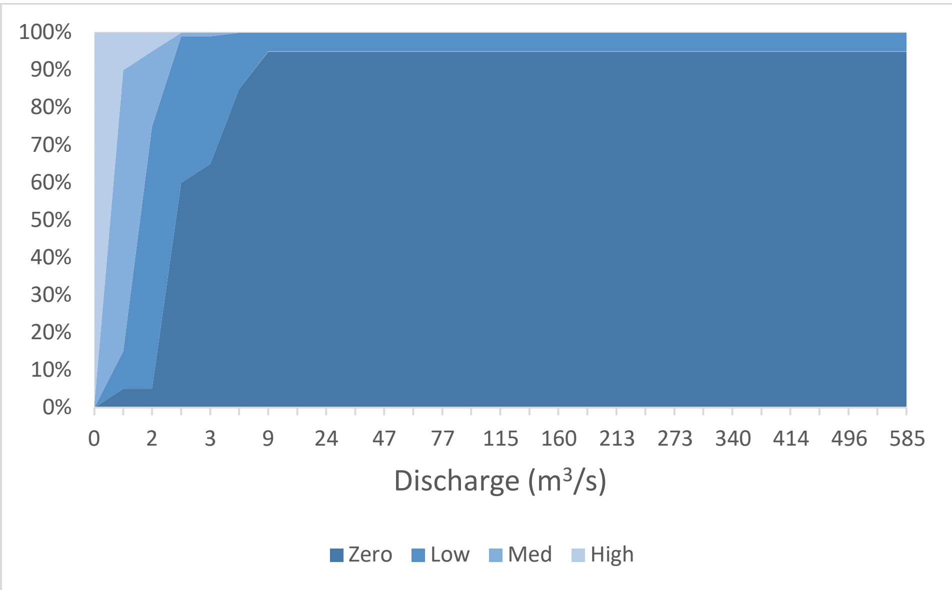

Figure 3-11: Flow-ecosystem relationship established in the study to represent the suitability of instream velocity depth characteristics to maintain macroinvertebrate communities, associated with discharge based on hydraulic relationships between flows and velocity and depth characteristics of biotopes to maintain diverse habitats associated with species. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

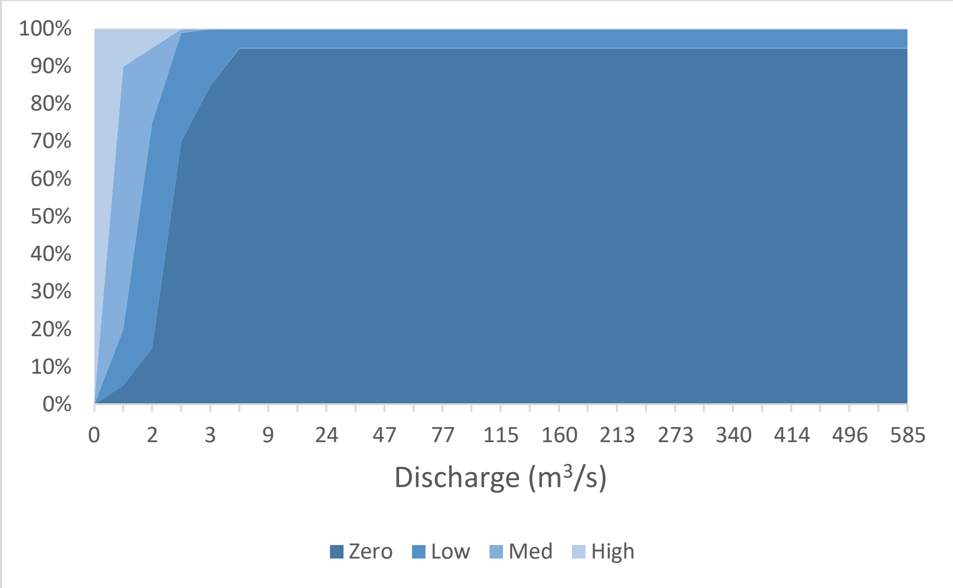

Figure 3-12: Flow-ecosystem relationship established in the study to represent the suitability of instream cover characteristics for macroinvertebrate communities, associated with discharge based on hydraulic relationships between flows and water levels with information on velocities to maintain cover characteristics. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

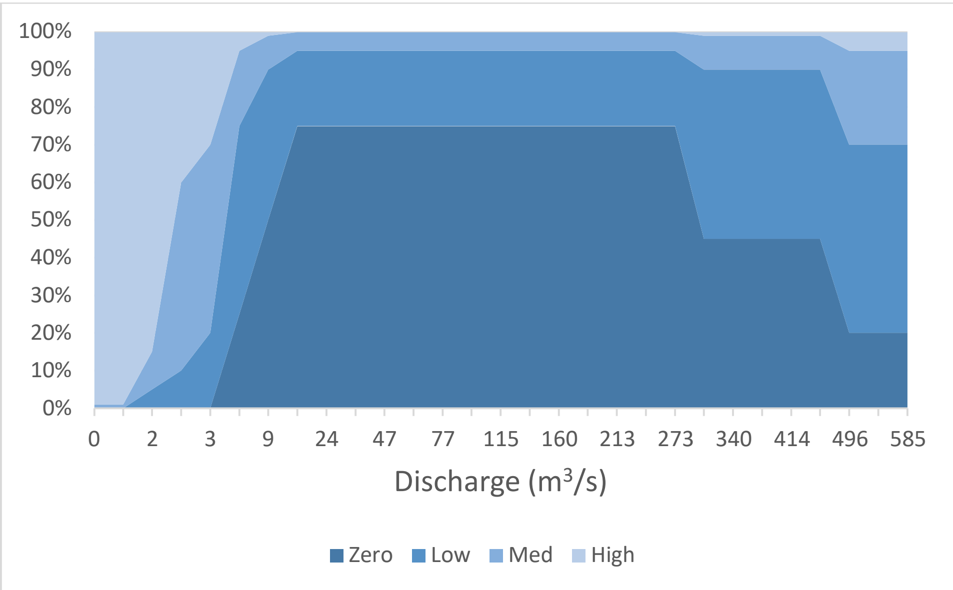

Figure 3-13: Flow-ecosystem relationship established in the study to represent the suitability instream substrate characteristics including gravel and maintenance of rocky substrates that are not embedded, requirement associated with discharge based on hydraulic relationships between flows and sheer velocities in the water to mobilise gravel substrates so that gravel bars can be formed. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

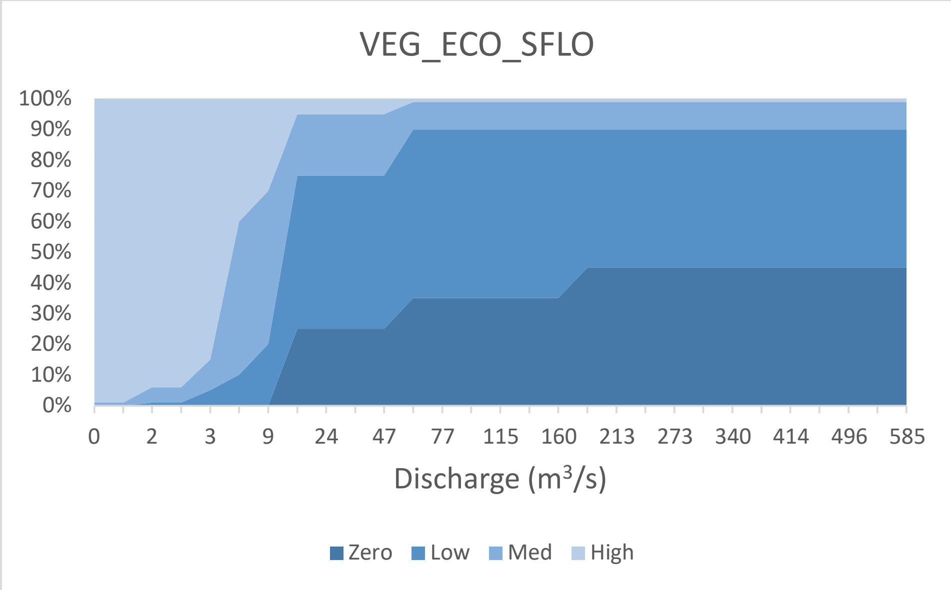

Figure 3-14: Flow-ecosystem relationship established in the study to represent the suitability of sediments to support aquatic and riparian vegetation, habitats associated with discharge based on hydraulic relationships between flows and sheer velocities in the water to mobilise sediments. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

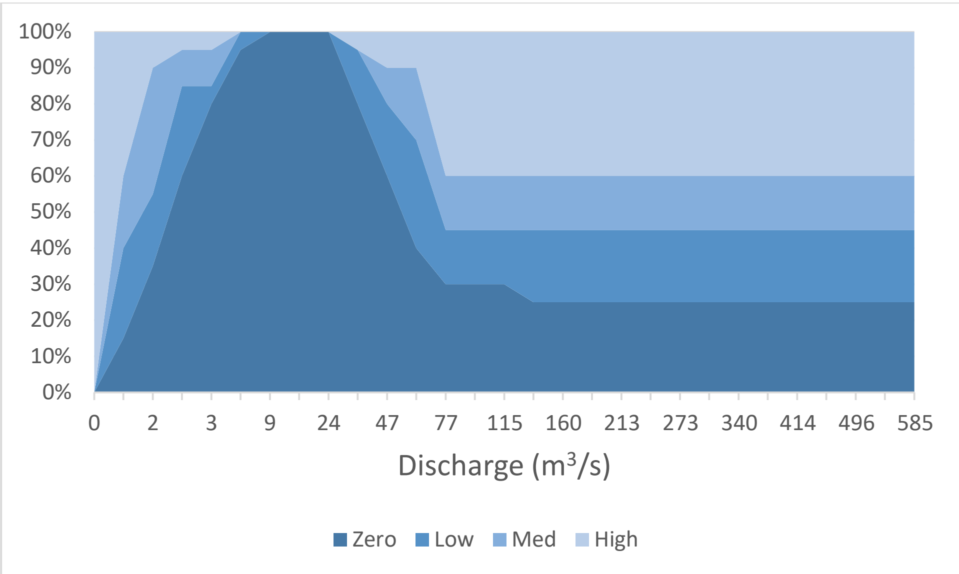

Figure 3-15: Flow-ecosystem relationship established in the study to represent the suitable water levels in the river to maintain riparian habitats for selected indicator species. Habitats associated with discharge based on hydraulic relationships between flows and water levels associated with banks and present and potential location of riparian plants. Habitats and species response data obtained in the study for the Limpopo River at LIMP-A41D-SPANW. Table represents relationships (left) which is graphically presented (right). Zero, low, moderate and high-risk ranks included.

The complete list of indicators and relationships used for each site is provided in Reports 4&5 and supplementary risk model support tools.

3.2.1 Flow-ecosystem indicator relationship requirements for e-flow determination.

In step 7 after the application of the BNs to determine e-flow requirements through an iterative process the requirements to provide suitable e-flows is completed to provide requirements for ecosystem indicator variables considered in the study. These requirements include data on flows (volume) for indicator variables associated with suitable timing and duration of flows to meet a determined requirement. This data was summarised and provided to the hydrologist to establish e-flow requirements for each site considered in the study. Requirements for base flows and freshets and floods are provided as summaries for each site in tables Table 3-3 to Table 3-34. The tables include flow duration requirements in the form of the shape of the flows required associated with the statistics should the statistics be applied as average flows or peak volumes and then for what period/duration are these flows required. Flood classes include small (Class 1) and large (Class 2) freshets, annual floods, (Class 3) annual large floods (Class 4) and infrequent large (1 in 3-5 year) floods (Class 5). Flood statistics provided to support allocation includes volume (m^3/s), daily average ($\bar{x}$) or peak nature of flows, period (days and) timing of flows as months of the year.

CROC-A24J-ROOIB

Table 3-3: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the CROC-A24J-ROOIB site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	4.0	9.0	9.0	9.0	9.0	9.0	9.0	4.0	4.0	4.0	4.0	4.0
50			7.0	8.0	8.0	8.0	8.0	8.0				
80	2.4	3.2	3.2	3.2	3.2	3.2	3.2	2.4	2.4	2.4	2.4	2.4
99.9	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Table 3-4: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the CROC-A24J-ROOIB site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	12	12				12
	daily x/peak		average				
	days		7				7
	Months		Nov, Dec				
Class 2	m^3/s	25	25	25	25		25
	daily x/peak		average	average	average		
	days		7	7	3		7
	Months		Jan, Feb	Jan, Feb, Mar	Jan, Feb, Mar		
Class 3	m^3/s	110-145			145	110	145
	daily x/peak				peak	peak	
	days				3	5	5
	Months				Jan, Feb	Feb	
Class 4	m^3/s	200-512				200	
	daily x/peak					peak	
	days						
	Months					1:2/3 flood	
Class 5	m^3/s	400			512	400	
	daily x/peak				peak	peak	
	days				5		
	Months				wet x1	1:5-10 flood	

LIMP-A41D-SPANW

Table 3-5: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-A41D-SPANW sites.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
30				16.0	16.0	16.0						
50	3.2	3.2	4.0	6.6	6.6	6.6	6.6	3.2	3.2	3.2	3.2	3.2
80	2.4	3.2	3.2	3.2	3.2	3.2	3.2	2.4	2.4	2.4	2.4	2.4
99.9	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

Table 3-6: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-A41D-SPANW sites.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	8	8	8			8
	daily x̄/peak		average	average			average
	days		7	7			7
	Months		Nov, Mar	Nov, Mar			Nov, Mar
Class 2	m^3/s	30-60	33	33	60	40	30-40
	daily x̄/peak		peak	peak	peak	peak	peak
	days		7	7	3	5	7
	Months		Nov, Jan, Feb	Nov, Jan, Feb	Dec, Jan, Feb, Mar	Dec, Jan, Feb, Mar	Nov, Dec, Jan, Feb, Mar
Class 3	m^3/s	100-280			280	100-130	280
	daily x̄/peak				peak	peak	peak
	days				3	3	3
	Months				Oct, Jan, Feb	Feb	Jan, Feb
Class 4	m^3/s	300-350				300-350	
	daily x̄/peak					peak	
	days					3	
	Months					1:5 year	
Class 5	m^3/s	>3000			3143		
	daily x̄/peak				Peak		
	days				5		
	Months				1:10 year		

MATL-A41D-WDRAAI

Table 3-7: Integrated monthly average base flow discharge (m³/s) requirements from the fish, invertebrates and vegetation indicator components for the MATL-A41D-WDRAAI site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.1	0.1	0.1	
50	0.0	0.4	1.0	1.3	1.3	0.8	0.5	0.2	0.1	0.1	0.0	0.0
80	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
95			0.0	0.1	0.0	0.0	0.0	0.0				
99.9			0.0	0.1	0.0	0.0	0.0					

Table 3-8: Integrated monthly average freshet and flood discharge (m³/s) requirements from the fish, invertebrates and vegetation indicator components for the MATL-A41D-WDRAAI site.

Class	Units	Range (m³/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m³/s	5-8		7.3	2.4	5	7.3
	daily x7peak			average	average	peak	average
	days			7	2	3	7
	Months			Jan, Feb, Mar	Oct, Dec, Feb, Mar	Jan, Feb, Mar	Oct, Dec, Jan, Feb, Mar
Class 2	m³/s	10-16			16	10	16
	daily x7peak				peak	peak	peak
	days				3	5	5
	Months				Feb, Mar	Feb	Feb, Mar
Class 3	m³/s	20-22	22			20	22
	daily x7peak		peak			peak	peak
	days		7			5	7
	Months		Nov, Jan, Feb			Feb	Nov, Jan, Feb
Class 4	m³/s	>35			46	35	
	daily x7peak				Peak	peak	
	days				3		
	Months				Feb	1 in 5 years	

LEPH-A50H-SEEKO

Table 3-9: Integrated monthly average base flow discharge (m³/s) requirements from the fish, invertebrates and vegetation indicator components for the LEPH-A50H-SEEKO site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	1.2	1.8	1.8	2.4	2.4	2.4	2.4	1.2	1.2	1.2	1.2	0.2
40	>0	>0	>0	1.0	2.0	2.0	1.0	>0	>0	>0	>0	>0
50	0.6	0.6	1.2	4.3	4.3	3.9	2.0	1.3	0.6	0.6	0.6	0.4
80	0.3	0.6	0.6	0.6	0.6	0.6	0.6	0.3	0.3	0.3	0.3	0.3
99.9	0.3	0.3	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4

Table 3-10: Integrated monthly average freshet and flood discharge (m³/s) requirements from the fish, invertebrates and vegetation indicator components for the LEPH-A50H-SEEKO site.

Class	Units	Range (m³/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m³/s	5-8	8		5	6	8
	daily x̄/peak		Peak		average	peak	average
	days		7		3	3	5
	Months		Jan, Feb, Mar		Oct, Dec, Feb, April	4 events per wet season	Oct, Nov, Dec, Jan, Feb, Mar, Apr
Class 2	m³/s	15-30	15		28	13-30	30
	daily x̄/peak		Peak		peak	peak	peak
	days		7		3	5	5
	Months		FEB		Jan, March	annual flood	Jan, Feb, Mar
Class 3	m³/s				99		90
	daily x̄/peak				Peak		peak
	days				5		5
	Months				Feb		Feb
Class 4	m³/s			136		80-120	130
	daily x̄/peak					peak	peak
	days			7			
	Months			Jan-Mar		1:2 event	1:2 year

LIMP-A36C-LIMPK

Table 3-11: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-A36C-LIMPK site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	4.3	15.0	15.0	15.0	15.0	15.0	15.0	4.3	4.3	4.3	4.3	4.3
40				10.0	10.0	15.0						
50	3.6	4.3	4.3	10.5	10.5	10.5	8.0	5.0	3.6	3.6	3.6	3.6
80	1.4	2.7	2.7	2.7	2.7	2.7	2.7	1.8	1.8	1.8	1.4	1.4
99.9	0.0	0.3	0.3	0.6	0.9	0.6	0.5	0.3	0.3	0.3	0.2	0.0

Table 3-12: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-A36C-LIMPK site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	15-25	15		21	20-25	25
	daily x7peak		Peak			peak	peak
	days		7	7		5	5
	Months		Jan, Feb, Mar	Jan - Mar		3 events per wet season	Jan, Feb, Mar
Class 2	m^3/s	30-50	30			35-50	50
	daily x7peak		Peak			peak	peak
	days		7			6	6
	Months		Jan, Feb, Mar			2 events per wet season	Jan, Feb, Mar
Class 3	m^3/s	200-300			293	200-250	250
	daily x7peak					peak	peak
	days					6	6
	Months					annual flood	Feb

MOGA-A36D-LIMPK

Table 3-13: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the MOGA-A36D-LIMPK site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
30				5.0	5.0	5.0						
50	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
99.9	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.1	1.0

Table 3-14: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the MOGA-A36D-LIMPK site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	5-15	5		11	10	10
	daily x̄/peak		Peak		average	peak	average
	days		7		3	4	4
	Months		Nov, Jan, Feb		Oct, Dec, Feb, Mar	3 events per wet season	Oct, Nov, Dec, Jan, Feb, Mar
Class 2	m^3/s	20-54	22		42	30	42
	daily x̄/peak		Peak		Peak	peak	peak
	days		5		3	5	5
	Months		Nov, Jan, Feb		Jan Feb	annual flood	Nov, Jan, Feb
Class 3	m^3/s	70-200			194	70-120	190
	daily x̄/peak				Peak	peak	peak
	days				5		5
	Months				Feb	1 event every 2nd or 3rd year	Feb
Class 4	m^3/s			284			
	daily x̄/peak						
	days			7			
	Months			1:2 year			

SHAS-Y20B-TULIB

Table 3-15: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the SHAS-Y20B-TULIB site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	0.1	3.0	3.6	3.6	3.6	3.6	3.6	0.9	0.9	0.9	0.9	0.9
50	0.0	0.3	2.6	4.6	5.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3-16: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the SHAS-Y20B-TULIB site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	15-35	16		35		35
	daily x/peak		average		average		average
	days		7		5		5
	Months		Jan, Feb		Oct, Dec, Feb		Oct, Dec, Jan, Feb
Class 2	m^3/s	48	48				48
	daily x/peak		Peak				peak
	days		3				3
	Months		Feb				Feb
Class 3	m^3/s	350			350		350
	daily x/peak				peak		peak
	days				3		3
	Months				Dec; Feb		Dec, Feb
Class 4	m^3/s			927		927	
	daily x/peak						
	days			7		7	
	Months			Jan - Mar		Jan - Mar	

LIMP-A71L-MAPUN

Table 3-17: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-A71L-MAPUN site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	5.0	5.0	13.0	70.0	70.0	70.0	13.0	5.0	5.0	5.0	5.0	5.0
50	4.0	4.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0
80	1.0	1.0	1.0	2.0	2.0	2.0	1.0	0.7	0.7	0.7	0.7	0.7
99.9	0.2	0.3	1.5	2.0	2.0	2.0	1.5	0.6	0.6	0.6	0.6	0.3

Table 3-18: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-A71L-MAPUN site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	20-45	24		45		45
	daily x7peak		Peak		daily		average
	days		7		5		5
	Months		Jan, Feb, Mar		Wet season x 4		Dec, Jan, Feb, Mar
Class 2	m^3/s	190-200			192		192
	daily x7peak				peak		peak
	days				3		3
	Months				Wet season x2		Jan, Feb
Class 3	m^3/s	600-1000				600-1000	600
	daily x7peak					peak	peak
	days						3
	Months					1 in 1/2-year flood	Feb
Class 4	m^3/s			2009	3560		
	daily x7peak				peak		
	days			7	5		
	Months			Jan - Mar	wet x 1		

UMZI-Y20C-BEITB

Table 3-19: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the UMZI-Y20C-BEITB site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	0.0	0.0	0.0	4.4	4.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0
40				1.7	1.7	1.7						
50	0.0	0.1	0.9	6.0	7.5	4.8	1.2	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3-20: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the UMZI-Y20C-BEITB site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	10-20	13			11	13
	daily x̄/peak		Peak			peak	average
	days		7			4	4
	Months		Jan, Feb			2 events per wet season	Jan, Feb, Apr
Class 2	m^3/s	30-40			38		38
	daily x̄/peak				average		average
	days				2		2
	Months				Dec Feb March		Dec, Jan, Feb, Mar
Class 3	m^3/s	100-110			103		103
	daily x̄/peak				peak		peak
	days				3		3
	Months				Jan Feb		Jan, Feb
Class 4	m^3/s	300-400			366	300	350
	daily x̄/peak				Peak	peak	peak
	days				3	5	3
	Months				Feb	annual flood	Feb
Class 5	m^3/s	>850	872		2300	850	
	daily x̄/peak					peak	
	days		7				
	Months		Jan - Mar			1 in 5 years	

SAND-A71K-R508B

Table 3-21: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the SAND-A71K-R508B site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	0.1	0.1	1.6	1.6	1.6	1.6	0.8	0.1	0.1	0.1	0.1	0.1
30				0.4	0.4							
50	0.1	0.3	0.3	0.4	0.5	0.5	0.3	0.3	0.2	0.2	0.2	0.1
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3-22: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the SAND-A71K-R508B site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s		6.4		14	12	12
	daily x̄/peak		Peak		ave	peak	average
	days	5-15	7		3	5	3
	Months		Feb		Nov, Jan, March Aril	annual flood in Jan or Feb	Nov, Dec, Jan, Feb, Mar, Apr
Class 2	m^3/s					30 - 50	50
	daily x̄/peak	30-50				peak	peak
	days					5	5
	Months					1 in 2-year flood	Feb
Class 3	m^3/s				146	100	
	daily x̄/peak	100-150			peak	peak	
	days				3		
	Months				Dec, Feb	1 in 5	
Class 4	m^3/s			662	850		
	daily x̄/peak	>600			Peak		
	days			7	5		
	Months			Jan-Mar	Feb		

LUVU-A91K-OUTPO

Table 3-23: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LUVU-A91K-OUTPO site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	3.2	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.2
50	2.8	4.2	6.5	13.0	17.6	15.4	8.2	4.8	3.7	2.8	2.4	2.3
80	1.2	1.6	2.4	2.4	2.4	2.4	2.4	1.6	1.6	1.6	1.6	1.2
99.9	1.8	2.1	2.2	2.7	2.9	3.0	2.9	2.0	1.8	1.6	1.6	1.6

Table 3-24: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LUVU-A91K-OUTPO site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	20-30	22			20	22
	daily x7peak		Peak			peak	average
	days		7			4	4
	Months		Jan, Feb, Mar			4 events per wet season	Jan, Feb, Mar, Apr
Class 2	m^3/s	60-70			68		68
	daily x7peak				daily		average
	days				3		3
	Months				Oct, Dec, Jan, Feb, March		Oct, Dec, Jan, Feb, Mar
Class 3	m^3/s	160				160	160
	daily x7peak					peak	peak
	days					5	5
	Months					annual flood in Feb	Feb
Class 4	m^3/s			785		350	
	daily x7peak					peak	
	days			7			
	Months			Jan - Feb		1 in 2–5-year flood	

MWEN-Y20H-MALAP

Table 3-25: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the MWEN-Y20H-MALAP site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	3.2	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.2
50	2.8	4.2	6.5	13.0	17.6	15.4	8.2	4.8	3.7	2.8	2.4	2.3
80	1.2	1.6	2.4	2.4	2.4	2.4	2.4	1.6	1.6	1.6	1.6	1.2
99.9	1.8	2.1	2.2	2.7	2.9	3.0	2.9	2.0	1.8	1.6	1.6	1.6

Table 3-26: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the MWEN-Y20H-MALAP site.

<table>
<tr><th>Class</th><th>Units</th><th>Range (m³/s)</th><th>Fish</th><th>Inverts</th><th>Geomorph</th><th>Veg</th><th>Int. freshets</th></tr>
<tr><td rowspan="4">Class 1</td><td>m³/s</td><td rowspan="4">20-30</td><td>22</td><td></td><td></td><td>20</td><td>22</td></tr>
<tr><td>daily x̄/peak</td><td>Peak</td><td></td><td></td><td>peak</td><td>average</td></tr>
<tr><td>days</td><td>7</td><td></td><td></td><td>4</td><td>4</td></tr>
<tr><td>Months</td><td>Jan, Feb, Mar</td><td></td><td></td><td>4 events per wet season</td><td>Jan, Feb, Mar, Apr</td></tr>
<tr><td rowspan="4">Class 2</td><td>m³/s</td><td rowspan="4">60-70</td><td colspan="4">68</td><td>68</td></tr>
<tr><td>daily x̄/peak</td><td colspan="4">daily</td><td>average</td></tr>
<tr><td>days</td><td colspan="4">3</td><td>3</td></tr>
<tr><td>Months</td><td colspan="4">Oct, Dec, Jan, Feb, March</td><td>Oct, Dec, Jan, Feb, Mar</td></tr>
<tr><td rowspan="4">Class 3</td><td>m³/s</td><td rowspan="4">160</td><td></td><td></td><td></td><td>160</td><td>160</td></tr>
<tr><td>daily x̄/peak</td><td></td><td></td><td></td><td>peak</td><td>peak</td></tr>
<tr><td>days</td><td></td><td></td><td></td><td>5</td><td>5</td></tr>
<tr><td>Months</td><td></td><td></td><td></td><td>annual flood in Feb</td><td>Feb</td></tr>
<tr><td rowspan="4">Class 4</td><td>m³/s</td><td rowspan="4"></td><td></td><td>785</td><td></td><td>350</td><td></td></tr>
<tr><td>daily x̄/peak</td><td></td><td></td><td></td><td>peak</td><td></td></tr>
<tr><td>days</td><td></td><td>7</td><td></td><td></td><td></td></tr>
<tr><td>Months</td><td></td><td>Jan - Feb</td><td></td><td>1 in 2–5-year flood</td><td></td></tr>
</table>

LIMP-Y30D-PAFUR

Table 3-27: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-Y30D-PAFUR site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	2.6	2.6	18.0	40.0	40.0	40.0	40.0	18.0	2.6	2.6	2.6	2.6
50	2.6	2.6	2.6	5.2	5.2	5.2	5.2	2.6	2.6	2.6	2.6	2.6
85	0.3	0.3	1.3	1.3	1.3	1.3	1.3	1.0	1.0	0.3	0.3	0.3
99.9	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Table 3-28: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-Y30D-PAFUR site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class I	m^3/s		60				
	daily x7peak		Peak				
	days		7				
	Months		Jan, Feb, Mar				

SHIN-B90H-POACH

Table 3-29: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the SHIN-B90H-POACH site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	0.3	0.3	0.3	2.7	2.7	2.7	0.3	0.3	0.3	0.3	0.3	0.3
30				1.0	1.0							
50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
60		0.1	0.1	0.1	0.1	0.1	0.1					
80	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3-30: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the SHIN-B90H-POACH site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	5-10	5			6	6
	daily x7peak		Peak			peak	peak
	days		7			3	3
	Months		Jan, Feb, Mar			3 events per wet season	Jan, Feb, Mar
Class 2	m^3/s	20			20		20
	daily x7peak				peak		peak
	days				3		3
	Months				Jan, Feb?		Jan, Mar
Class 3	m^3/s	30-35	33			30	33
	daily x7peak		Peak			peak	peak
	days		3			5	3
	Months		Feb			annual flood	Feb
Class 4	m^3/s				143	>50	
	daily x7peak				Daily average	peak	
	days				4		
	Months				Feb	1 in 2 yrs. flood	

GLET-B81J-LRANC

The e-flows (Ecological Reserve) for this site have been established as a part of South African RDM determination processes by the South African DWS and have been gazetted and are thus legally binding. These documented e-flows needed to be used in this study to provide e-flow data but were then tested using the PROFLO approach in the integrated assessment.

LETA-B83A-LONEB

The e-flows (Ecological Reserve) for this site have been established as a part of South African RDM determination processes by the South African DWS and have been gazetted and are thus legally binding. These documented e-flows needed to be used in this study to provide e-flow data but were then tested using the PROFLO approach in the integrated assessment.

OLIF-B73H-BALUL

The e-flows (Ecological Reserve) for this site have been established as a part of South African RDM determination processes by the South African DWS and have been gazetted and are thus legally binding. These documented e-flows needed to be used in this study to provide e-flow data but were then tested using the PROFLO approach in the integrated assessment.

ELEP-Y30C-SINGU

Table 3-31: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the ELEP-Y30C-SINGU site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
50	10.0	10.0	10.0	10.0	12.0	12.0	12.0	10.0	10.0	10.0	10.0	10.0
80	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
99.9	1.3	1.3	3.3	3.3	3.3	3.3	3.3	1.3	1.3	1.3	1.3	1.3

Table 3-32: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the ELEP-Y30C-SINGU site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	20-30	21				21
	daily x̄/peak		Peak				average
	days		7				7
	Months		Dec, Jan, Feb				Dec, Jan, Feb
Class 2	m^3/s	30-60	36		49	40-60	50
	daily x̄/peak		Peak		Ave	peak	average
	days		3		2	4	3
	Months		Feb, Mar		Nov, Jan, Feb, March	3 events per wet season	Nov, Jan, Feb, Mar
Class 3	m^3/s	200-500			203	480	480
	daily x̄/peak				Peak	peak	peak
	days				4	5	4
	Months				Dec, Feb	annual flood	Feb

LIMP-Y30F-CHOKW

Table 3-33: Integrated monthly average base flow discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-Y30F-CHOKW site.

Percentiles	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20	10.0	10.0	21.3	21.3	21.3	21.3	21.3	21.3	10.0	10.0	10.0	10.0
50	7.0	7.0	19.4	50.0	50.0	50.0	50.0	19.4	7.0	7.0	7.0	7.0
80	1.4	1.4	2.8	2.8	2.8	2.8	2.8	2.8	1.4	1.4	1.4	1.4
99.9	0.2	0.2	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.2	0.2	0.2

Table 3-34: Integrated monthly average freshet and flood discharge (m^3/s) requirements from the fish, invertebrates and vegetation indicator components for the LIMP-Y30F-CHOKW site.

Class	Units	Range (m^3/s)	Fish	Inverts	Geomorph	Veg	Int. freshets
Class 1	m^3/s	60-120	62		75	115	75
Class 1	daily $\bar{x}$/peak	60-120	Peak		average	peak	average
Class 1	days	60-120	7		3	3	4
Class 1	Months	60-120	Jan, Feb, Mar		Oct, Dec, Feb March	3 events per wet season	Oct, Nov, Dec, Jan, Feb, Mar
Class 2	m^3/s	140-180	141			175	175
Class 2	daily $\bar{x}$/peak	140-180	Peak			peak	average
Class 2	days	140-180	3			3	3
Class 2	Months	140-180	Feb, Mar			2 events per wet season	Feb, Mar, Apr
Class 3	m^3/s	265			265		265
Class 3	daily $\bar{x}$/peak	265			Peak		peak
Class 3	days	265			3		3
Class 3	Months	265			Jan Feb		Jan, Mar
Class 4	m^3/s	630				630	630
Class 4	daily $\bar{x}$/peak	630				peak	peak
Class 4	days	630				5	5
Class 4	Months	630				annual flood	Feb
Class 5	m^3/s	>1000			1386	1600	
Class 5	daily $\bar{x}$/peak	>1000			Peak	peak	
Class 5	days	>1000			5		
Class 5	Months	>1000			Feb	1 in 3–5-year flood	

3.3 Integrated e-flow determination

The final part of the e-flow determination process was to apply the BN probability models to evaluate the relative risk of the natural, present day and preliminary e-flow scenarios to consider their suitability for integrated e-flows to represent the suitable balance between the use and protection of the water resources considered in the study. Here the relative risk of flow and non-flow stressors have been considered on a relative scale to between the fish, invertebrate and vegetation endpoints so that the integrated consequences of altered flows (importantly the e-flows) scenario can be considered. Results are presented graphically in Figure 3-16 to Figure 3-21.

3.3.1 Fish communities

In Figure 3-16**Error! Reference source not found.** the relative risk scores to FISH-ECO-END for each flow scenario considered to determine the e-flows have been considered from a fish perspective. Results include clear difference in risk to the fish endpoints when the natural scenarios are compared to the present-day scenarios. All the sites have a zero to low relative risk under natural conditions but under present and e-flow conditions, the relative risk increases with many sites experiencing medium risk with possible high risk. Due to the requirement for e-flows to maintain moderately modified (Class C) at one site or a largely modified (Class D) ecological state at another, the risk to the fish at many of the sites remains the same as present when under e-flow conditions or increases slightly into the moderate or threshold of potential concern. These ecological classes include aspects of the drought, base flows, freshets and floods. The outcomes of the e-flow requirements are provided as flow-duration tables with associated percentiles to ensure volumes are provided. These states are still considered sustainable and may be appropriate for hard working rivers.

From the hydrology results (Section 3.1) the considerable change in flows observed at most sites considered in the study has resulted in significant increases in risk with many sites periodically experiencing high risk that would be unsustainable. The risk projections from the Crocodile River, Limpopo River (at Spanwerk in the upper reaches of the catchment and Chokwe in the lower reaches of the basin), the seasonal rivers in the middle reaches of the basin including Mogalakwena, Shashe, Umzingwane and Sand Rivers and the perennial Letaba, Olifants and Elephantes Rivers are high representing rivers that are heavily used. In particular the perennial rivers experience no-flow conditions and are often more seasonal now than perennial (Table 2-3). The fish of these rivers are particularly vulnerable as their "permanent" habitats have been lost. Many of the no-flow, non-migratory fishes are not represented in these reaches of river and many migratory fishes do not have access to many of these sites as barriers affect migrations. In the seasonal rivers the freshets and flood flows are not generally restricted and the reduced fish diversities (relative to the perennial rivers) still migrate into and use these rivers during high flow periods. But the abundance and quality of refuge areas the migratory fish require to maintain populations in the main stem Limpopo River, particularly in the lower reaches are declining. This affects the populations in the main stem and in the tributaries as migrations have reduced. The dams located in the tributaries also affect migration potential and within these dams alien species are introduced which add to the competition with indigenous fishes.

The application of the Fish Response Assessment Index resulted in overall ecological categories of fishes that reflect a hard working but suitable ecological category. So the risk assessment outcomes for the e-flows established to meet or slightly improve fish communities are acceptable in this study. Increased risk to fish communities associated with e-flows in the perennial Letaba and Olifants Rivers and the seasonal Mogalakwena and Shashe Rivers were observed (Figure 3-16**Error! Reference source not found.**). These risk projections in the Letaba and Olifants Rivers are excessive and suggest that the e-flows are not sufficient to maintain suitable fish communities in these rivers, but these e-flows cannot be adjusted as they have been formally gazetted through the National Water Act (108 of 1998) in South Africa as a part of the Resource Directed Measures of the country. We recommend that our evidence is considered and these e-flows are prioritised for review in the next round of evaluations and or monitoring to ensure that suitable e-flows are provided for these rivers. In the Mogalakwena and Shashe Rivers freshet and flood flows are required to maintain the fish communities in a suitable state. Presently while base flows have been considerably reduced in the study area freshet and flood flows exceed the requirements migratory fish need to maintain suitable hard-working conditions in the rivers. Therefore increased risk associated with the e-flow scenarios for these two seasonal rivers is acceptable. The remaining results represent suitable risk projections that need to be monitored due to uncertainty in the results, considered in the uncertainty section, but can be implemented to meet the vision for each site considered in the study.

The probability of each risk rank occurring to the fish endpoint is presented in Figure 3-17**Error! Reference source not found.**. Here the shape of the risk profile is considered in the context of the most likely risk rank outcome presented in Figure 3-16**Error! Reference source not found.**. The probability of zero rank occurring for all natural scenarios considered in the study dominates the graph as expected with probabilities ranging from 54% to 75% probability for the fish endpoints under natural conditions. Thereafter the natural scenarios result in >5% probability of high risk. These profiles shift considerably in the present scenarios with moderate and high-risk ranks dominating the graphs. These results represent the massive change in the state of the environmental drivers and how the fish communities have probably responded to these changes given the evidence available for the study. Similarly to the outcomes above the e-flows result in reduced chance of high-risk rank expect for the Groot Letaba River and the Shashe River site. The Shashe River site can be explained as the requirements of the fish communities are primarily based on freshet and flood flows, but the e-flows for the Groot Letaba River site is insufficient to maintain the fish in a sustainable condition. The likely risk rank (Figure 3-16**Error! Reference source not found.**) and probability of each rank occurring (Figure 3-17**Error! Reference source not found.**) identify the Groot Letaba and Olifants River as the most threatened in the study. Thereafter the fish communities of the Elephantes River and Limpopo River at Chokwe are threatened by multiple flow and non-flow stressors and in the upper reaches the Mogalakwena and Shashe River fish communities are also impacted.

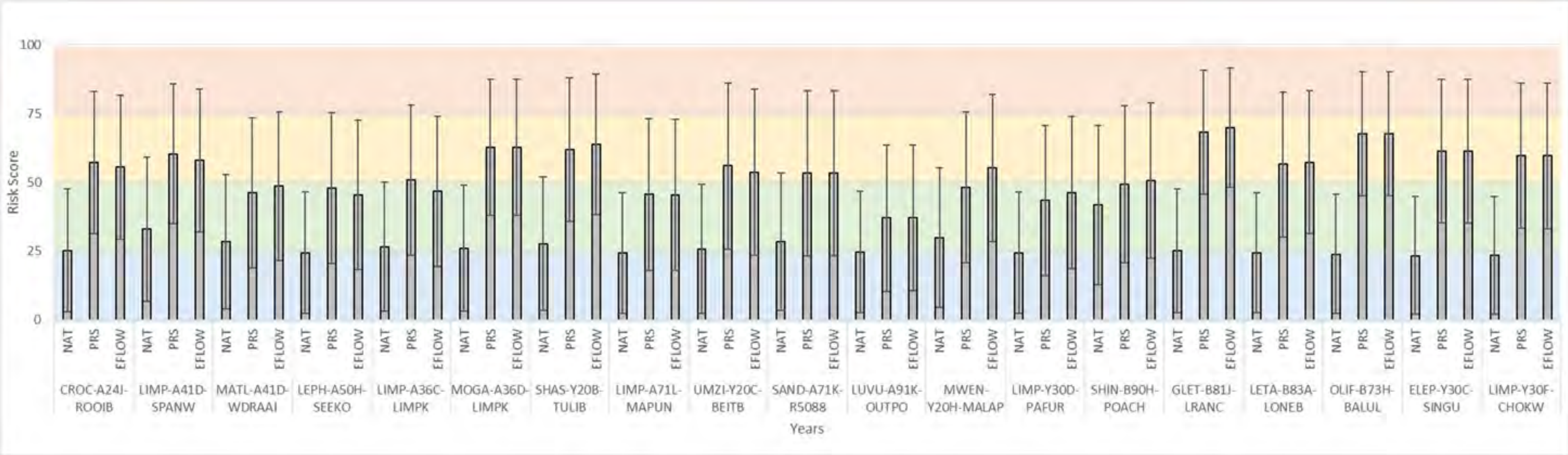

Figure 3-16: Highest likely relative risk scores to FISH-ECO-END for each scenario (Natural, Present, E-Flow), including standard deviation representing risk profile. Risk scores are relative and aligned to risk ranks scores including: zero 0-25 (blue), low 26-50 (green), medium 51-75 (yellow) and high 76-100 (orange).

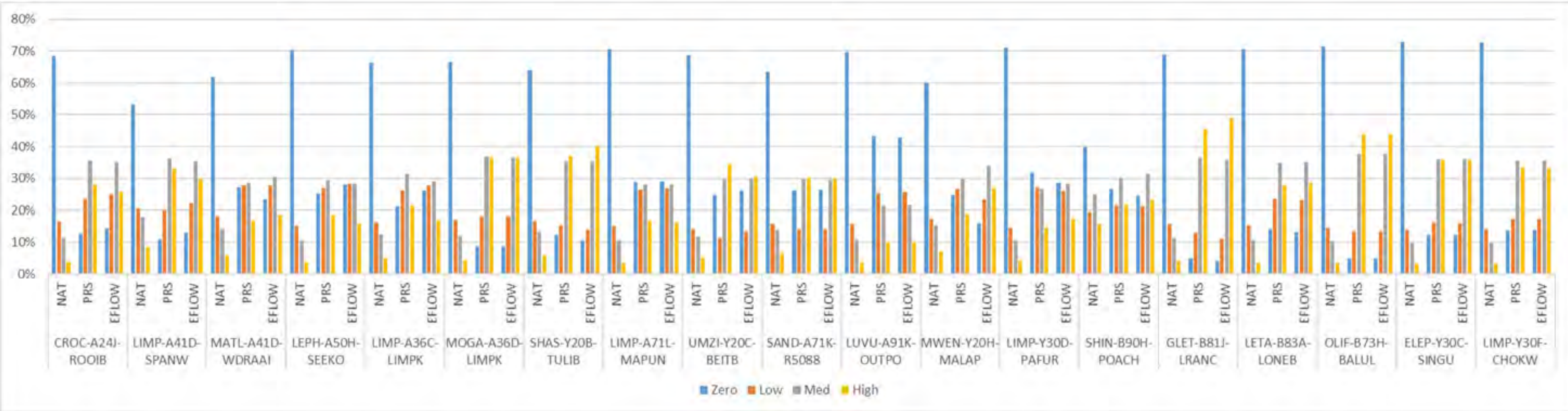

Figure 3-17: Relative risk outcomes representing probability of each risk rank occurring to the FISH-ECO-END endpoint.

3.3.2 Invertebrate communities

The invertebrate community response to multiple flow and non-flow variables differs spatially (between sites) to the fish (Figure 3-18**Error! Reference source not found.** and Figure 3-19**Error! Reference source not found.**).The invertebrate community (INV-ECO-END) endpoint (Figure 3-9) indicates zero relative risk under natural conditions and low relative risk for most sites under the present and e-flow scenarios. But as with the fish communities (FISH-ECO-END) endpoint the relative risk to the invertebrate communities is very similar temporally when the present and e-flow scenarios are compared. The majority of the sites have a less than 30% probability of low and medium risk and less than 20% probability of high risk (Figure 3-10). A noticeable exception is the SAND-A71K-R5088 site that has more than 30% probability of medium and high risk. These results suggest that e-flows afforded to invertebrates in the preliminary assessment are sufficient and that in the highly seasonal rivers high risk to the invertebrates can be expected if the freshet and flood flows are reduced or their timing is changed. The invertebrate communities in the Sand River and Olifants River are characterised to be the most threatened due to flow and non-flow drivers/stressors such as water quality. In this assessment the response of the invertebrates to altered flows associated with e-flows result in similar risk or reduced risk at all sites considered. The invertebrates were observed to generally require less water compared to fish and all sites would probably occur in a suitable (low) to threshold of potential concern (moderate) rank with the Olifants and Sand River communities alone being exposed to relatively high chances of high-risk ranks. While the probability of high risk to fish endpoints at many sites exceeded 30% and in the Shashe and Groot Letaba the probability of high risk exceeded 40%, in contrast the greater chance of high risk for macroinvertebrates is all except the sand river below 30%. Interestingly the trends in risk to the fish and other ecological components of the ecosystem considered in the study, including invertebrates and riparian vegetation differ. This can be attributed to many factors including (1) the natural flow and habitat dynamics of different sites in the basin where different communities of species are proposed to occur, (2) to multiple stressors including flow and non-flow variables that affect one part of the ecosystems considered and (3) the variability of species and their ability to resist flow and non-flow stressors varies considerably in the basin. Different components of the ecosystem for example fish and invertebrates differ between perennial, seasonal and episodic rivers and interestingly while the diversity of macroinvertebrate communities are generally greater in the upper and middle reaches of the basin the fish communities are generally more diverse in the middle and lower reaches of the basin.

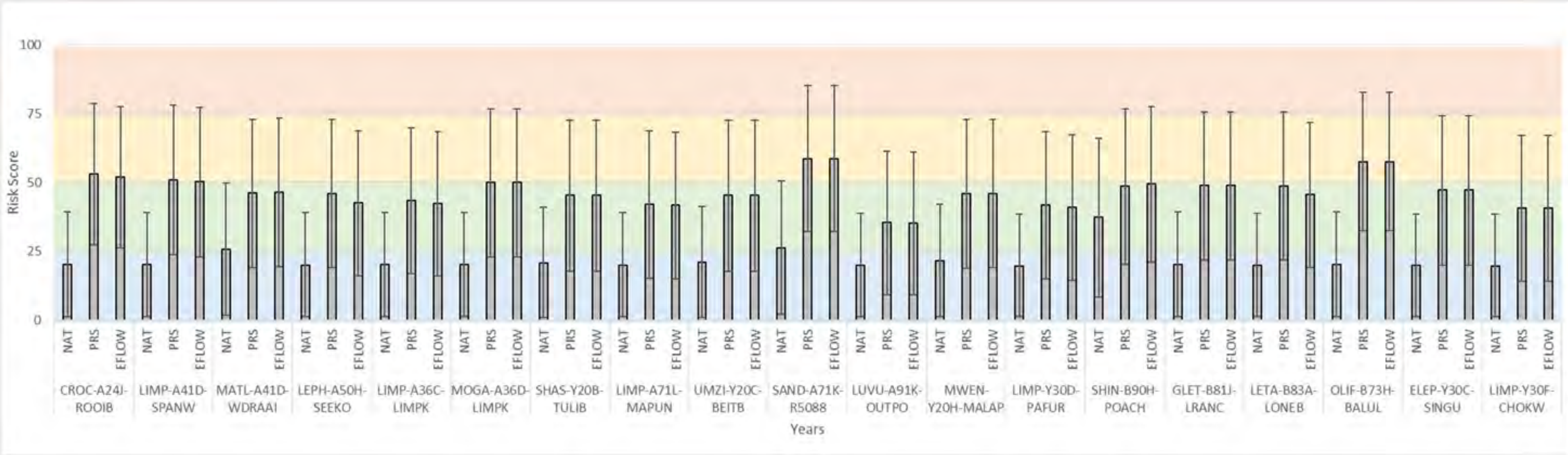

Figure 3-18: Highest likely relative risk scores to INV-ECO-END for each scenario (Natural, Present, E-Flow), including standard deviation representing risk profile. Risk scores are relative and aligned to risk ranks scores including: zero 0-25 (blue), low 26-50 (green), medium 51-75 (yellow) and high 76-100 (orange).

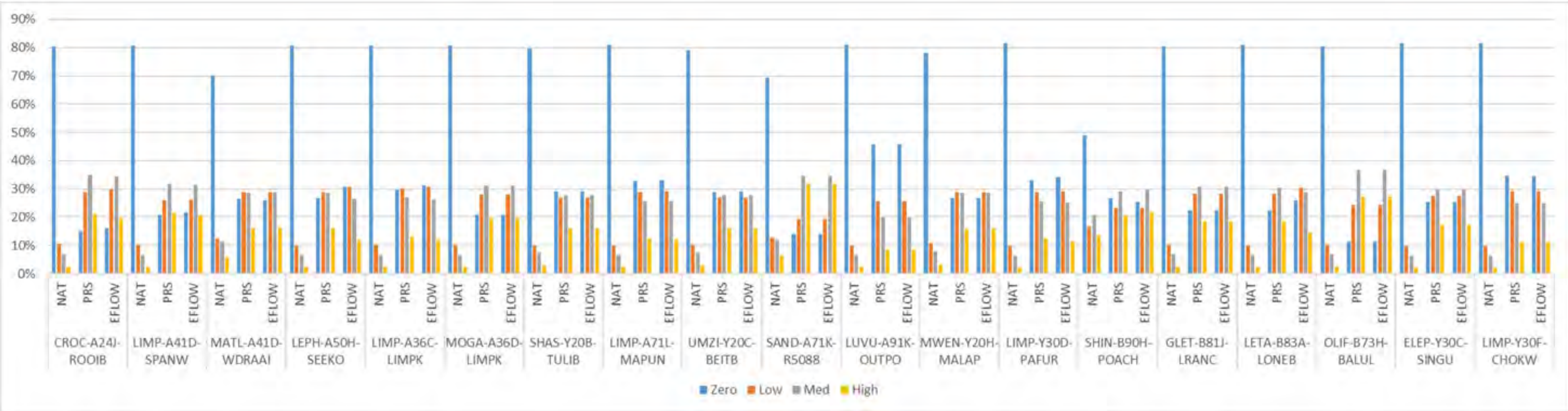

Figure 3-19: Relative risk outcomes representing probability of each risk rank occurring to the INV-ECO-END endpoint.

3.3.3 Riparian vegetation

The risk trends of primarily flow stressors and non-flow stressors to riparian vegetation has been observed to be uniformly high relative to the fish and invertebrates, particularly associated with the present scenario (Figure 3-20 and Figure 3-21). For this ecosystem component all the riparian plant communities at all sites were observed to be in a threshold of potential concern state (Figure 3-20) with high risk for most sites presently >30% chance of failure. Interestingly in this case study the riparian communities in the main stem Limpopo River and lower Elephantes and Luvuvhu Rivers fared slightly better than the tributaries of the Limpopo River (Figure 3-21). There is a possibility that the smaller sites respond faster to flow alterations and that the main stem Limpopo River and Elephantes are also on a declining trend in quality. The riparian plant communities were identified in this study as important indicators of base flows and freshet and flood flows and are particularly vulnerable to changes in the perenniality of the rivers. All the e-flows proposed for the sites will result in better base flows which will result in slightly better riparian vegetation communities overall. While the probable ecological consequence of the altered flows associated with the e-flows will improve riparian vegetation communities from present states, the high potential for high risk or periodic failure is concerning and need to be monitored.

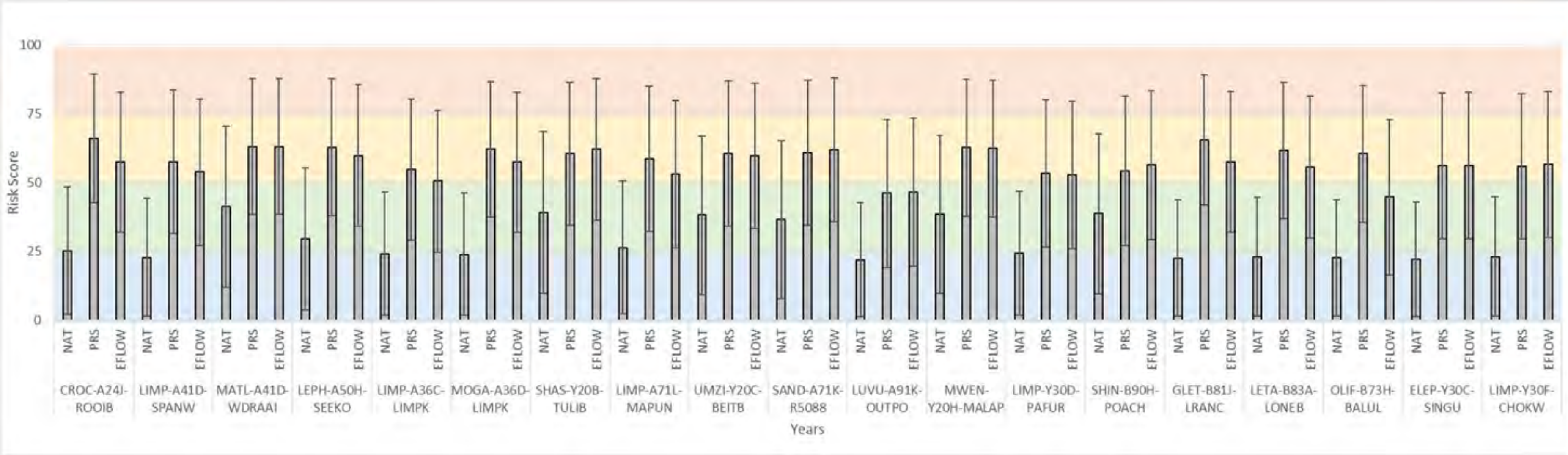

Figure 3-20: Highest likely relative risk scores to VEG-ECO-END for each scenario (Natural, Present, E-Flow), including standard deviation representing risk profile. Risk scores are relative and aligned to risk ranks scores including: zero 0-25 (blue), low 26-50 (green), medium 51-75 (yellow) and high 76-100 (orange).

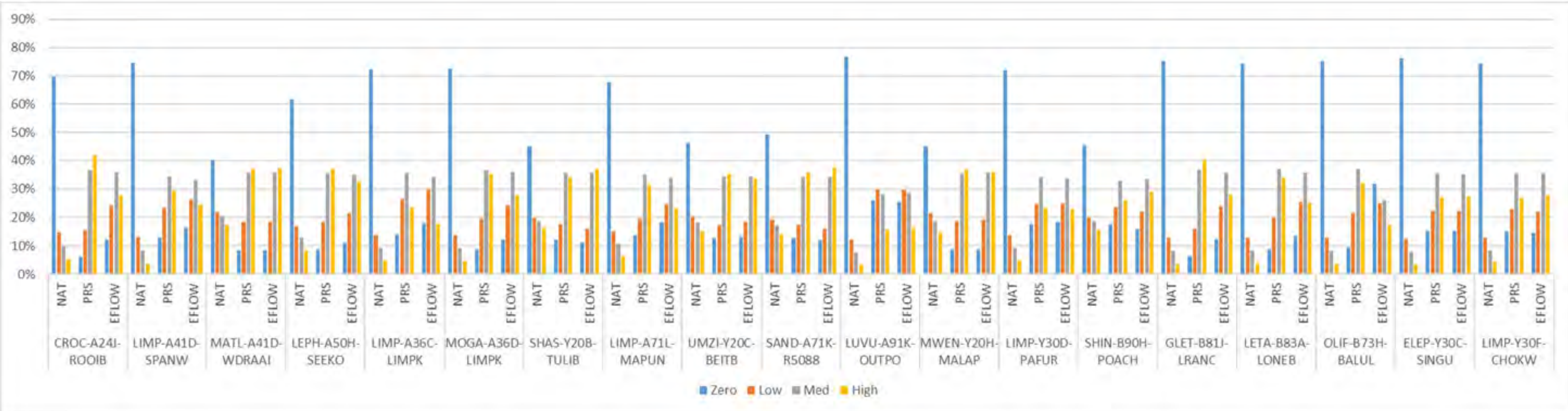

Figure 3-21: Relative risk outcomes representing probability of each risk rank occurring to the VEG-ECO-END endpoint.

3.4 E-flow statistics

Following the determination of the e-flow requirements for the sites considered in the study using indicator requirements and the integration of the requirements and testing of the synergistic effects of altered flows associated with these requirements some amendments to requirements has resulted in final e-flow requirements for the study area. A summary of the e-flow statistics is presented in Table 3-35 and detailed summaries are provided in the Appendix A (Table 6.1). Please refer to the specialist report for more information (Report 6: *Present Ecological State of the Limpopo River: Ecological Responses to Change*).

Table 3-35: Summary of the e-flow statistics established in the study using indicator requirements for each site considered in the study. Note the e-flow requirements for the Groot Letaba River, Letaba River and Olifants River have been extracted from formal gazettes and only tested in this study.

Rivers	E-flow site	nMAR ($10^6 m^3$)	%Drought	%Baseflows	%Floods	%Total
Crocodile River	CROC-A24J-ROOIB	596	9.48	25.73	9.37	35.09
Limpopo River	LIMP-A41D-SPANW	591	6.31	24.67	12.4	37.07
Matlabas River	MATL-A41D-WDRAAI	40	1.04	10.64	39.23	49.86
Lephalale River	LEPH-A50H-SEEKO	142	8.79	18.09	21.02	39.11
Limpopo River	LIMP-A36C-LIMPK	801	3.03	23.15	11.35	34.51
Mogalakwena River	MOGA-A36D-LIMPK	243	13.98	19.24	17.82	37.06
Shashe River	SHAS-Y20B-TULIB	687	0	5.33	11.96	17.29
Limpopo River	LIMP-A71L-MAPUN	1684	2.6	16.15	8.12*	24.27#
				>2000 m³/s (3-5year flood for >7 days).		
Umzingwani River	UMZI-Y20C-BEITB	438	0	4.74	15.5	20.23
Sand River	SAND-A71K-R508B	74	0	9.02	23.41	32.43
Luvuvhu River	LUVU-A91K-OUTPO	560	12.29	24.1	15.97	40.06
Mwenedzi River	MWEN-Y20H-MALAP	412				
Limpopo River	LIMP-Y30D-PAFUR	2792	1.16	10.46	1.63*	12.08#
				>2000 m³/s (3-5year flood for >7 days).		
Shingwedzi River	SHIN-B90H-POACH	87	0.93	15.57	16.34	31.91
Groot Letaba River	GLET-B81J-LRANC	441	***	***	***	42.53**
Olifants River	OLIF-B73H-BALUL	1918	10.01	17.72	3.34	21.06
Elefantes River	ELEP-Y30C-SINGU	2552	5.52	15.65	3.56*	19.21#
				>500 m³/s (3-5year flood for >5 days).		
Limpopo River	LIMP-Y30F-CHOKW	5572	2.57	10.69	5.08*	15.77#
				>1600 m³/s (3-5year flood for >7 days).		

Note (*) E-flow models only provide annual floods but for these sites in the Limpopo River main stem important multi-year or 1:3 or 1:5-year floods are included.

(**) data from DWS reserve study limited to total MAR% consider appendix (Table 9-29) for more detail.

(***) no data available

(#) The portion of e-flows for these sites do not include 1:3 or 1:5-year floods which are not modelled into the e-flow requirement. These floods need to be provided in addition to e-flow requirements.

4 DISCUSSION & CONCLUSION

Environmental flows for the rivers of the Limpopo Basin have been established which represent a suitable balance between the abstraction of and or alteration of the flow regime in the Limpopo Basin and the protection of the ecosystem. The e-flows established in the study include drought flows, base low and base high flows for all of the sites considered in the study, which has contributed to the determination of the portion of total flows (mean annual runoff) required to sustain the river ecosystems. In addition, freshet and flood flows from all sites except the main stem Limpopo River and lower Elephantes River sites from the middle reaches of the Limpopo River at the Shashe River to the estuary, have also contributed to the determination of the portion of the MAR needed to maintain the rivers. These e-flows range from 17% to 49% (median of 34.8%) of the MAR to maintain ecosystems. This includes requirements for the seasonal Shashe and Umzingwani Rivers (17.9% and 20.2% respectively), and the 39%-49% for the Lephalale, Luvuvhu and Matlabas Rivers which are all perennial rivers. The e-flows for the main stem Limpopo River includes floods that are not required each year but only once in three to five years. As such, although the e-flows for the sites on the main stem Limpopo River and lower Elephantes River are only between 12% and 24.2% of the MAR, an additional 500m^3/s in the Elephantes River and 2000m^3/s in the Limpopo River is also required. These e-flow requirements are all considerably more than what is presently being provided in the rivers of the basin suggesting that existing abstraction and or alteration of instream flows must be managed to meet the e-flow requirements.

Importantly, the e-flows proposed for nine of the sites considered, return naturally perennial rivers back into their perennial conditions, although with reduced flows compared to their natural state. These presently seasonal rivers include the Crocodile River at CROC-A24J-ROOIB, Lephalala River at LEPH-A50H-SEEKO, Mogalakwena River at MOGA-A36D-LIMPK and Letaba River at LETA-B83A-LONEB which have minimum e-flows of 1.728m^3/s, 0.264m^3/s, 0.9m^3/s and 0.7 m^3/s in October respectively. October represents the lowest observed flows in the hydrological record. In addition, the e-flows will return the Groot Letaba River at GLET-B81J-LRANC to 0.4 m^3/s in May, a perennial state. The e-flows proposed for the presently seasonal main stem Limpopo River sites at LIMP-A41D-SPANW, LIMP-A36C-LIMPK, LIMP-A71L-MAPUN and LIMP-Y30D-PAFUR will return these sites to their natural perennial states, but with reduced flows down to 1.029 m^3/s, 0.04 m^3/s, 0.1 m^3/s and 0.1 m^3/s in October. While these reduced flows are significantly lower than the natural states, they are considerably greater than present flows and should result in considerable improvements to the wellbeing of the Limpopo River. The e-flows established also include some historically seasonal rivers that will remain in their seasonal state, but with improved flows from present, including the Matlabas River at MATL-A41D-WDRAAI, the Shashe River at SHAS-Y20B-TULIB, the Umzingwani River at UMZI-Y20C-BEITB, the Mwenedzi River at MWEN-Y20H-MALAP and the Shingwedzi River at SHIN-B90H-POACH. There are only four sites considered in the study which are presently in a perennial state and are proposed to remain in this condition to maintain the wellbeing of the Limpopo Basin ecosystem, the Luvuvhu River at LUVU-A91K-OUTPO, the Olifants River at OLIF-B73H-BALUL, the Elephantes River at ELEP-Y30C-SINGU and the lower Limpopo River at LIMP-Y30F-CHOKW. All of these sites occur below major dams in the basin that are able to maintain, or on occasion (Elephantes

River at ELEP-Y30C-SINGU for example), augment the base flows of the river. Sustained perenniality of these rivers will ensure that the ecosystems become sustainable, a recovery from present conditions.

The north-eastern part of the Limpopo Basin, including the Crocodile-West and upper Limpopo Rivers, have generally been transformed from perennial rivers into seasonal rivers which has resulted in considerable changes to the wellbeing of the Limpopo River ecosystem. In particular the fish communities that depended on the perennial state of the rivers have been transformed. Today few populations that were once established in the upper reaches of the Limpopo River and in many larger tributaries remain. Today many migratory species still utilise these rivers during freshet and flood periods but many species that have historically occurred in many of the tributaries no longer occur there. The riparian vegetation of the Limpopo River ecosystem has also responded to the changes in perenniality of the rivers. In the south-western rivers of the Limpopo Basin which is dominated by the Olifants/Elephantes River, flows have also been considerably reduced and on many occasions in recent times, no-flow periods have been observed which has probably resulted in severe impacts to the wellbeing of these ecosystems. In the Letaba River and many of the tributaries of the upper Limpopo River, including the Crocodile-West River, water quality impacts have exacerbated the effects of reduced flows in the basin. If the flows of the rivers in the basin had been maintained the resilience of the ecosystems to resist the effects of altered flows and water quality perturbations would have been increased. In this study, evidence is provided that improved flows will contribute to a reduction of the water quality impacts observed in the Crocodile River.

The aim of this project was to provide the necessary evidence to determine holistic e-flows for increasing the resilience of communities and ecosystems in the Limpopo Basin to changes in streamflow resulting from basin activities and climate change. This report meets the first part of the aim and includes the e-flow requirements to maintain the ecosystems in a suitable and sustainable condition. The socio-ecological implications of altered flows, and the benefits of establishing and meeting e-flows are included in the second final report titled: "*Risk of altered flows to the ecosystem services of the Limpopo Basin*".

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6 APPENDIX A – Justification Tables

Table 6-1: Example of The Justification Table for The Parent Nodes of The Bayesian Network for The Limpopo E-Flow Study

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Demand/potential for sub.fishery (SUB_FISH_POT)	Risk of multiple stressors to fisheries for people requires people to occur and require/depend on fish as a source of food. Ranks selected for this node include no demand/people represented (measure of variable) by the abundance (unit) of people who live within 2km from river with knowledge of subsistence fishing practice (Zero-low rank), moderate demand or people (Mod rank) where people do not depend on fish but utilize fishery and high (High rank) demand and or dependence where livelihoods depend on seasonal or permanent fish provision.	DATA FROM THIS STUDY
Barriers affecting migrations (SUB_FISH_BAR)	Physical (structure or reduced flows), chemical and or disturbance to wildlife (impacts of alien fauna or people) representing measure of this variable that affects the migration of catadromous (*Anguillid spp.*) and potadromous species (cyprinids and siluriformes) used for subsistence fisheries in that basin. Potential (unit zero, low, moderate and high) of barrier on fish migrations used in establishment of no barrier (Zero rank), temporary barriers that may delay seasonal migrations (Low rank) partial/seasonal barrier that may hamper fish migrations during important life cycle phases but do not significant affect population (Mod Rank) and permanent barriers that restrict species migrations (High Rank). [NO_BARRIERS]	DATA FROM THIS STUDY
Sediment supply (SUB_FISH_SSUP)	Reduction or excessive increase in sediment from upstream or associated with runoff from terrestrial areas due to type and extent (km2 or %) of land use activities (measure) that will directly affect habitat availability within the river associated with river flows that will describe geomorphic/instream habitat characteristics for substrate and cover preferring indicator fishes targeted for subsistence (Cyprinids and large growing siluriformes). Ranks selected include condition of catchment, land use activities or upstream supply of sediment that provides potential for habitat diversity to be maintained in natural/pristine condition (Zero), near-natural conditions that do not affect indicator species (Low), acceptable condition to provide minimal requirements for indicator species (consider abundances on reach scale) (Mod) and unacceptable loss of substrate types that will significantly affect fish communities. [LANDUSE_SSUP]	DATA FROM THIS STUDY
Sediment removal flows (SUB_FISH_SFLO)	River flows measured as discharge (m^3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress to mobilise and sort sediments to maintain instream habitat diversity preferred by indicator fisheries species (cyprinids) in a near to natural condition (Zero rank), altered distributions but suitable abundances of required habitats for indicator species (Low rank), altered habitat distributions that will not significantly affect targeted fisheries species (tilapians, cyprinids and siluriformes) (Mod rank) and altered flows that significantly change substrate characteristics that will result in loss of instream substrates required by fisheries indicator species for lifecycle events. [DISCHARGE_YR]	DATA FROM THIS STUDY

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Velocity / depth habitat characteristics (SUB_FISH_VD)	Relative distribution and abundance (unit m^2) of instream velocity-depth habitat (slow-deep, slow-shallow, slow-very shallow, fast-intermediate, fast-shallow and fast-deep) distributions (measure) associated with requirements of indicator fishes targeted for subsistence fishery (large growing cyprinids). Ranks include distribution and abundances that will support pristine/natural community of indicator species (Zero), occurrence of (but altered) habitat distributions for indicator species (Low), modified velocity-depth habitat distributions for at least one fisheries indicator species while majority of indicator species is provided for (Mod) and significant alteration of velocity-depth habitat characteristics that affects fish community significantly. [DISCHARGE_YR]	
Cover characteristics (SUB_FISH_COV)	Relative distribution and abundance (unit m^2) of cover features preferred by fisheries indicator species from the study area (cyprinids). Ranks include distribution and abundances that will support pristine/natural community of indicator species (Zero), occurrence of (but altered) of cover distributions for indicator species (Low), modified cover distributions for at least one fisheries indicator species while majority of indicator species is provided for (Mod) and significant alteration of cover characteristics that affects fish community significantly. [DISCHARGE_YR]	DATA FROM THIS STUDY
Cues for life cycles of sub.fish (SUB_FISH_CUES)	Endpoint represent cues for the life cycles of subsistence fisheries. (Zero rank) There are no changes in cues, or life stages of subsistence fisheries, (Low rank) Changes have occurred, but it does not impact the cues or life stages of subsistence fisheries, (Mod rank) Changes in cues have impacted some of the life stages of subsistence fisheries, (High rank) Changes in cues has disrupted the life cycles of subsistence's fisheries [DISCHARGE_HF; SEASONALITY]	DATA FROM THIS STUDY
Demand/potential for harvesting (SUB_VEG_POT)	Risk of multiple stressors to plants for livelihoods requires people to occur and require/depend on plants as a harvestable resource. Ranks selected for this node include no demand/people represented (measure of variable) by the abundance (unit) of people who live within 2km from river with knowledge of plant harvest / use (Zero-low rank), moderate demand or people (Mod rank) where people do not depend on vegetation but utilize plants opportunistically and high (High rank) demand and or dependence where livelihoods depend on seasonal or permanent service from vegetation.	DATA FROM THIS STUDY
Water levels characteristics - high flow (SUB_VEG_DEPH)	An interactive output defining the range in discharge (Q; m^3/s) associated with the indicator activation discharge (discharge required at stem level) for the wet and dry season to maintain riparian vegetation communities. Flows should ideally fluctuate within this range for the duration of the hydro period, maintaining seasonality for each riparian community (Zero Rank). Where variation is beyond range limits, the potential exists for vegetation to respond accordingly. Where such response in distribution within the channel, including abundance and species compositional shifts is within current ecostatus (Low rank) the response is deemed expected variation dynamics. Greater shifts in the required discharge range have the potential to cause riparian vegetation community changes and/or shift beyond the current ecostastus limits (Mod, rank), and where change is sever or seasonality is lost, the change in riparian community integrity prevents acceptable functionality or service being rendered (High rank). [DISCHARGE_HF; SEASONALITY; DISCHARGE_LF]	DATA FROM THIS STUDY

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Water levels characteristics - low flow (SUB_VEG_DEPL)	An interactive output defining the range in discharge (Q; m^3/s) associated with the indicator activation discharge (discharge required at stem level) for the wet and dry season to maintain riparian vegetation communities. Flows should ideally fluctuate within this range for the duration of the hydro period, maintaining seasonality for each riparian community (Zero Rank). Where variation is beyond range limits, the potential exists for vegetation to respond accordingly. Where such response in distribution within the channel, including abundance and species compositional shifts is within current ecostatus (Low rank) the response is deemed expected variation dynamics. Greater shifts in the required discharge range have the potential to cause riparian vegetation community changes and/or shift beyond the current ecoststus limits (Mod, rank), and where change is sever or seasonality is lost, the change in riparian community integrity prevents acceptable functionality or service being rendered (High rank).	DATA FROM THIS STUDY
Sediment supply (SUB_VEG_SSUP)	Significant reduction or increase in sediment volume and fine-coarse ratio from upstream or laterally associated with runoff from terrestrial areas due to type and extent (% catchment degradation) of land use activities (degradation intensity) and degradation that will directly affect habitat availability within the river associated with river flows that will describe geomorphic/instream habitat characteristics for substrate availability and location for indicator vegetation. Ranks selected include condition of catchment, land use activities or upstream supply of sediment that provides potential for habitat diversity to be maintained in natural/pristine condition (Zero), near-natural conditions that do not affect indicator species (Low), acceptable condition to provide minimal requirements for indicator species (consider abundances on reach scale) (Mod) and unacceptable loss of substrate types that will significantly affect vegetation communities. [LANDUSE_SSUP]	DATA FROM THIS STUDY
Sediment removal flows (SUB_VEG_SFLO)	River flows measured as discharge (m^3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress to mobilise sediments to maintain instream habitat diversity preferred by indicator vegetation in a near natural condition (Zero rank), altered distributions but suitable abundances of required habitats for indicator species (Low rank), altered habitat distributions that will not significantly affect riparian vegetation (Mod rank) and altered flows that significantly change substrate characteristics that will result in loss of riparian substrates and morphological features required by indicator vegetation species for lifecycle events. [DISCHARGE_YR]	DATA FROM THIS STUDY
Demand/potential for livestock (LIV_VEG_POT)	Risk of multiple stressors to plants for livestock requires livestock (people proximity) to occur and require/depend on plants as a grazing resource. Ranks selected for this node include no demand/livestock represented (measure of variable) by the abundance (unit) of livestock who enter the riparian zone for grazing (Zero-low rank), moderate demand or livestock (Mod rank) where livestock do not depend on grazing in the riparian zone but graze opportunistically and high (High rank) demand and or dependence where livestock depend on grazing riparian vegetation for survival.	DATA FROM THIS STUDY
Demand for water for domestic use (DOM_WAT_DEM)	Risk of multiple stressors to domestic water use(volume)and number of people(population no) who depend on the water resource for domestic use. Ranks selected for this node include no volume of water demanded by the no of people who live within 2km from river (Zero-low rank), moderate demand water by the people (Mod rank) where people depend on the water use but they have alternatives (High rank) high amount of water demanded and dependence for livelihoods high	DATA FROM THIS STUDY
River flows (DOM_WAT_RFLO)	River flows measured as discharge (m^3/s) adequate to provide water(volume) as per domestic demands (Zero rank), altered river flow distribution but suitable and adequate volume for domestic use (Low rank), altered river flow that will not significantly affect volume of water required to meet domestic demands (Mod rank) and altered flows and domestic water use demands significantly not met and which affects livelihoods [DISCHARGE_YEAR]	DATA FROM THIS STUDY

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Demand/potential for flood control (FLO_ATT_POT)	The potential for floods to occur based on the riparian zone and habitats and flood attenuation structures like weirs.	
Sediment supply (RIV_ASS_SSUP)	Significant reduction or increase in fine sediment volume and fine-coarse ratio from upstream or lateral supply associated with runoff from terrestrial areas due to degradation type (degradation intensity) and extent (% catchment degradation). Connectivity and catchment position plays a role too, with distal or poorly connected sources having a smaller impact compared to local or well buffered sources. The shift in sediment supply will directly affect fine substrate availability within the river channel and associated with river flows that will inundate the existing finer sediment stores. Ranks selected include degradation condition of catchment, land use activities or upstream supply of sediment that provides potential for habitat diversity to be maintained in natural/pristine condition (Zero), near-natural conditions that do not affect the availability of substrates (Low), acceptable condition to provide minimal requirements for nutrient cycling (Mod) and unacceptable loss of substrate types that will significantly affect nutrient cycling. [LANDUSE_SSUP]	DATA FROM THIS STUDY
Sediment removal flows (RIV_ASS_SFLO)	River flows measured as discharge (m^3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress to mobilise and sort fine and medium sized sediments to maintain instream sediment transport and deposition (Zero rank), altered distributions but suitable abundances of a range of sediment sizes and volumes (Low rank), altered habitat distributions that will not significantly affect sediment erosion and deposition/transport processes (Mod rank) and altered flows that significantly change substrate characteristics that will result in loss of fine substrates and morphological features required to assimilate nutrients. [DISCHARGE_YR]	DATA FROM THIS STUDY
Potential for disease (WAT_DIS_DPOT)	Risk of waterborne diseases to occur based on presence or absence of aquatic predators to control diseases. Relates to high presence of aquatic predators to control all diseases (zero), Relates to moderate presence of aquatic predators to control some diseases(low), Relates to low presence of species of aquatic predators to control some diseases, most essential species missing (mod) and no presence of aquatic predators to control any diseases (high)	DATA FROM THIS STUDY
WAT_DIS_VFLO	Most host vectors of diseases are restricted to stagnant waters (e.g. Culicidae, Lymnaedidae, Planorbidae). Decreased in velocity-flow increase slow flowing to stagnant waters, and with high nutrient inputs allows for the establishment of aquatic plants. Low flows and high nutrient inputs therefore potentially provides perfect conditions for host vectors. Relates to high presence of fast velocity flows (zero), Relates to moderate presence of fast velocity flows (low), Relates to moderate to high presence of slow flowing to stagnant waters with aquatic plants present (mod) and the dominance of slow flowing and stagnant waters with aquatic plants abundant (high)	Lu et al. 2018; Haggerty et al. 2020
Potential for resilience (RES_RES_POT)	River flows measured as discharge (m3/s) associated with velocities (m/s) using hydraulics to provide suitable volume to allow for dilution / transport of contaminants. [DISCHARGE_YR]	

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Sediment supply (RES_RES_SSUP)	Significant reduction or increase in fine sediment volume and fine-coarse ratio from upstream or lateral supply associated with runoff from terrestrial areas due to degradation type (degradation intensity) and extent (% catchment degradation). Connectivity and catchment position plays a role too, with distal or poorly connected sources having a smaller impact compared to local or well buffered sources. The shift in sediment supply will directly affect fine substrate availability within the river channel and associated with river flows that will inundate the existing finer sediment stores. Ranks selected include degradation condition of catchment, land use activities or upstream supply of sediment that provides potential for habitat diversity to be maintained in natural/pristine condition (Zero), near-natural conditions that do not affect the availability of substrates (Low), acceptable condition to provide minimal requirements for nutrient cycling (Mod) and unacceptable loss of substrate types that will significantly affect the resilience of the resource. [LANDUSE_SSUP]	DATA FROM THIS STUDY
Sediment removal flows (RES_RES_SFLO)	River flows measured as discharge (m^3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress to mobilise fine and medium sized sediments to maintain instream sediment transport and deposition (Zero rank), altered distributions but suitable abundances of a range of sediment sizes and volumes (Low rank), altered habitat distributions that will not significantly affect sediment transport processes (Mod rank) and altered flows that significantly change substrate characteristics that will result in loss of fine substrates and morphological features required to maintain the resource resilience. [DISHARGE_YEARLY]	DATA FROM THIS STUDY
Environmental potential for fish (FISH_ECO_POT)	The availability of habitat preferences represents the environment potential to support fish communities. Ranks selected for this node include complete or sufficient environment potential to support expected fish community structure, function and composition (Zero-low rank), moderate environment potential (Mod rank) where the environment supports most but not all expected fish community and low environment potential (High rank) where environment support of fish communities is unsustainable and/or disfunctional.	DATA FROM THIS STUDY
Barriers affecting migrations (FISH_ECO_BAR)	Barrier (physical structure) stop the migration of fish species. This affects the life history, movement and distribution of fish communities. Zero: No barriers, life history, movement and distribution are not affected, low: Temporary barrier that affect seasonal migration (<1m causeways, culverts, floodgates), medium: Permanent barrier (<5m weirs without working fish way, road and rail crossings) that may affect migration during important lifecycle phases but do not significantly affect population, high: Permanent barrier (>5m dams without working fish way) that restrict species migration. [NO_BARRIERS]	Harris 2016

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Sediment supply (FISH_ECO_SSUP)	Increased sedimentation (erosion, agricultural and urban land use) cause abrasion of biota and habitats, cause suffocation of sessile organisms, reduces the availability of habitats (filled and covered with sand, aquatic vegetation is killed) and transport pollution. Complex habitats provide a wide range of niche space, thus decreasing niche overlap and increasing diversity. Zero: Condition of catchment, land use activities, upstream supply of sedimentation is limited and maintain habitat diversity (pristine condition), Low: Some evidence of sedimentation, sufficient amount of habitat diversity still present, Medium: Land use activities and upstream supply of sedimentation increasing, micro habitats covered in sedimentation, High: Unacceptable loss of substrate, no habitat diversity available for survival of fish communities.Significant reduction or increase in sediment volume and fine-coarse ratio from upstream or lateral supply associated with runoff from terrestrial areas due to degradation type (degradation intensity) and extent (% catchment degradation). Connectivity and catchment position plays a role too, with distal or poorly connected sources having a smaller impact compared to local or well buffered sources. The shift in sediment supply will directly affect habitat availability within the river associated with river flows that will describe geomorphic/instream habitat characteristics for substrate availability and location for indicator fish species. Ranks selected include degradation condition of catchment, land use activities or upstream supply of sediment that provides potential for habitat diversity to be maintained in natural/pristine condition (Zero), near-natural conditions that do not affect indicator species (Low), acceptable condition to provide minimal requirements for indicator species (consider abundances on reach scale) (Mod) and unacceptable loss of substrate types that will significantly affect fish communities. [LANDUSE_SSUP]	Berkman and Rabeni 1987
Sediment removal flows (FISH_ECO_SFLO)	River flows measured as discharge (m^3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress to mobilise and sort fine and medium sized sediments to maintain instream habitat diversity preferred by indicator fish communities in a near natural condition (Zero rank), altered distributions but suitable abundances of required habitats for indicator species (Low rank), altered habitat distributions that will not significantly affect fish communities (Mod rank) and altered flows that significantly change substrate characteristics that will result in loss of instream substrates and morphological features required by indicator fish species for lifecycle events. [DISCHARGE_YEAR]	
Velocity / depth habitat characteristics (FISH_ECO_VD)	Changes to the flow regimes affect resources and habitat availability. Hydrological variability influences the physical habitat of riverine systems and thus shapes the structure and diversity of aquatic communities. Different fish species can be used as indicators for different velocity depth classes (Slow-deep, slow-shallow, fast-deep, fast-shallow). Zero: All velocity depth classes are available in high abundances and distribution to support all indicator fish species, pristine condition, Low: There are changes in the abundances and distribution of different velocity depth classes. All indicator fish species are still present, medium: Some of the velocity depth classes abundances are reduced, majority of indicator fish species are still present, High: There are significant alteration of velocity depth classes which affect fish communities, most of the indicator fish species are absent. [DISCHARGE_YR]	Cattanéo 2005; Poff and Allan 1995

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Cover characteristics (FISH_ECO_COV)	There is a strong relationship between riparian vegetation, instream habitat and community structure in aquatic ecosystems. Different cover features included overhanging vegetation, marginal vegetation, aquatic vegetation, undercut bank, substrate. Different fish species have different preferences for different cover features. Zero: All cover features are available in good distribution and abundances all indicator species are present. Physical structure available and conditions comparable to pre-anthropogenic activities, ideal depth for indicator species to provide cover. Ideal marginal vegetation cover for indicator fish guild, Low: There are some indications of alteration, but all cover features and indicator species are present. Suitable availability of and conditions of physical structures, suitable depth available. Suitable percentage of cover available for indicator fish, Medium: Some of the cover features absent, majority of indicator fish species are still present. Concerning loss of physical structure associated potential impact on indicator species, moderate loss of depth for indicator species resulting in observable response of species to cover change. Low availability of cover for indicator fish guild representing threshold of potential concerns, High: There are significant alteration in cover features which affect fish communities, most of the indicator fish species are absent. Critical loss of substrate associates=d potential impact on fish indicators. Significant loss of depth for indicator species resulting in significant reduction of cover. Critical low to zero marginal vegetation cover available for indicator fish guild. [DISHARGE_YR]	Dala-Corte et al. 2016
Environment potential for vegetation (VEG_ECO_POT)	The availability of habitat preferences represents the environment potential to support riparian vegetation communities. Ranks selected for this node include complete or sufficient environment potential to support expected riparian community structure, function and composition (Zero-low rank), moderate environment potential (Mod rank) where the environment supports most but not all expected community components and low environment potential (High rank) where environment support of riparian communities is unsustainable and/or dysfunctional.	DATA FROM THIS STUDY
Sediment supply (VEG_ECO_SSUP)	Significant reduction or increase in sediment volume and fine-coarse ratio from upstream or laterally associated with runoff from terrestrial areas due to type and extent (% catchment degradation) of land use activities (degradation intensity) and degradation that will directly affect habitat availability within the river associated with river flows that will describe geomorphic/instream habitat characteristics for substrate availability and location for indicator vegetation. Ranks selected include condition of catchment, land use activities or upstream supply of sediment that provides potential for habitat diversity to be maintained in natural/pristine condition (Zero), near-natural conditions that do not affect indicator species (Low), acceptable condition to provide minimal requirements for indicator species (consider abundances on reach scale) (Mod) and unacceptable loss of substrate types that will significantly affect vegetation communities. [LANDUSE_SSUP]	DATA FROM THIS STUDY
Sediment removal flows (VEG_ECO_SFLO)	River flows measured as discharge (m3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress to mobilise sediments to maintain instream habitat diversity preferred by indicator vegetation in a near natural condition (Zero rank), altered distributions but suitable abundances of required habitats for indicator species (Low rank), altered habitat distributions that will not significantly affect riparian vegetation (Mod rank) and altered flows that significantly change substrate characteristics that will result in loss of riparian substrates and morphological features required by indicator vegetation species for lifecycle events. [DISCHARGE_YR]	DATA FROM THIS STUDY

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Environment potential for invertebrates (INV_ECO_POT)	Instream aquatic invertebrate communities are influenced by physical and chemical parameters, and in turn as primary processors of organic material, they are key to nutrient cycling in aquatic ecosystems. Emerging adults export nutrients from the aquatic environment into the terrestrial, and most larvae and adults form important parts of riverine, riparian, and terrestrial foodwebs. Aquatic invertebrates in "healthy" aquatic ecosystems perform crucial functions as "free services" to other life form dependant on these systems. La Notte et al. (2017) calculated the financial worth of Europe's sustainable water purification ecosystem service as up to €31 billion per year. Ranks selected for this node are based on Present Ecological State (PES - A, B, C, D, E, F categories) for the aquatic macroinvertebrate community. PES natural to largely natural (Zero-low rank), PES largely natural to moderately impaired (B/C - C) (Mod rank); PES < C (High rank).	Finn et al. (2011); La Notte et al. (2017); Liquete et al. (2016); Sanpera-Calbert et al. (2009)
Barriers affecting migrations (INV_ECO_BAR)	This node considers the importance of longitudinal river connectivity for amphidromous migrations of macro-invertebartes using Palaemonid indicator species. The larval stages of most freshwater prawn species (Palaemonidae: *Macrobrachium*) requires access to saline water to complete development. With some species hatched larvae drift downstream to saline water, and after metamorphosis, post larvae migrate back to freshwater. With other species ovigerous females migrate to estuaries, where eggs hatch a free-swimming zoeae, progressing through 12 larval stages before migrating into freshwater in post larval stage. The larvae of *Macrobrachium* species currently present in the Limpopo and Luvuvhu, and historically Letaba (last 1960) and Olifants (last 1980) all require salinity of 8 - 12 ppt to develop (Cort & Schoonbee (1993). Migrational barrier potential ranked are zero, low, moderate and high. No barrier (Zero); temporary barriers which may delay seasonal migrations (Low); partial/seasonal barrier that may hamper migrations during important life cycle phases but do not significant affect population (Moderate); permanent barriers that restrict species migrations (High). [NO_BARRIERS]	Alam et al. (2017); Bauer & Delahoussaye (2008); Bertini et al. (2014); Hart et al. (2001).

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Sediment supply (INV_ECO_SSUP)	In the context of geomorphic substrates that provide habitat for macro-invertebrate communities. The potential for the supply of sediment into the rivers has been considered. Sedimentation is a natural process, but increased sediment inputs and deposition associated with upstream and onsite anthropogenic impacts. Sediment input and deposition potentially reduces habitat heterogeneity, smothering available interstitial spaces. Severity impact of sedimentation affects dependant on shape, size, density of particles; potential for microbial colonisation; availability of nutrients; and water flow, velocity, turbulence and temperature. Ranks selected for this node include consideration of condition of catchment and land use activities that may affect supply of sediment that can potentially affect habitat diversity. Measure include an intact catchment area with pristine buffer of sediments from entering the river that supports indicator species (Zero), near-natural conditions that do not affect indicator species (Low), acceptable condition to provide minimal requirements for indicator species (consider abundances on reach scale) (Mod) and unacceptable loss of substrate types that will significantly affect aquatic macroinvertebrate communities. Significant reduction or increase in sediment volume and fine-coarse ratio from upstream or lateral supply associated with runoff from terrestrial areas due to degradation type (degradation intensity) and extent (% catchment degradation). Connectivity and catchment position plays a role too, with distal or poorly connected sources having a smaller impact compared to local or well buffered sources. The shift in sediment supply will directly affect habitat availability within the river associated with river flows that will describe geomorphic/instream habitat characteristics for substrate availability and location for indicator invertebrate species. Ranks selected include degradation condition of catchment, land use activities or upstream supply of sediment that provides potential for habitat diversity to be maintained in natural/pristine condition (Zero), near-natural conditions that do not affect indicator species (Low), acceptable condition to provide minimal requirements for indicator species (consider abundances on reach scale) (Mod) and unacceptable loss of substrate types that will significantly affect invertebrate communities. [LANDUSE_SSUP]	Connolly & Pearson (2007); Cort & Schoonbee (1993); Holmukzi & Biggs (2003); Kreutzweiser et al. (2005); Suren et al. (2005)
Sediment removal flows (INV_ECO_SFLO)	River flows measured as discharge (m3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress which mobilise sediments, maintaining instream substrate and hydraulic biotope diversity. Indicator aquatic macroinvertebrates for upper (cold water, cobble-boulder taxa e.g., Blepharoceridae, Synlestidae, Baetidae: Demoreptus sp., etc.), mid reach (cool - warm water, cobble-boulder-gravel taxa e.g., Aeshnidae: Pinheyschna subpupillata, Libellulidae: Zygonyx natalensis, Tricorythidae: Tricorythus sp., Heptageniidae: Afronus sp., etc.), lower reach (warm water, gravel-sand-mud (Gomphidae, Unionidae, Corbiculidae and marginal & aquatic vegetation biotopes taxa e.g., Heptageniidae: Compsoneuria sp., Coenagrionidae: Pseudagrion sp., Palaemonidae: Macrobrachium sp. River flows measured as discharge (m^3/s) associated with velocities (m/s) using hydraulics to provide suitable shear stress to mobilise fine and medium sized sediments to maintain instream habitat diversity preferred by indicator invertebrate communities in a near natural condition (Zero rank), altered distributions but suitable abundances of required habitats for indicator species (Low rank), altered habitat distributions that will not significantly affect invertebrate communities (Mod rank) and altered flows that significantly change substrate characteristics that will result in loss of instream substrates and morphological features required by indicator invertebrate species for lifecycle events. [DISCHARGE_YR]	Smith & Stopp (1978)

Variable title (BN CODE)	Justification (Incl. indicator and measure (units) and specify rank descriptions, standard Zero, Low, Moderate (Mod) and High, or continuous or categorical etc.)	References
Velocity / depth habitat characteristics (INV_ECO_VD)	Presence-absence and abundance of instream velocity-depth habitat (slow-deep, slow-shallow, slow-very shallow, fast-intermediate, fast-shallow and fast-deep) distributions (measure) and substrate type (boulder, cobble, gravel, sand) associated with requirements of indicator aquatic macroinvertebrates. Ranks include distribution and abundances that will support pristine/natural community of indicator species (Zero), occurrence of (but altered) habitat distributions for indicator species (Low), modified velocity-depth habitat distributions for at least one fisheries indicator species while majority of indicator species is provided for (Mod) and significant alteration of velocity-depth habitat characteristics that affects fish community significantly. [DISCHARGE_YR]	Evidence generated in this study
Cover characteristics (INV_ECO_COV)	In the headwaters and mid reaches, substrates such as boulder, cobble and gravel and marginal vegetation provide important cover. In the lower reaches marginal and aquatic vegetation provide cover for the majority of macroinvertebrates, and sand, mud, silt substrates provide cover for filter feeders (Unionidae, Corbiculidae) important cover. [DISCHARGE_YR]	DATA FROM THIS STUDY
Demand/potential for recreation (REC_SPIR_POT)	The availability of river's natural character that represents the environment potential for people to swim and conduct spiritual rituals. Ranks selected for this node include optimal environment (flow and depth potential to support people's appreciation and enjoyment of the water body and spiritual use) (Zero-low rank), moderate environment potential (Mod rank) flow, depth and natural character of river supports most but not all expected parts for spiritual, appreciation, enjoyment (High rank) significant parts of the river's natural character, flow, depth do not support the river's potential for people's enjoyment and spiritual use	DATA FROM THIS STUDY
Velocity / depth habitat characteristics (REC_SPIR_VD)	Distribution and abundance (unit m2) of instream velocity-depth habitat (slow-deep, slow-shallow, slow-very shallow, fast-intermediate, fast-shallow and fast-deep) distributions (measure) associated with requirements for swimming and spiritual water use. Ranks include distribution and abundances of natural character, varied depth and velocity (Zero), occurrence of (but altered) river's natural character for swimming and spiritual use (Low), modified velocity-depth habitat distributions, changing river's natural character for some locations, while majority of areas maintained (Mod) and significant alteration of velocity-depth habitat characteristics with complete change of river's natural character and locations for swimming and spiritual use. [DISCHARGE_YR]	DATA FROM THIS STUDY
Demand/potential for tourism (TOURISM_POT)	The availability of river's natural character that represents the environment potential for people to enjoy tourists' attraction and activities (fishing competition, water rafting, bird watching). Ranks selected for this node include optimal environment (flow and depth, water quality) potential to the area's physical environment for tourism (Zero-low rank), moderate environment potential (Mod rank) flow, depth, water quality, natural character of river supports some parts of the river for tourism but not all parts (High rank) significant parts of the river's natural character, flow, depth, water quality support the river's potential for tourism	DATA FROM THIS STUDY

Table 6-2: Example of The Conditional Probability Table for The Parent Nodes of The Bayesian Network For The Limpopo E-Flow Study

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
Maintain fisheries for livelihoods (SUB_FISH_END)	Endpoint representing integration of potential for subsistence fisheries (causal leg of risk assessment) and holistic environment including instream and other stressors that affect subsistence fish communities per risk region/site. This node represents the endpoint selected through the visioning process of the study as a part of provisioning services in the study.	Zero	Either oversupply of fish for potential subsistence fishery, or no demand for subsistence fishery associated with no people or subsistence fisheries activities.
		Low	Supply and demand for subsistence fishery matched resulting in sustainable provision of fish that meets livelihoods demand of community.
		Moderate	Provision of fish does not meet demand for subsistence fishery but is suitable to provide critical requirement of community to remain sustainable. This represents "worst" but acceptable condition of fishery for community.
		High	Unacceptable or unsustainable demand for fish or under supply of fish, or unsuitable quality of fish that will negatively affect human health. This rank represents potential for this endpoint not being met as a result of one or many stressors.
Environment for sub.fish (SUB_FISH_ENV)	Endpoint representing integration of instream environment for subsistence fish communities and impacts like barriers and alien fauna affecting fish subsistence fish communities per risk region/site. This node represents the endpoint selected through the visioning process of the study as part of provisioning services in the study.	Zero	Complete environment potential to support subsistence fishery, no impact of barriers and alien fauna and competition
		Low	Sufficient environment potential to support subsistence fishery, low impact of barriers and alien fauna and competition
		Moderate	Moderate environment potential where the environment supports most but not all subsistence fisheries, moderate impact of barriers and alien fauna and competition
		High	Low environment potential where environment support of subsistence fisheries is unsustainable and/or dysfunctional, high impact of barriers and alien fauna and competition
Instream environment for sub. fish (SUB_FISH_INST)	Endpoint representing integration of physical habitat for subsistence fisheries, water quality for subsistence fisheries and cues for life cycles of subsistence fisheries.	Zero	Complete environment potential to support subsistence fishery, physical habitat available, water quality in a good range, lifecycles of subsistence fisheries is undisrupted

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		Low	Sufficient environment potential to support subsistence fishery, physical habitat available, water quality in a good range, lifecycles of subsistence fisheries is undisrupted
		Moderate	Moderate environment potential where the environment supports most but not all subsistence fisheries, not all physical habitat required are available, water quality in a tolerable range, some part of the lifecycles of subsistence fisheries are disrupted
		High	Low environment potential where environment support of subsistence fisheries is unsustainable and/or dysfunctional, physical habitat required is not available, water quality in an intolerable range, lifecycles of subsistence fisheries is disrupted
Physical habitat for sub. fish (SUB_FISH_HAB)	Endpoint representing integration of geomorphic substrates, velocity depth classes and cover characteristics.	Zero	The physical habitat (velocity depth classes, geomorphic substrates, cover features) available and conditions comparable to pre-anthropogenic activities
		Low	Some alterations to the physical habitat (velocity depth classes, geomorphic substrates, cover features) but suitable availability and conditions present to sustain subsistence fisheries.
		Moderate	Concerning loss to physical habitat (velocity depth classes, geomorphic substrates, cover features) not all expected subsistence fisheries are present.
		High	Critical loss to physical habitat (velocity depth classes, geomorphic substrates, cover features) absences of subsistence fisheries.
Alien fauna competition/predating fish (SUB_FISH_ALI)	Occurrence and abundance (measure and unit) of competing/predacious impact of known alien fauna (fish) on indigenous fishes	Zero	Occurrence and abundance (measure and unit) of competing impact of known alien fauna (fish) on indigenous fishes considered where ranks represent no threat/potential impact. 0 individuals.
		Low	Occurrence of alien (not invasive) species that will not significantly affect life cycle of any indigenous species. 1 individual.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		Moderate	Occurrence of alien species (invasive) with potential to affect indigenous populations significantly in low abundances. > 1 individual.
		High	Presence of alien species in high abundances that poses high threat to indigenous populations. Invasive species dominate the site.
Geomorphic substrates (SUB_FISH_GEOM)	Diversity of substrates across a range of geomorphic units (benches, banks, floodplains)	Zero	Habitat and sediment heterogeneity without blanket deposition of fine sediment; no undue incision of active channel and flood features
		Low	Localised scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ localised blanket deposition of fine sediment on inset benches, banks and flood features
		Moderate	Frequent scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thin blanket deposition of fine sediment on inset benches, banks and flood features
		High	Extensive scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thick blanket deposition of fine sediment on inset benches, banks and flood features
Maintain plants for livelihoods (SUB_VEG_END)	Endpoint representing demand potential for harvesting plants (causal leg of risk assessment) and supply of plants for harvest per risk region/site. This node represents the endpoint selected through the visioning process of the study as a part of provisioning services in the study.	Zero	Either oversupply of riparian plants for livelihoods, or no demand for riparian plants for livestock grazing
		Low	Supply and demand for riparian plants for livelihoods, matched resulting in sustainable provision that meets demand of people.
		Moderate	riparian plants for livelihoods does not meet demand for subsistence harvesting but is suitable to provide critical requirement.
		High	Unacceptable and unsuitable riparian plants for livelihoods and likely to negatively affect people's health. This rank represents potential for this endpoint not being met.
		Zero	The availability of plants / plant material is in keeping with background (reference) expectations for the risk region.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
Supply of plants for harvest (SUB_VEG_SUPP)	The combination of available plants /plant material comprising edible and medicinal plants, wood and reeds or large sedges, that can be harvested per risk region.	Low	The availability of plants / plant material is in keeping with current day availability for the risk region.
		Moderate	The availability of plants / plant material has been reduced from current day availability, but reduced resource is still available for harvest for the risk region.
		High	The availability of plants / plant material has been reduced from current day availability and is no longer available for harvest for the risk region.
Edible & medicinal plants (SUB_VEG_EDMED)	Endpoint representing edible and medicinal plants expected in the risk region and that are dependent on available riparian habitats for their existence and distribution.	Zero	Riparian habitats are intact and all expected edible and medicinal plants for the risk region are available.
		Low	Riparian habitats are intact and most expected edible and medicinal plants for the risk region are available.
		Moderate	Riparian habitats are altered and only a portion of expected edible and medicinal plants for the risk region are available.
		High	Riparian habitats are altered/dysfunctional and none / few of the expected edible and medicinal plants for the risk region are available.
Wood for fuel/construction (SUB_VEG_WOOD)	Endpoint representing trees and shrubs expected in the risk region and that are dependent on available riparian habitats for their existence and distribution.	Zero	Riparian habitats are intact and all expected woody plants for the risk region are available.
		Low	Riparian habitats are intact and most expected woody plants for the risk region are available.
		Moderate	Riparian habitats are altered and only a portion of expected woody plants for the risk region are available.
		High	Riparian habitats are altered/dysfunctional and none/few of the expected woody plants for the risk region are available.
Riparian habitat for vegetation (SUB_VEG_RIP)	Diversity of riparian habitats across a range of geomorphic features / zones. Habitat diversity key components are substrate and hydrolocal / hydraulic characteristics. Endpoint represents the	Zero	Riparian habitat diversity intact, all expected geomorphic units and substrates are represented for the risk region and hydraulic / hydrological characteristics promote species diversity and abundance.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
	biophysical template which facilitates plant / vegetation potential response to environment.	Low	Riparian habitat diversity mostly intact, all expected geomorphic units and substrates are represented for the risk region and hydraulic / hydrological characteristics promote species diversity and abundance.
		Moderate	Riparian habitat diversity reduced, geomorphic unit and substrate diversity reduced, and hydraulic / hydrological characteristics promote species dominance with loss of diversity.
		High	Riparian habitat diversity lost, geomorphic unit and substrate diversity reduced, and hydraulic / hydrological characteristics promote species dominance with loss of diversity.
Geomorphic substrate (SUB_VEG_GEOM)	Diversity of substrates across a range of geomorphic units (benches, banks, floodplains)	Zero	Habitat and sediment heterogeneity without blanket deposition of fine sediment; no undue incision of active channel
		Low	Localised scour of fine sediment resulting in removal of inset branches and continuous bank erosion/ localised blanket deposition of fine sediment on inset benches, banks and flood features
		Moderate	Frequent scour of fine sediment resulting in removal of inset branches and continuous bank erosion/ thin blanket deposition of fine sediment on inset benches, banks and flood features
		High	Extensive scour of fine sediment resulting in removal of inset branches and continuous bank erosion/ thick blanket deposition of fine sediment on inset benches, banks and flood features
Reeds for fuel/construction (SUB_VEG_REED)	Endpoint representing reeds and large sedges expected in the risk region and that are dependent on available riparian habitats for their existence and distribution.	Zero	Riparian habitats are intact and all expected reeds and sedges for the risk region are available.
		Low	Riparian habitats are intact and most expected reeds and sedges for the risk region are available.
		Moderate	Riparian habitats are altered and only a portion of expected reeds and sedges for the risk region are available.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		High	Riparian habitats are altered/dysfunctional and none/few of the expected reeds and sedges for the risk region are available.
Maintain plants for domestic livestock (LIV_VEG_END)	Endpoint representing demand potential for grazing (causal leg of risk assessment, abundance of livestock) and available riparian habitat for livestock. This node represents the endpoint selected through the visioning process of the study as a part of provisioning services in the study.	Zero	Either oversupply of riparian plants for livestock grazing, or no demand for riparian plants for livestock grazing
		Low	Supply and demand for riparian plants for livestock grazing, matched resulting in sustainable provision that meets demand of livestock.
		Moderate	riparian plants for livestock grazing do not meet demand for subsistence livestock but is suitable to provide critical requirement of livestock to live.
		High	Unacceptable and unsuitable riparian plants for livestock grazing and likely to negatively affect livestock health. This rank represents potential for this endpoint not being met.
Riparian habitat for livestock (LIV_VEG_RIP)	Diversity of riparian habitats across a range of geomorphic features / zones that support riparian species suitable for grazing. Habitat diversity key components are substrate and hydrological / hydraulic characteristics.	Zero	Riparian habitat diversity intact, all expected geomorphic units and substrates are represented for the risk region and hydraulic / hydrological characteristics promote species diversity and abundance.
		Low	Riparian habitat diversity mostly intact, all expected geomorphic units and substrates are represented for the risk region and hydraulic / hydrological characteristics promote species diversity and abundance.
		Moderate	Riparian habitat diversity reduced, geomorphic unit and substrate diversity reduced, and hydraulic / hydrological characteristics promote species dominance with loss of diversity.
		High	Riparian habitat diversity lost, geomorphic unit and substrate diversity reduced, and hydraulic / hydrological characteristics promote species dominance with loss of diversity.
LIV_VEG_SAFE	Based on presence/absence of instream and off stream predators that threaten safety of livestock	Zero	Relates to no predation that threatens safety of livestock
		Low	Relates to low threat due to presence of predators but low abundance and species poses low threat to livestock

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		Moderate	Relates to moderate threat due to presence of predators but low abundance and species poses threat to juveniles but not adults.
		High	Relates to high threat due to presence of predators that poses threat to livestock.
Environment for flood control (FLO_ATT_ENV)	The riparian zone / habitats and overall vegetation abundance and structure all contribute to reach roughness which attenuates risk to flood damage e.g. function is intact with high vegetation cover, especially reeds and woody component.	Zero	Riparian habitat diversity intact, all expected geomorphic units and substrates are represented for the risk region and hydraulic / hydrological characteristics promote species diversity and abundance.
		Low	Riparian habitat diversity mostly intact, all expected geomorphic units and substrates are represented for the risk region and hydraulic / hydrological characteristics promote species diversity and abundance.
		Moderate	Riparian habitat diversity reduced, geomorphic unit and substrate diversity reduced and hydraulic / hydrological characteristics promote species dominance with loss of diversity.
		High	Riparian habitat diversity lost, geomorphic unit and substrate diversity reduced and hydraulic / hydrological characteristics promote species dominance with loss of diversity.
Geomorphic substrate (RIV_ASS_GEOM)	Diversity of substrates across a range of geomorphic units (benches, banks, floodplains)	Zero	Habitat and sediment heterogeneity without blanket deposition of fine sediment; no undue incision of active channel and flood features
		Low	Localised scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ localised blanket deposition of fine sediment on inset benches, banks and flood features
		Moderate	Frequent scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thin blanket deposition of fine sediment on inset benches, banks and flood features
		High	Extensive scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thick blanket deposition of fine sediment on inset benches, banks and flood features

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
Geomorphic substrates (RES_RES_GEOM)	Diversity of substrates across a range of geomorphic units (benches, banks, floodplains)	Zero	Habitat and sediment heterogeneity without blanket deposition of fine sediment; no undue incision of active channel and flood features
		Low	Localised scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ localised blanket deposition of fine sediment on inset benches, banks and flood features
		Moderate	Frequent scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thin blanket deposition of fine sediment on inset benches, banks and flood features
		High	Extensive scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thick blanket deposition of fine sediment on inset benches, banks and flood features
Maintain fish communities (FISH_ECO_END)	Endpoint representing integration of potential for fish communities (causal leg of risk assessment) and holistic environment including instream environment for fish communities and other stressors (barriers, disturbance to wildlife) that affect fish communities per risk region/site. This node represents the endpoint selected through the visioning process of the study as a part of supporting services in the study.	Zero	Complete or sufficient environment potential to support expected fish community structure, function and composition
		Low	Sufficient environment potential to support expected fish community structure, function and composition
		Moderate	Moderate environment potential (Mod rank) where the environment supports most but not all expected fish community
		High	Low environment potential (High rank) where environment support of fish communities is unsustainable and/or dysfunctional.
Environmental condition for fish (FISH_ECO_ENV)	Endpoint representing integration of instream environment for fish communities and impacts like barriers and disturbance to wildlife to fish communities per risk region/site. This node represents the endpoint selected through the visioning process of the study as part of supporting services in the study.	Zero	Complete or sufficient environment potential to support expected fish community structure, function and composition
		Low	Sufficient environment potential to support expected fish community structure, function and composition
		Moderate	Moderate environment potential (Mod rank) where the environment supports most but not all expected fish community
		High	Low environment potential (High rank) where environment support of fish communities is unsustainable and/or dysfunctional.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
Instream environment for fish (FISH_ECO_INS)	Endpoint representing integration of cues for life cycles of indicator fish, physical habitat for indicator fish and water quality for indicator fish.	Zero	Complete environment potential to support fish communities, physical habitat available, water quality in a good range, lifecycles of indicator species is undisrupted
		Low	Sufficient environment potential to support fish communities, physical habitat available, water quality in a good range, lifecycles of indicator species is undisrupted
		Moderate	Moderate environment potential where the environment supports most fish communities, not all physical habitat required are available, water quality in a tolerable range, some part of the lifecycles of indicator fish are disrupted
		High	Low environment potential where environment support of fish communities is unsustainable and/or dysfunctional, physical habitat required is not available, water quality in an intolerable range, lifecycles of indicator species is disrupted
Physical habitat for indicator fish (FISH_ECO_HAB)	Endpoint representing integration of geomorphic substrates, velocity depth classes and cover characteristics.	Zero	The physical habitat (velocity depth classes, geomorphic substrates, cover features) available and conditions comparable to pre-anthropogenic activities
		Low	Some alterations to the physical habitat (velocity depth classes, geomorphic substrates, cover features) but suitable availability and conditions present to sustain fish communities
		Moderate	Concerning loss to physical habitat (velocity depth classes, geomorphic substrates, cover features) not all expected fish species are present.
		High	Critical loss to physical habitat (velocity depth classes, geomorphic substrates, cover features) absences of fish communities.
	Diversity of substrates across a range of geomorphic units (benches, banks, floodplains)	Zero	Habitat and sediment heterogeneity without blanket deposition of fine sediment; no undue incision of active channel and flood features

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
Geomorphic substrates (FISH_ECO_GEOM)		Low	Localised scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ localised blanket deposition of fine sediment on inset benches, banks and flood features
		Moderate	Frequent scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thin blanket deposition of fine sediment on inset benches, banks and flood features
		High	Extensive scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thick blanket deposition of fine sediment on inset benches, banks and flood features
Cues for life cycles of indicator fish (FISH_ECO_CUES)	Endpoint represent cues for the life cycles of subsistence fisheries	Zero	There are no changes in cues, or life stages of indicator fish species
		Low	Changes have occurred but it does not impact the cues or life stages of indicator fish species
		Moderate	Changes in cues have impacted some of the life stages of indicator fish species
		High	Changes in cues has disrupted the life cycles of indicator fish species
Disturbance to wildlife (FISH_ECO_DTW)	Endpoint represent alien fauna on fish	Zero	Occurrence and abundance (measure and unit) of competing impact of known alien fauna (fish) on indigenous fishes considered where ranks represent no threat/potential impact. 0 individuals.
		Low	Occurrence of alien (not invasive) species that will not significantly affect life cycle of any indigenous species. 1 individual.
		Moderate	Occurrence of alien species (invasive) with potential to affect indigenous populations significantly in low abundances. > 1 individual.
		High	Presence of alien species in high abundances that poses high threat to indigenous populations. Invasive species dominate the site.
Alien fauna on fish (FISH_ECO_ALI)	Endpoint representing alien fauna competition and alien fauna predation. (Maybe alien fauna hybridization).	Zero	Occurrence and abundance (measure and unit) of competing impact of known alien fauna (fish) on indigenous fishes considered where ranks represent no threat/potential impact. 0 individuals.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		Low	Occurrence of alien (not invasive) species that will not significantly affect life cycle of any indigenous species. 1 individual.
		Moderate	Occurrence of alien species (invasive) with potential to affect indigenous populations significantly in low abundances. > 1 individual.
		High	Presence of alien species in high abundances that poses high threat to indigenous populations. Invasive species dominate the site.
Maintain vegetation communities (VEG_ECO_END)	Endpoint representing integration of environment potential for vegetation (causal leg of risk assessment) and environment condition for vegetation, which represents riverine conditions for vegetation communities (as represented by the interaction of substrate and flow) that may/may not be affected by alien flora.	Zero	The environment has the potential to maintain riparian vegetation communities and the environmental conditions cater for expected community structure, abundance and diversity.
		Low	The environment has the potential to maintain riparian vegetation communities and the environmental conditions mostly cater for expected community structure, abundance and diversity, with low perturbation from expectations.
		Moderate	The environment has some potential to maintain riparian vegetation communities and/or the environmental conditions acceptably cater for expected community structure, abundance and diversity, with moderate perturbation from expectations.
		High	The environment has limited potential to maintain riparian vegetation communities and/or the environmental conditions cater poorly for expected community structure, abundance and diversity, with high levels of perturbation from expectations.
Environment condition for vegetation (VEG_ECO_ENV)	Endpoint representing integration of river environment for vegetation, which represents riverine conditions for vegetation communities (as represented by the interaction of substrate and flow) that may/may not be affected by alien flora.	Zero	The river environment for riparian vegetation is in keeping with background (reference) expectations, and alien vegetation is absent or negligible
		Low	The river environment for riparian vegetation is in keeping with background (near reference) expectations, and alien vegetation is low, or comprised of annuals only.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		Moderate	The river environment for riparian vegetation is satisfactory and moderately in keeping with expectations, and alien vegetation is present (annual and perennial) but has low to moderate negative affect on diversity.
		High	The river environment does not support riparian vegetation well, and is not in keeping with expectations, and alien vegetation is dominant (and invasive), and has significantly reduced indigenous diversity.
River environment for vegetation (VEG_ECO_RIV)	The only input is the instream environment for vegetation, suggest amalgamation of the two and call as is (representing instream and riparian) and delete instream node?	Zero	Combination of substrate and flow/depth characteristics required for riparian vegetation exist and are in keeping with background [reference] expectations.
		Low	Combination of substrate and flow/depth characteristics required for riparian vegetation exist and are mostly in keeping with background [reference] expectations.
		Moderate	Perturbations of substrate and/or flow/depth characteristics required for riparian vegetation exist and therefore hinder expected occurrence of riparian vegetation.
		High	An absence of either substrate or flow/depth characteristics required for riparian vegetation, singly or in combination, but do not facilitate riparian vegetation occurrence /persistence.
Instream habitat for aquatic vegetation (VEG_ECO_INS)	Endpoint representing integration of water quality, geomorphic substrates and hydraulic/hydrological preferences. The combination of these three parameters affects microsite characteristics for aquatic and riparian vegetation recruitment (most importantly) and persistence.	Zero	Combination of substrate, water quality and flow/depth characteristics required for aquatic vegetation exist and are in keeping with background [reference] expectations.
		Low	Combination of substrate, water quality and flow/depth characteristics required for aquatic vegetation exist and are mostly in keeping with background [reference] expectations.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		Moderate	Perturbations of substrate, water quality or flow/depth characteristics required for aquatic vegetation exist and therefore hinder expected occurrence of aquatic vegetation.
		High	An absence of either substrate, water quality or flow/depth characteristics required for aquatic vegetation, singly or in combination, but do not facilitate aquatic vegetation occurrence.
Geomorphic substrates (VEG_ECO_GEOM)	Diversity of substrates across a range of geomorphic units (benches, banks, floodplains)	Zero	Habitat and sediment heterogeneity without blanket deposition of fine sediment; no undue incision of active channel
		Low	Localised scour of fine sediment resulting in removal of inset branches and continuous bank erosion/ localised blanket deposition of fine sediment on inset benches, banks and flood features
		Moderate	Frequent scour of fine sediment resulting in removal of inset branches and continuous bank erosion/ thin blanket deposition of fine sediment on inset benches, banks and flood features
		High	Extensive scour of fine sediment resulting in removal of inset branches and continuous bank erosion/ thick blanket deposition of fine sediment on inset benches, banks and flood features
Environment condition for invertebrates (INV_ECO_ENV)	The potential for the environment to be suitable for invertebrates in this study is based on knowledge of inst. Env for inverts, barriers and Alien fauna. Conditional relationship. Deterioration of instream env and increase in barriers and inc. in aliens results in increase in risk. Measure available river-stream length (potential habitat) based on historical species distribution data as reference. Compare against current available stream-river length habitats (linked and free flowing rivers). Use % free flowing habitat to set parameters. Express number of manmade barriers in relation to river-stream length to determine severity of fragmentation.	Zero	Free-flowing River (no manmade barriers - measure fluvial distance), influencing migration (i.e., Palaemonidae: *Macrobrachium* sp. in lower reaches), habitat loss (e.g., fluvial habitats, flow modification, over abstraction, etc.), and sources for introductions of alien invasive species (competition, predation, introducing new diseases, parasites). Alien invasive fauna absent or present in very low abundance.
		Low	Free-flowing river habitat (fluvial connectivity) reduced by ≤20% (e.g., distance between 1st barrier and estuary/mouth compared against "reference") - in case of *Macrobrachium* sp.. Upstream barriers/fluvial length, potential habitat reduced by ≤20%. Alien invasive fauna present but in low abundance.

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		Moderate	Free-flowing river habitat (fluvial connectivity) reduced by 20 - 40% (e.g., distance between 1st barrier and estuary/mouth compared against "reference") - in case of *Macrobrachium* sp.. Upstream barriers/fluvial length, potential habitat reduced by 20 - 40%. Alien invasive fauna present and abundant.
		High	Free-flowing river habitat (fluvial connectivity) reduced by ^{3}40% (e.g., distance between 1st barrier and estuary/mouth compared against "reference") - in case of *Macrobrachium* sp.. Upstream barriers/fluvial length, potential habitat reduced by ^{3}40%. Alien invasive fauna present and very abundant.
Geomorphic substrates (INV_ECO_GEOM)	Diversity of substrates across a range of geomorphic units (benches, banks, floodplains)	Zero	Habitat and sediment heterogeneity without blanket deposition of fine sediment; no undue incision of active channel and flood features
		Low	Localised scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ localised blanket deposition of fine sediment on inset benches, banks and flood features
		Moderate	Frequent scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thin blanket deposition of fine sediment on inset benches, banks and flood features
		High	Extensive scour of fine sediment resulting in removal of inset benches and continuous bank erosion/ thick blanket deposition of fine sediment on inset benches, banks and flood features
Maintain recreation and spiritual act (REC_SPIR_END)	Endpoint representing integration of river's physical environment for recreation and spiritual activities and holistic environment including instream and other stressors that affect use of river for recreation and spiritual activities per risk region/site. This node represents the endpoint selected through the visioning process of the study as a part of supporting services in the study.	Zero	Water depth and flow heterogenous to maintain a pristine and natural character of the river for recreational water use (people 's appreciation and enjoyment of the water body) and spiritual use.
		Low	Water depth and flow heterogenous most parts of the river's natural character is maintained for recreational water use (people 's appreciation and enjoyment of the water body) and spiritual use.
		Moderate	Minimal disturbances which obstruct flow and depth, changing some parts of the river from their natural character for recreational and spiritual use

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
		High	Absence of water flow and shallow water levels throughout the seasons, with excessive sedimentation leading to homogenous area with complete change of river's natural character for recreational and spiritual use
Safe environment condition for recreation (REC_SPIR_SAFE)	Endpoint representing integration of physical and social environment affecting recreation per risk region/site. This node represents the endpoint selected through the visioning process of the study as part of supporting services in the study.	Zero	Ultimate safe environment to support recreation with no impact of hazards
		Low	Sufficiently safe environment with potential to support recreation and spiritual rituals with no impact of hazards
		Moderate	Moderately safe environment with potential to support recreation and spiritual activities with moderate hazards
		High	Dangerous environment with limited potential to support recreation and spiritual rituals with high hazards
Access and safely for recreation (REC_SPIR_ACC)	End point representing social and physical barriers present to prevent access to areas for recreational, spiritual activities and safety of users	Zero	Relates to no social and physical barriers present to prevent access to tourist areas with safe environment
		Low	Relates to a few/low present social and physical and barriers with low threat to access tourist areas by interested population.
		Moderate	Relates to moderately present social and physical barriers/threats that inhibit access to recreation sites for interested population
		High	Relates to major and high social threats and physical barriers that discourages access to recreation areas for interested population
Maintain tourism (TOURISM_END)	Endpoint representing integration of potential for tourism (causal leg of risk assessment) and holistic environment including environment for tourism and other stressors which include barriers that affect tourism per risk region/site. This node represents the endpoint	Zero	Either heterogenous and optimal environment for potential tourism or no demand for tourism associated and no people with interest in tourism.
		Low	Environmental conditions for tourism matched demand resulting in sustainable provision of tourist areas to meet demand of people and access

Variable title (BN CODE)	Description for conditional probability tables (CPTs)	Ranks	Description of ranks for variable
	selected through the visioning process of the study as a part of supporting services in the study.	Moderate	environmental conditions for tourism do not meet demand but is suitable to provide critical requirements of people for tourism remain sustainable and acceptable condition of fishery for community.
		High	Unacceptable or unsustainable demand for tourism or river environment not suitable for acceptable tourist environment which will affect their social well-being. This rank shows potential for this endpoint not being met as a result of one or many stressors.
Environment condition for tourism (TOURISM_ENV)	Endpoint representing integration of physical environment for tourism and impacts like social barriers affecting tourism per risk region/site. This node represents the endpoint selected through the visioning process of the study as part of supporting services in the study.	Zero	Ultimate environment potential to support tourism with no impact of social barriers and physical environment.
		Low	Sufficient environment potential to support tourism with no impact of social barriers and physical environment.
		Moderate	Moderate environment potential where the physical environment supports tourism with moderate impact of social barriers
		High	Low environment potential where the physical environment supports tourism with high impact of social barriers and unsustainable and/or dysfunctional tourism

7 APPENDIX B - Hydrology

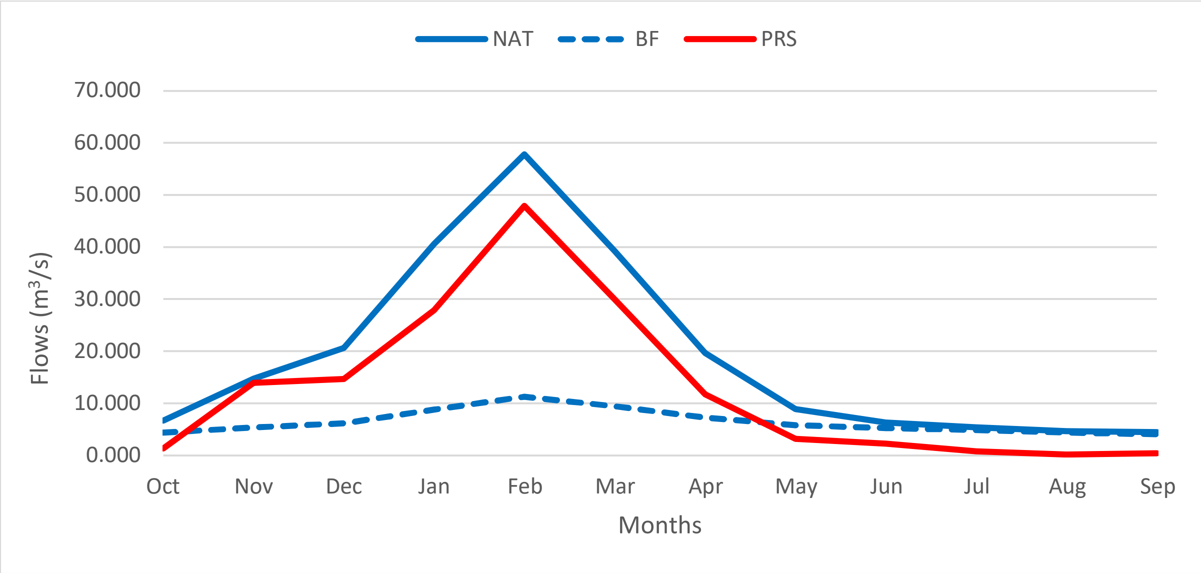

Figure 7-1: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Crocodile River (CROC-A24J-ROOIB).

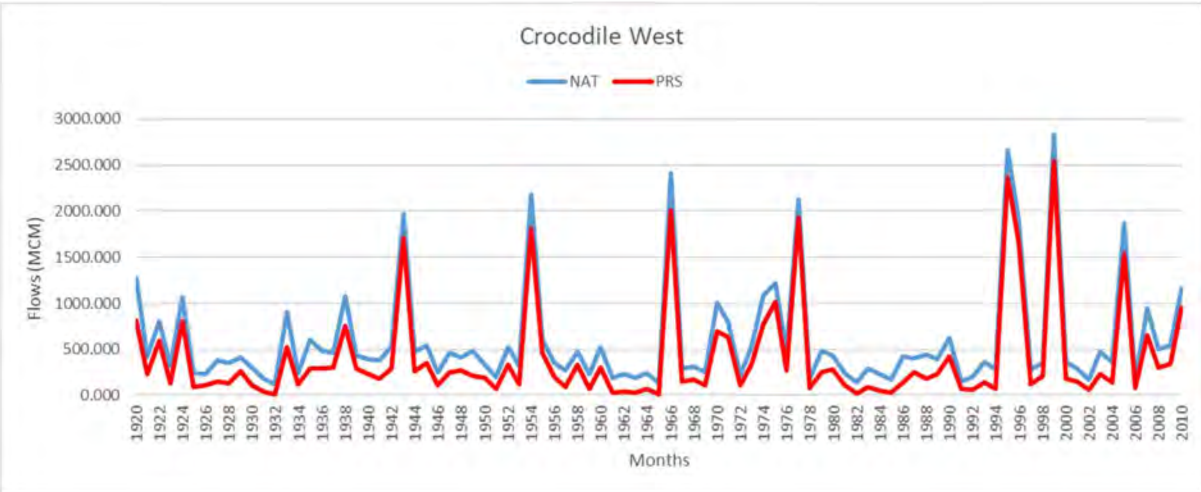

Figure 7-2: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Crocodile River (CROC-A24J-ROOIB).

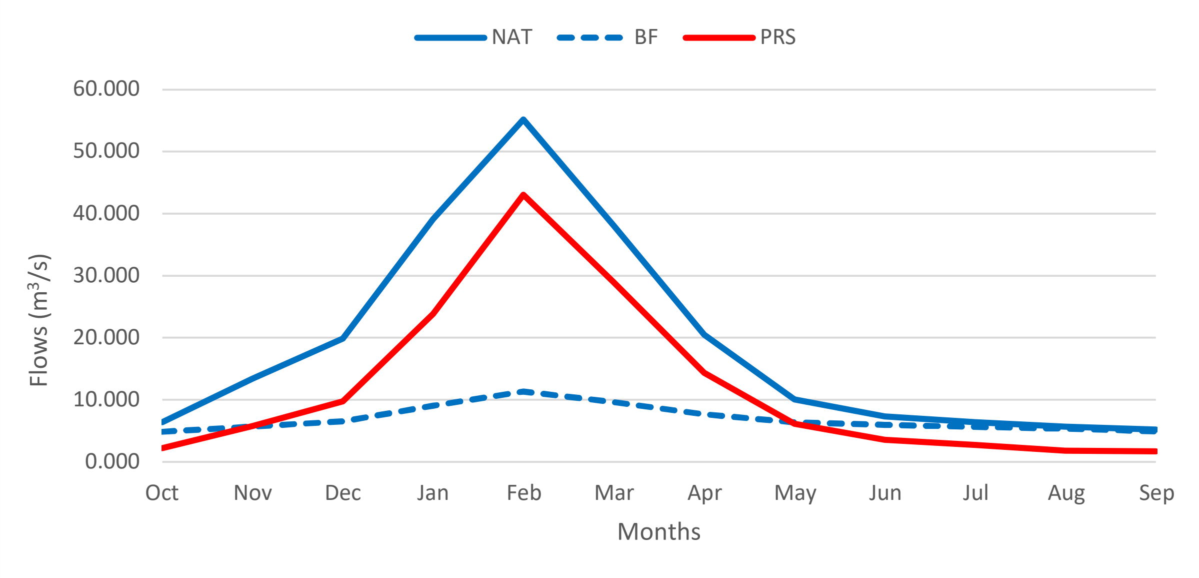

Figure 7-3: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Limpopo River at Spanwerk (LIMP-A41D-SPANW).

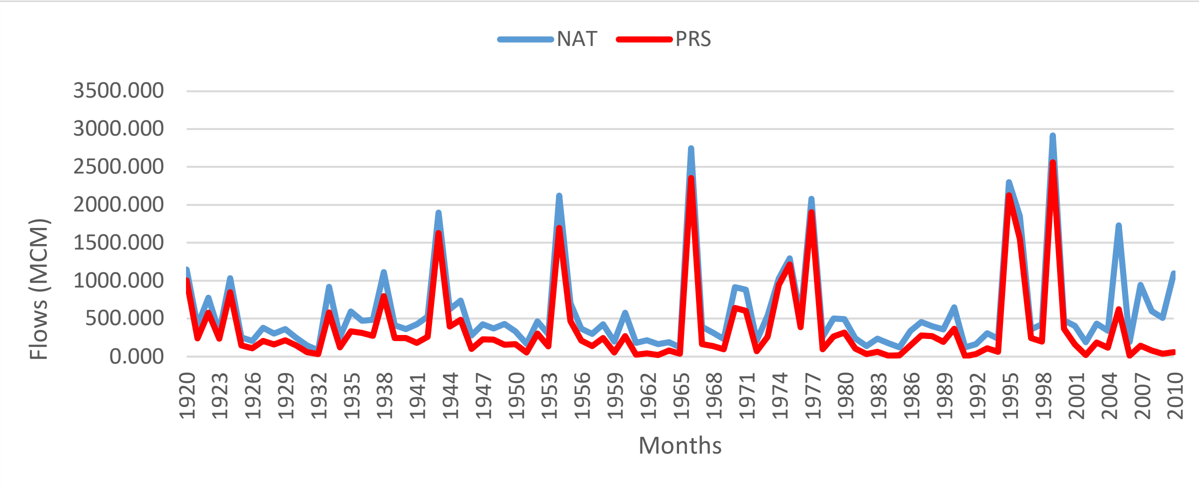

Figure 7-4: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Limpopo River at Spanwerk (LIMP-A41D-SPANW).

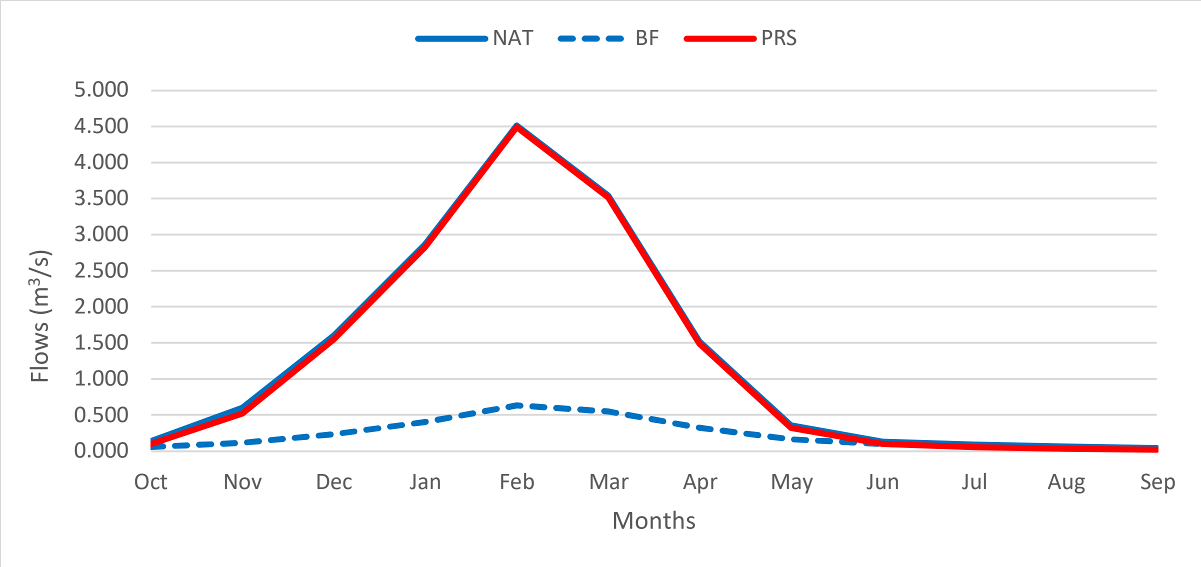

Figure 7-5: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Matlabas River (MATL-A41D-WDRAAI).

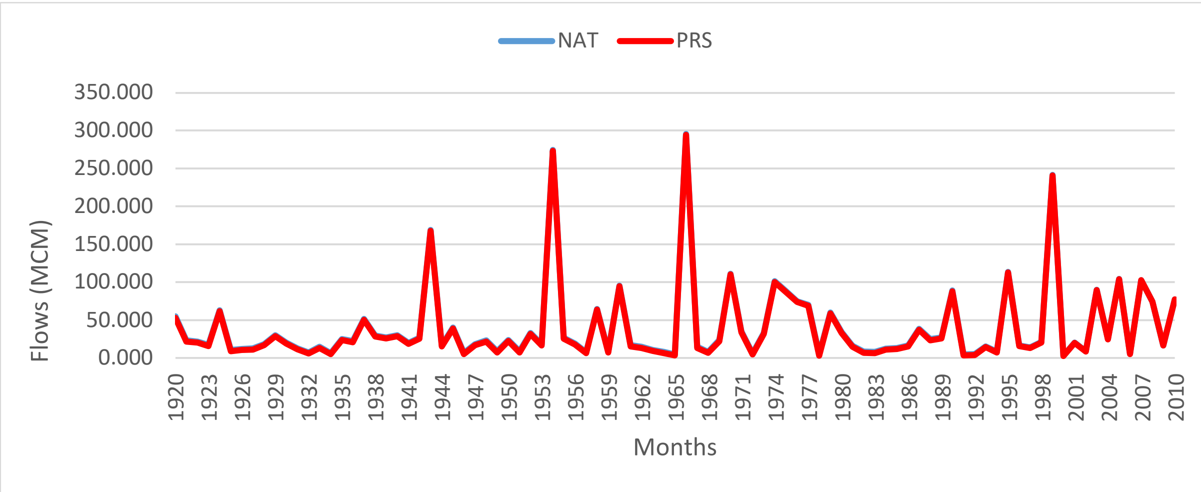

Figure 7-6: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Matlabas River (MATL-A41D-WDRAAI).

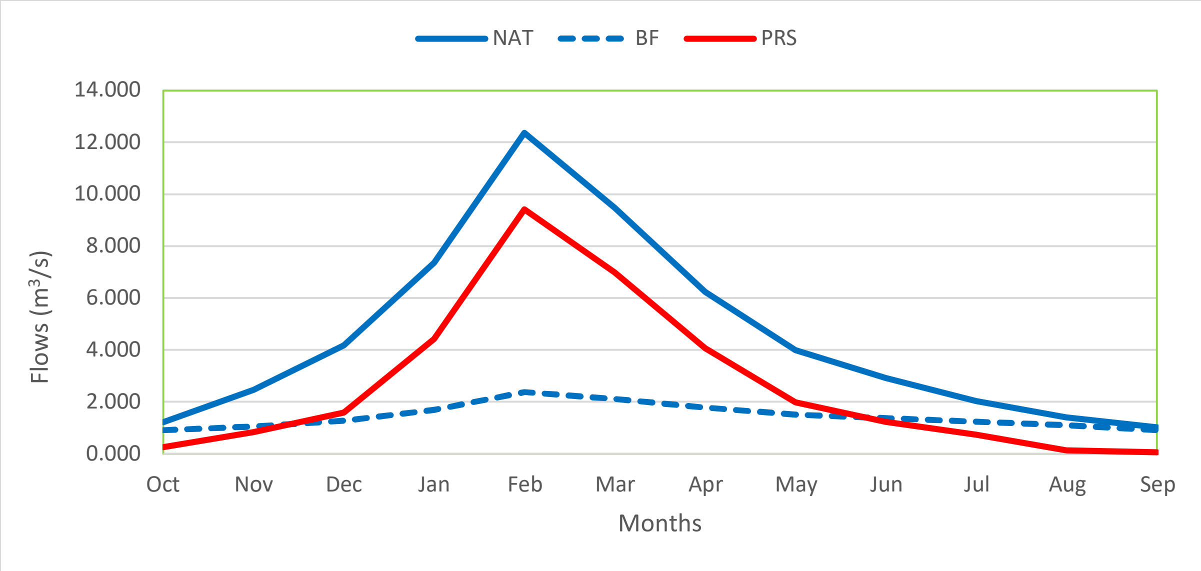

Figure 7-7: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Lephalala River (LEPH-A50H-SEEKO).

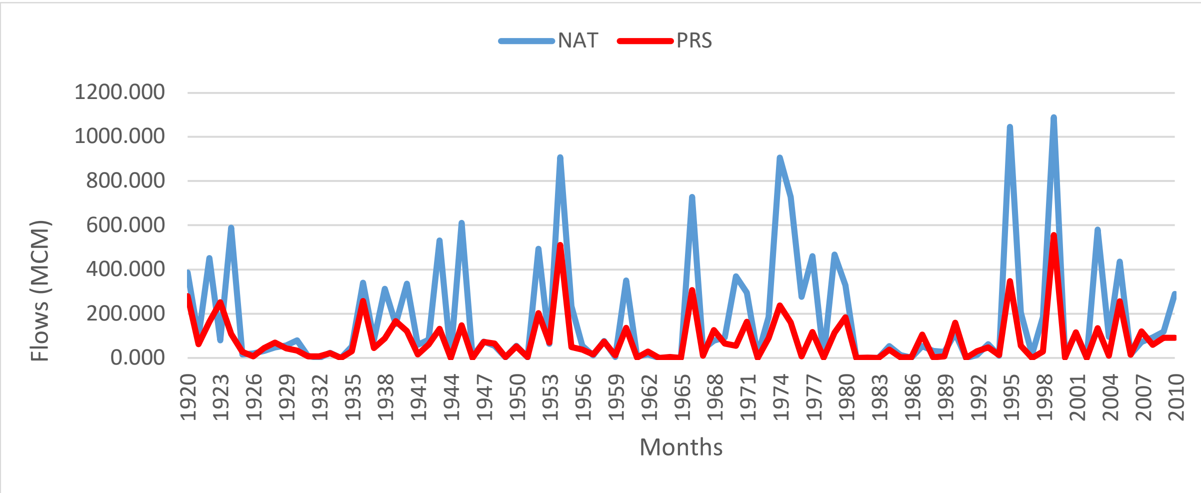

Figure 7-8: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Lephalala River (LEPH-A50H-SEEKO).

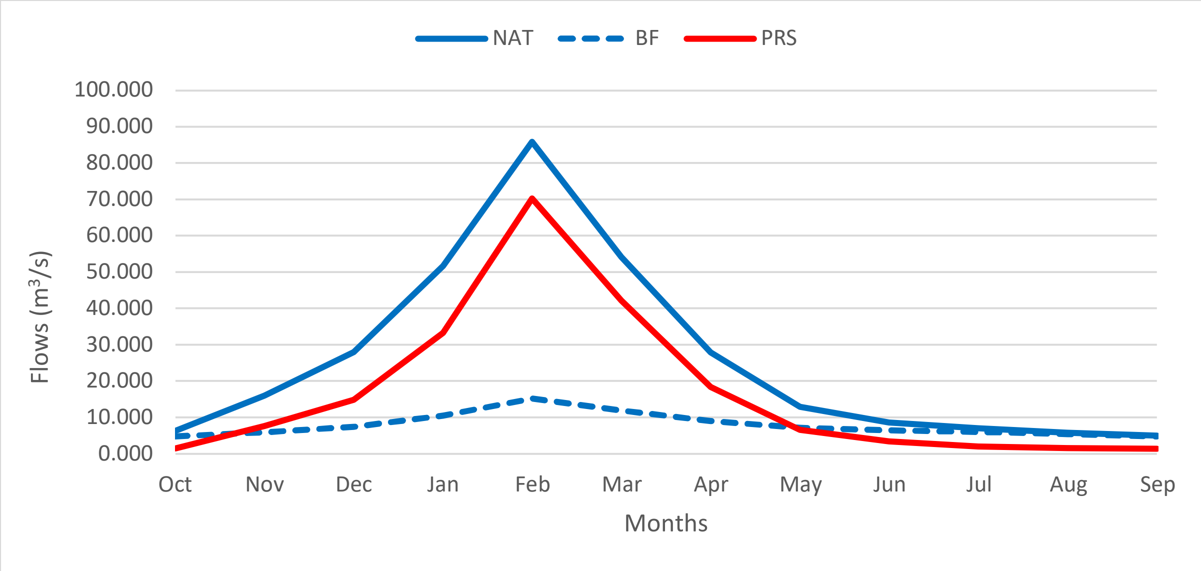

Figure 7-9: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Limpopo River at Limpokwena (LIMP-A36C-LIMPK).

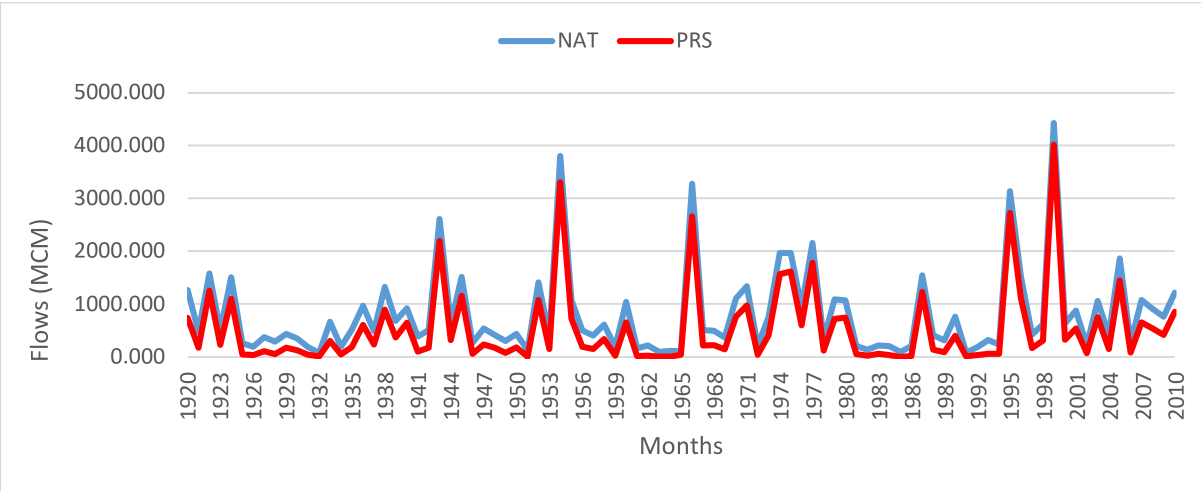

Figure 7-10: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Limpopo River at Limpokwena (LIMP-A36C-LIMPK).

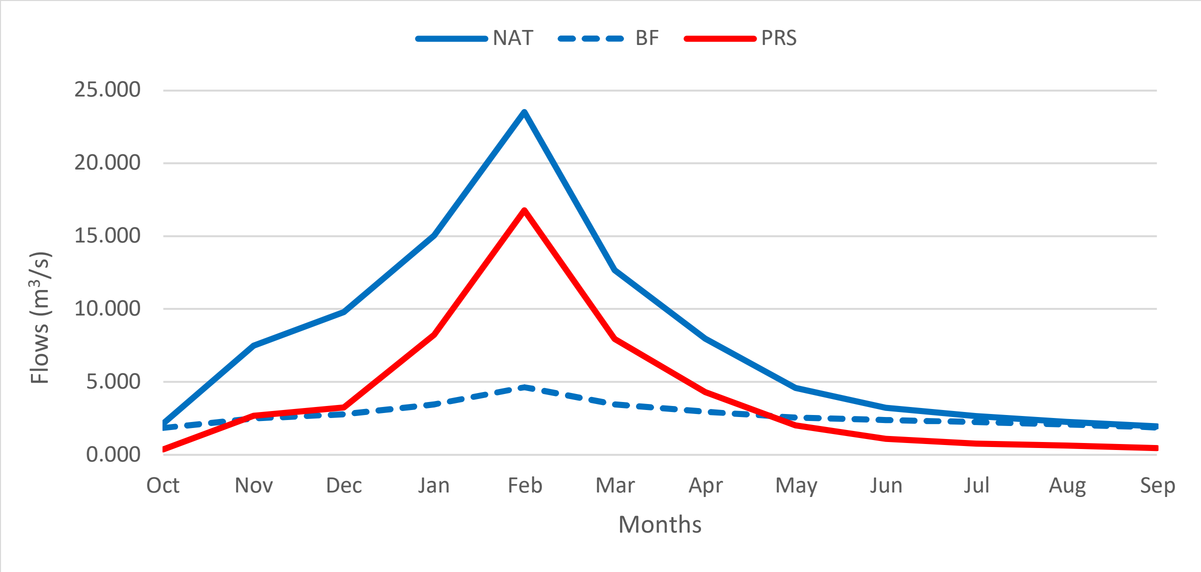

Figure 7-11: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Mogalakwena River (MOGA-A36D-LIMPK).

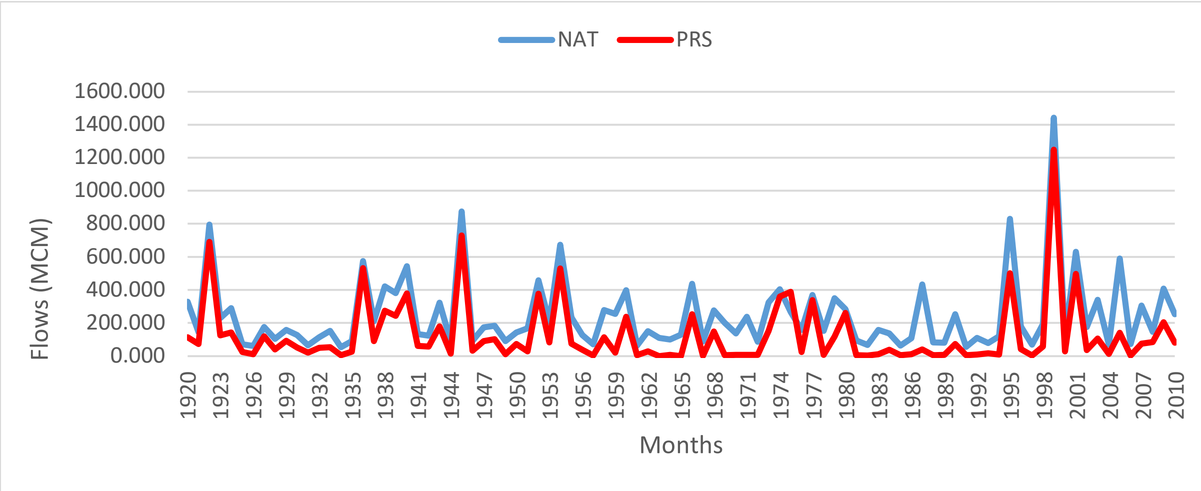

Figure 7-12: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Mogalakwena River (MOGA-A36D-LIMPK).

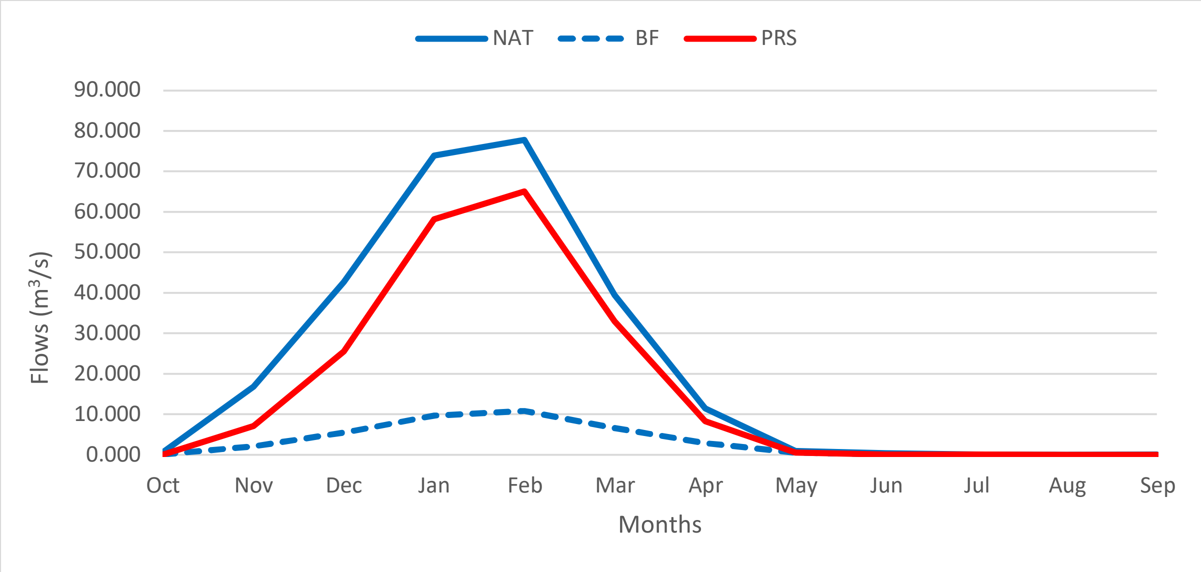

Figure 7-13: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Shashe River (SHAS-Y20B-TULIB).

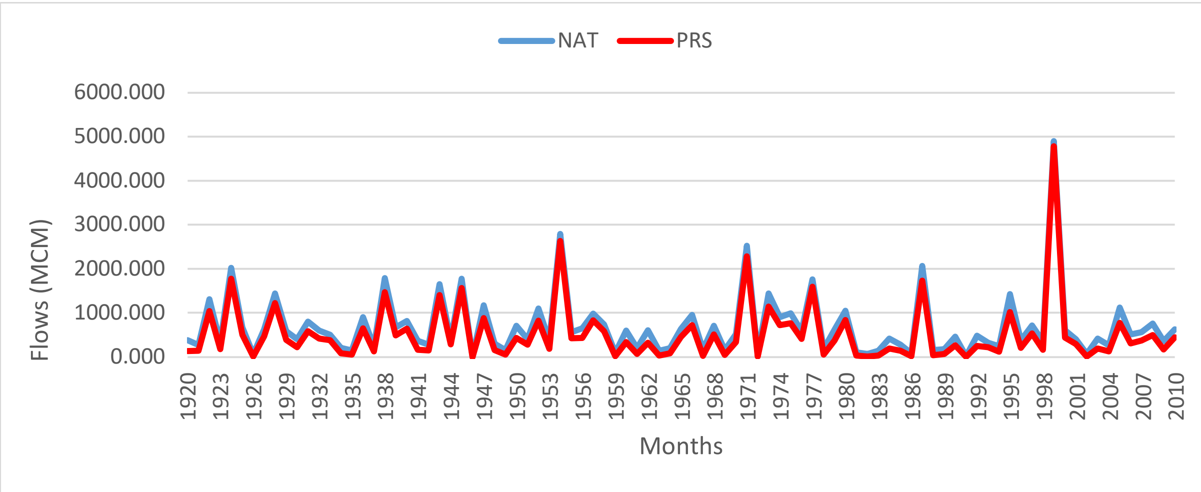

Figure 7-14: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Shashe River (SHAS-Y20B-TULIB).

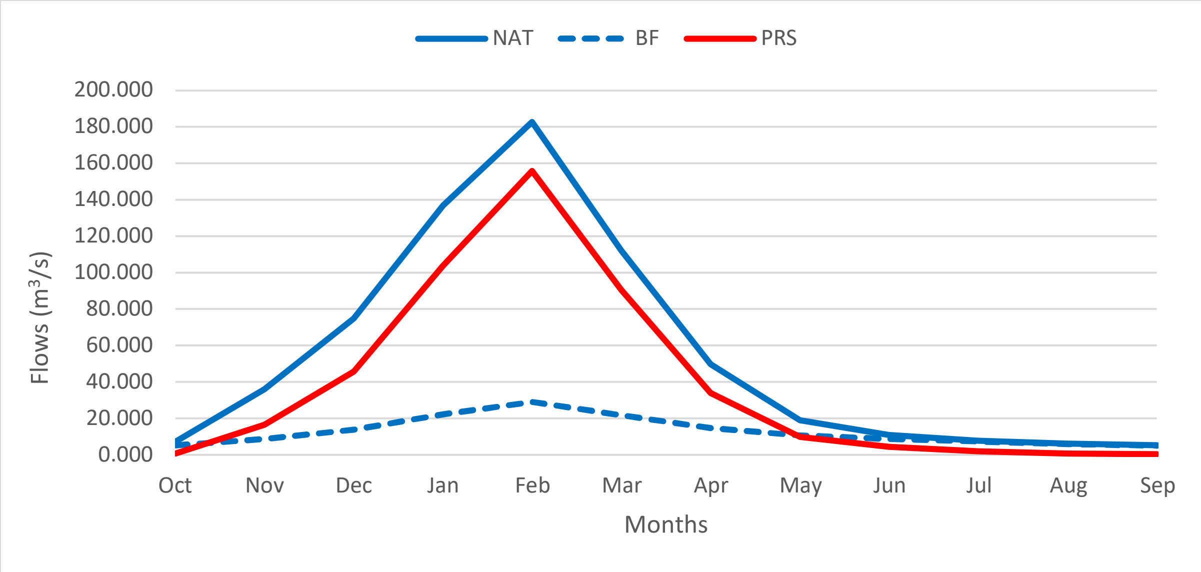

Figure 7-15: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Limpopo River (LIMP-A71L-MAPUN).

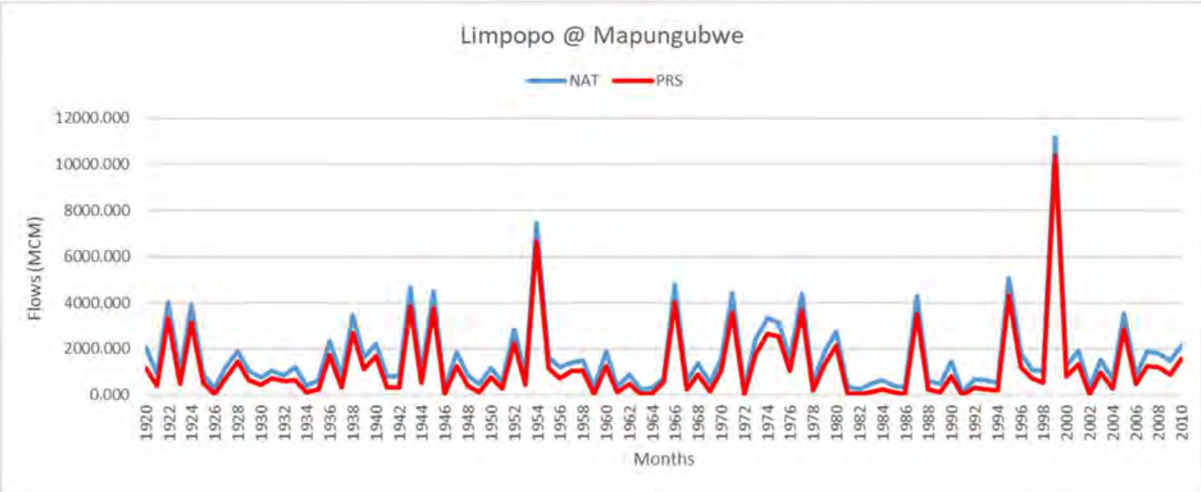

Figure 7-16: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Limpopo River (LIMP-A71L-MAPUN).

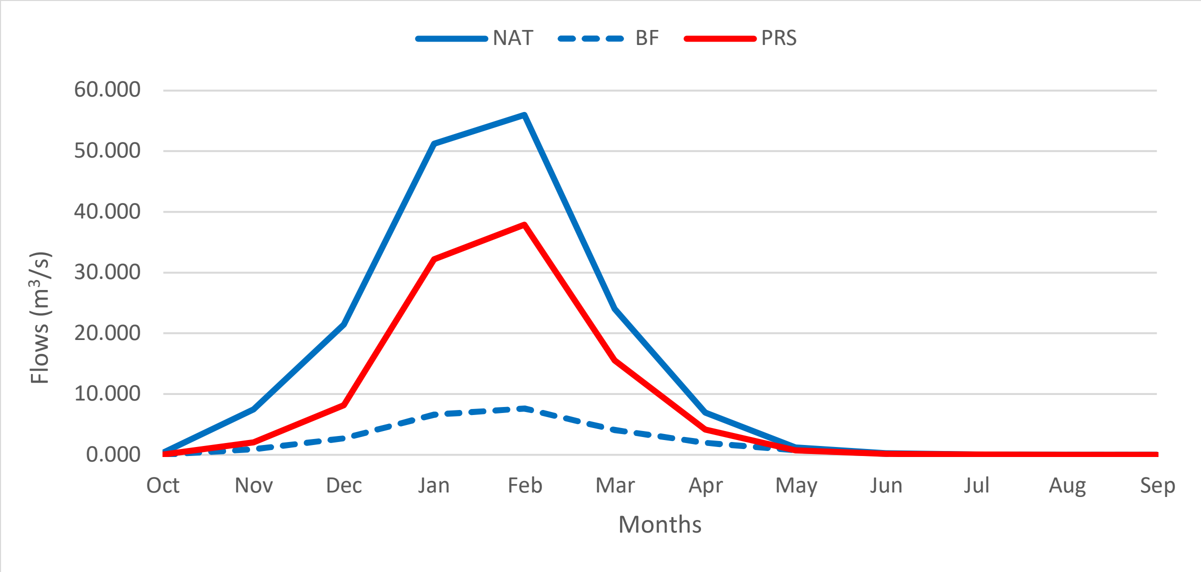

Figure 7-17: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Umzingwani River (UMZI-Y20C-BEITB).

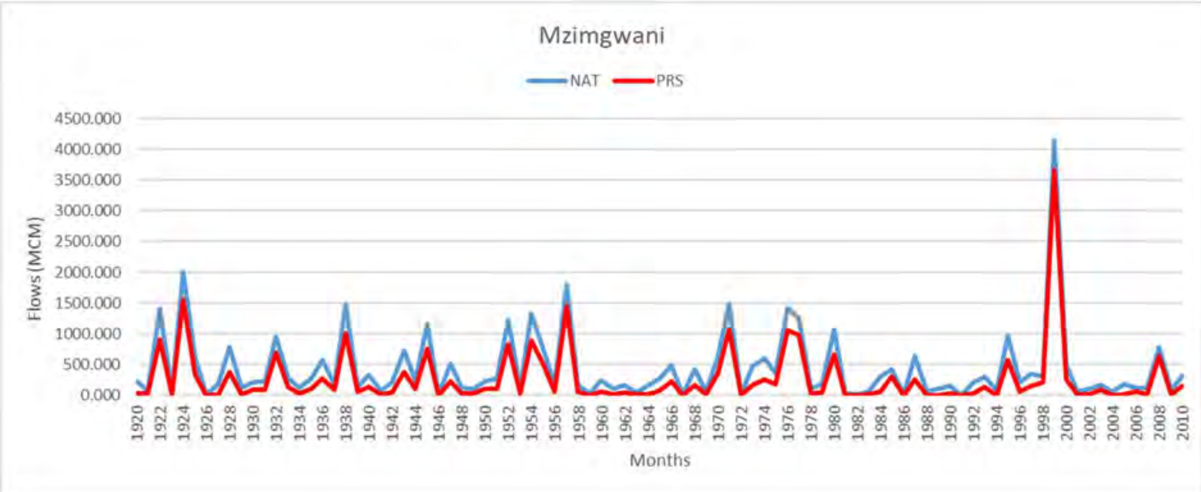

Figure 7-18: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Umzingwani River (UMZI-Y20C-BEITB).

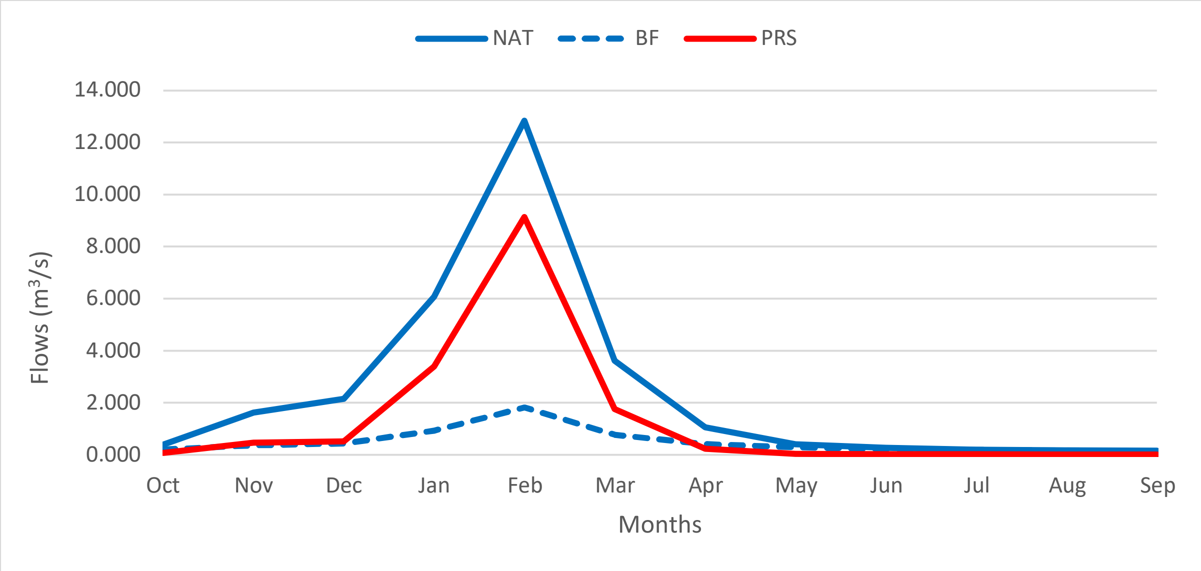

Figure 7-19: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Sand River (SAND-A71K-R508B).

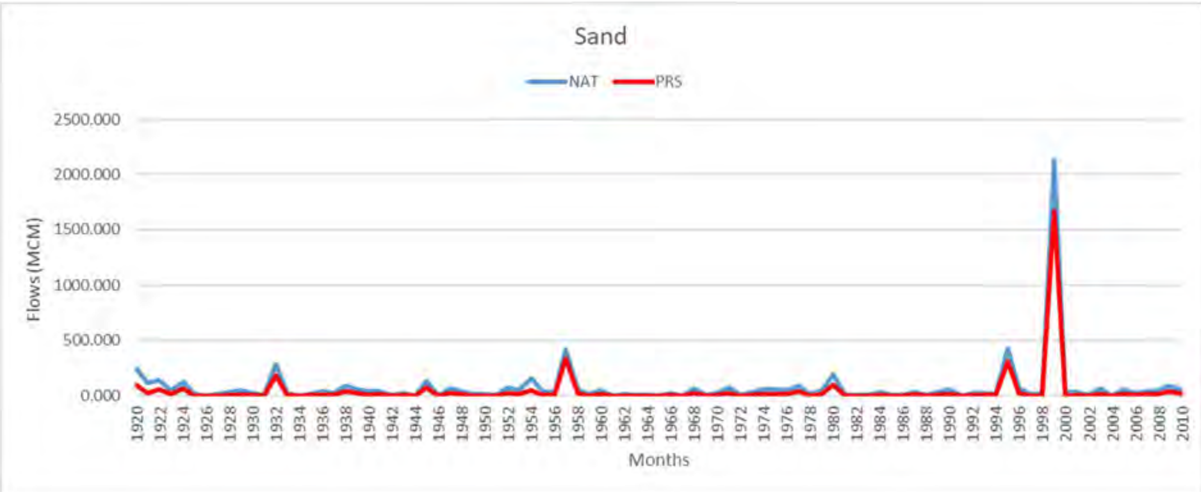

Figure 7-20: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Sand River (SAND-A71K-R508B).

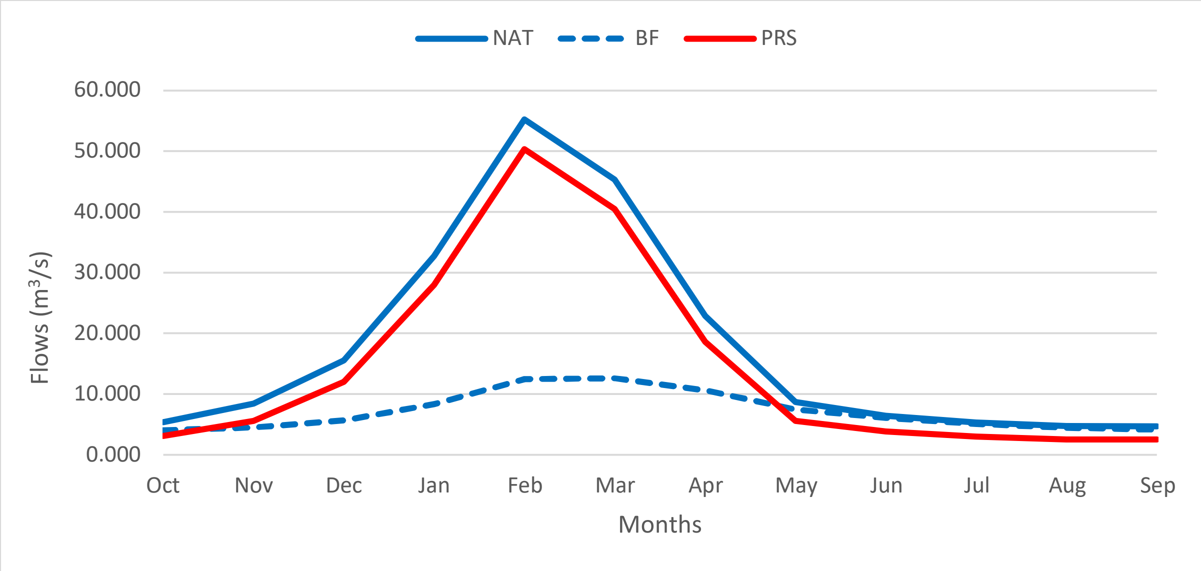

Figure 7-21: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Luvuvhu River (LUVU-A91K-OUTPO).

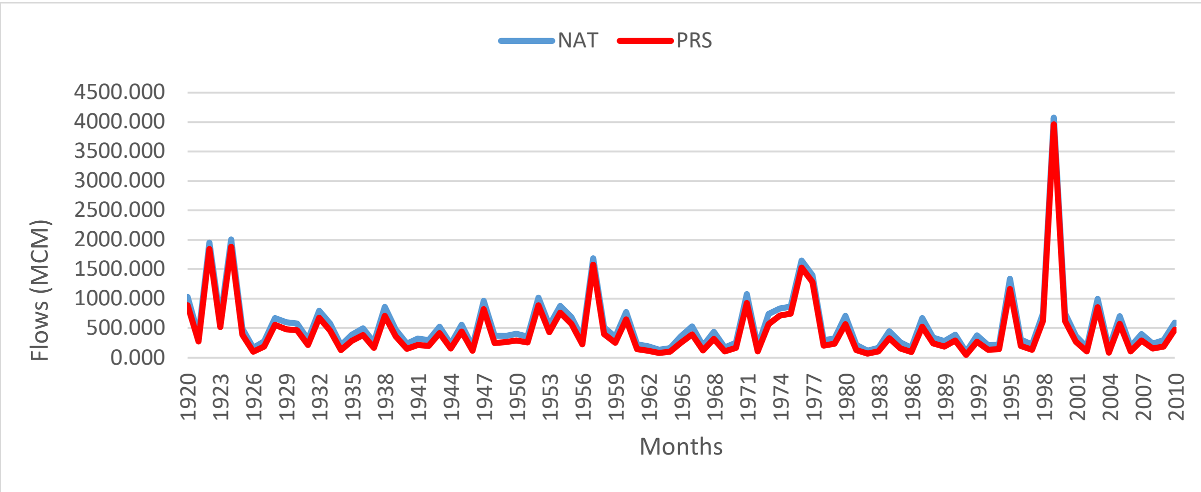

Figure 7-22: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Luvuvhu River (LUVU-A91K-OUTPO).

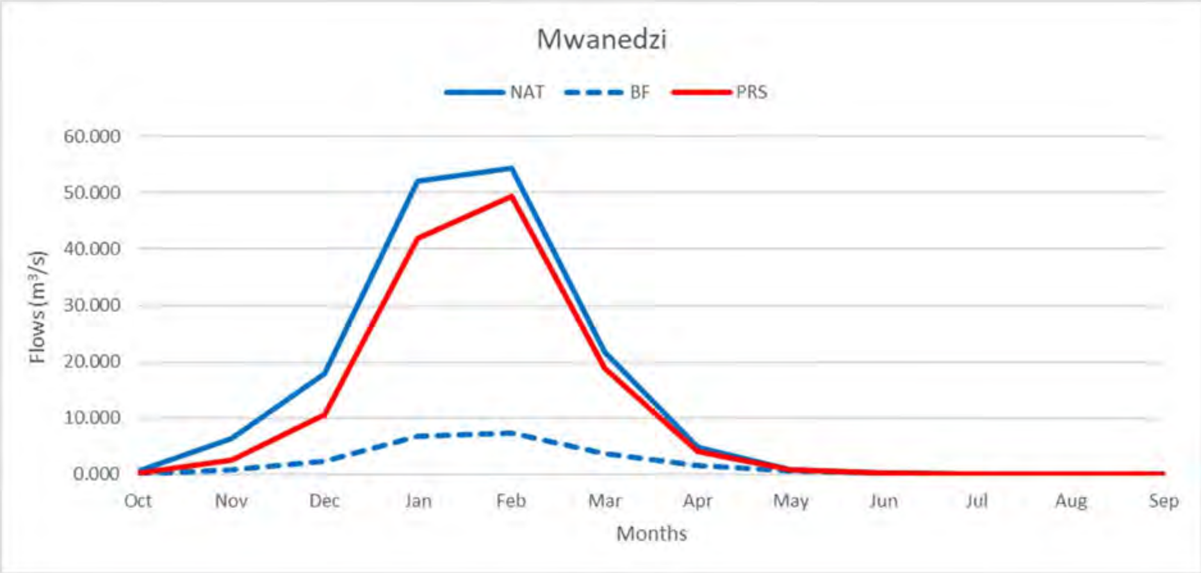

Figure 7-23: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Mwenedzi River (MWEN-Y20H-MALAP).

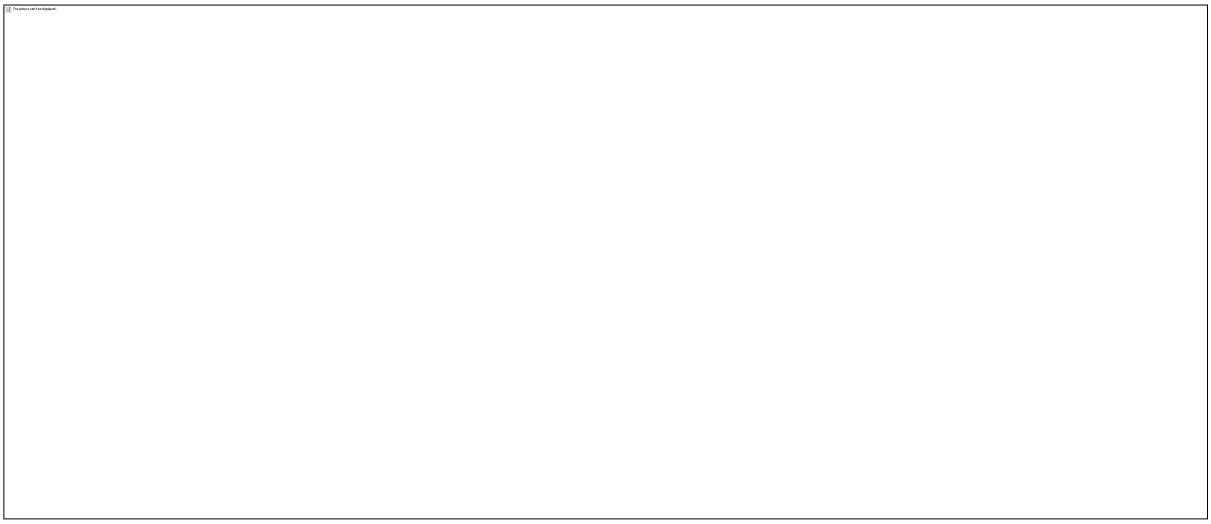

Figure 7-24: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Mwenedzi River (MWEN-Y20H-MALAP).

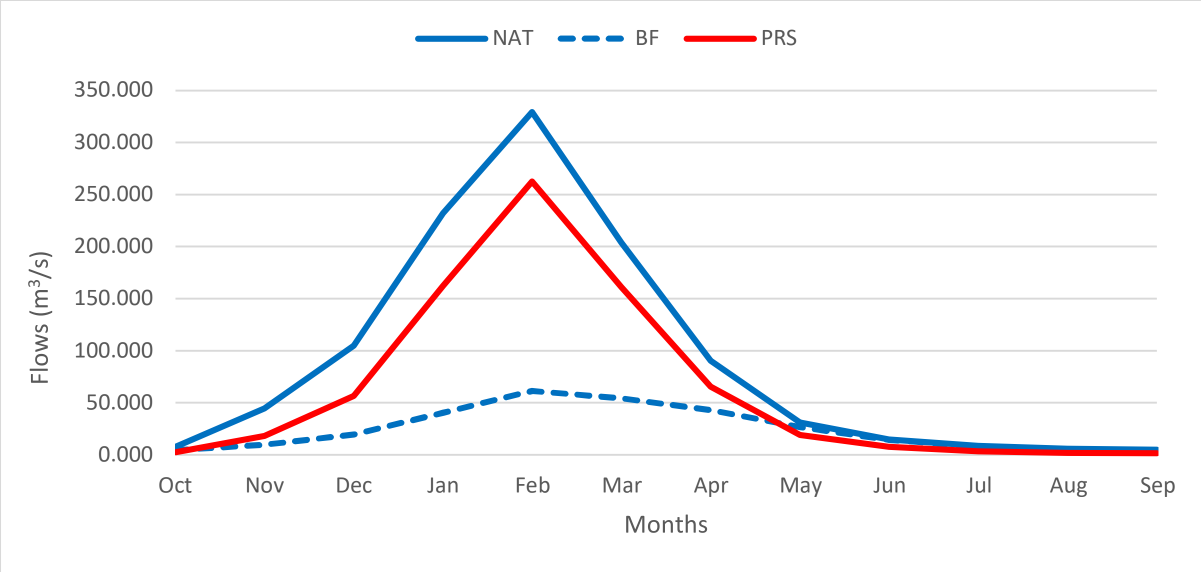

Figure 7-25: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Limpopo River at Pafuri (LIMP-Y30D-PAFUR).

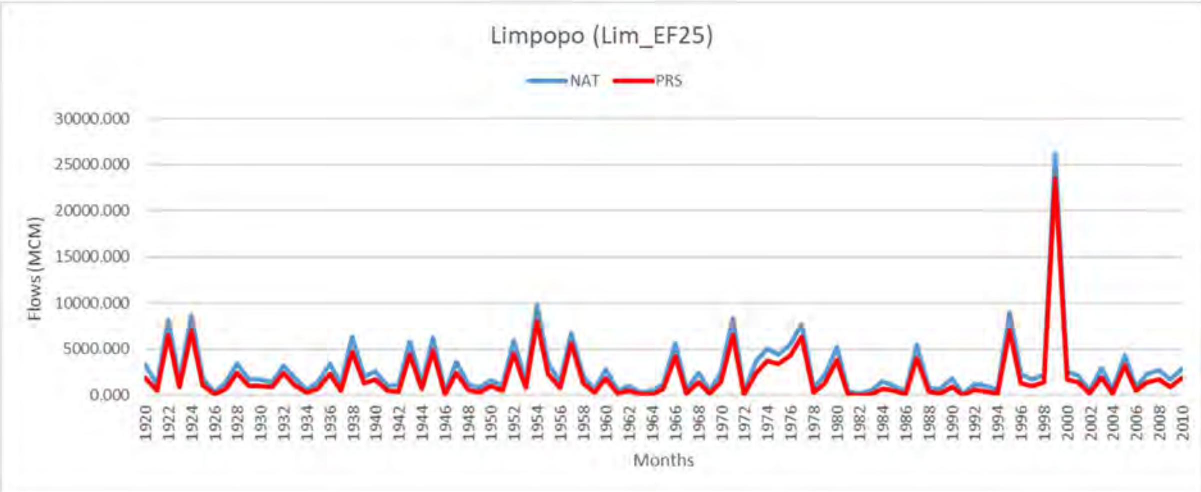

Figure 7-26: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Limpopo River at Pafuri (LIMP-Y30D-PAFUR).

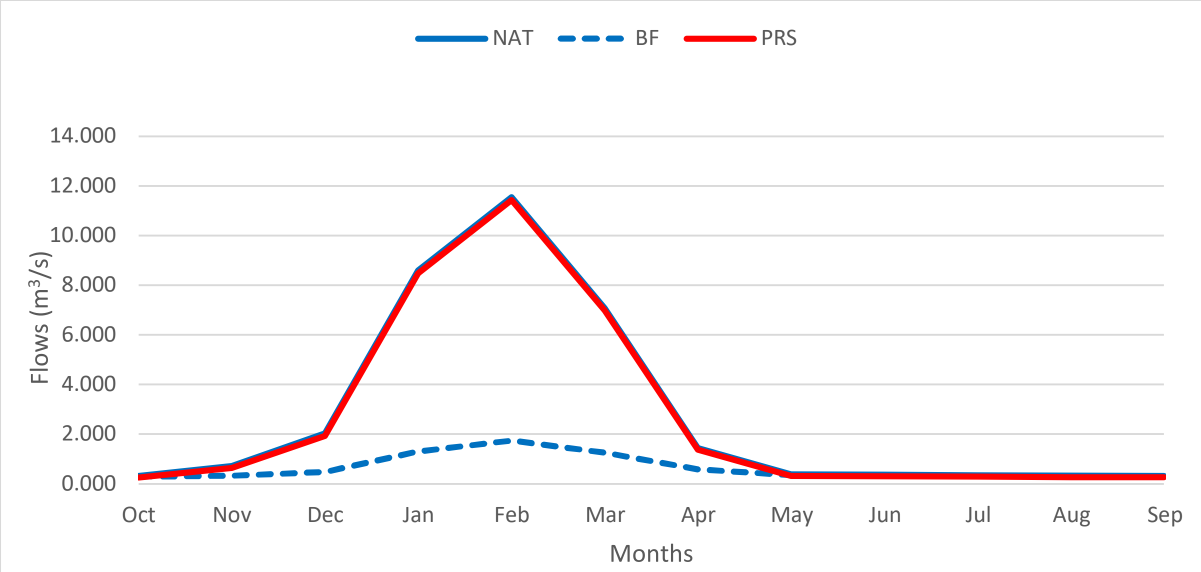

Figure 7-27: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Shingwedzi River (SHIN-B90H-POACH).

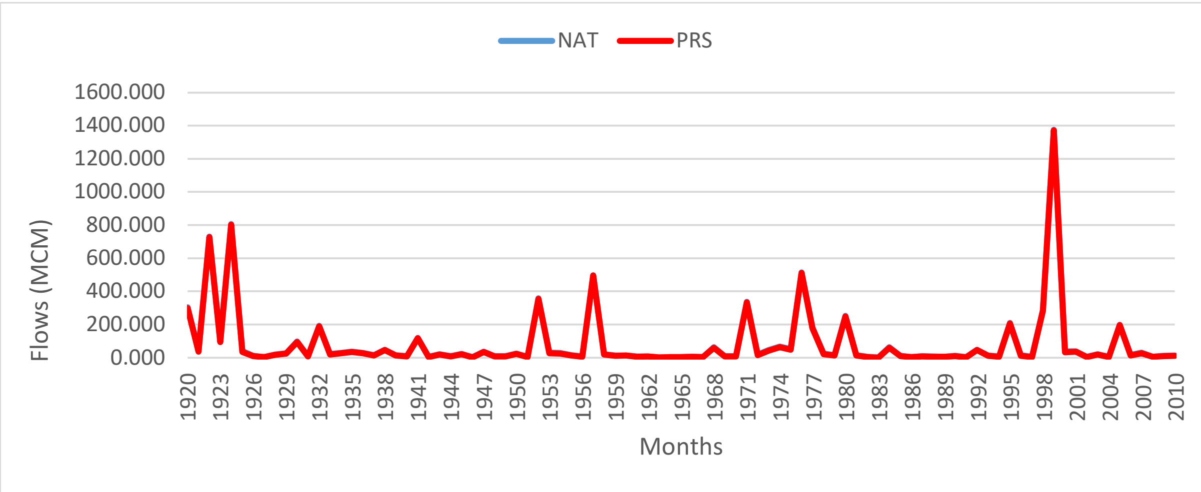

Figure 7-28: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Shingwedzi River (SHIN-B90H-POACH).

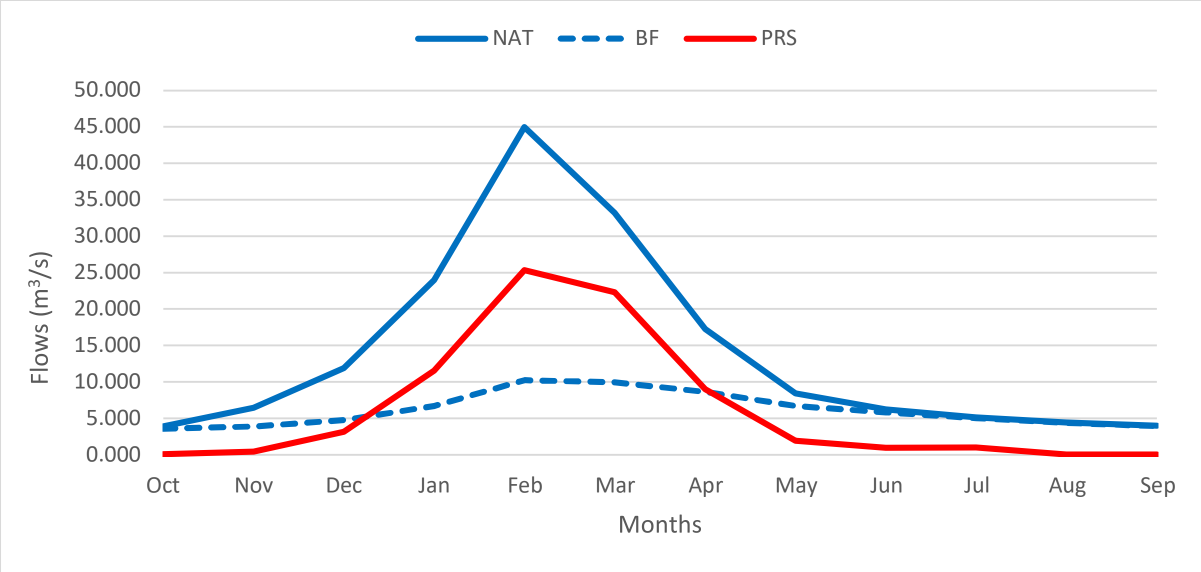

Figure 7-29: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Groot Letaba River GLET-B81J-LRANC).

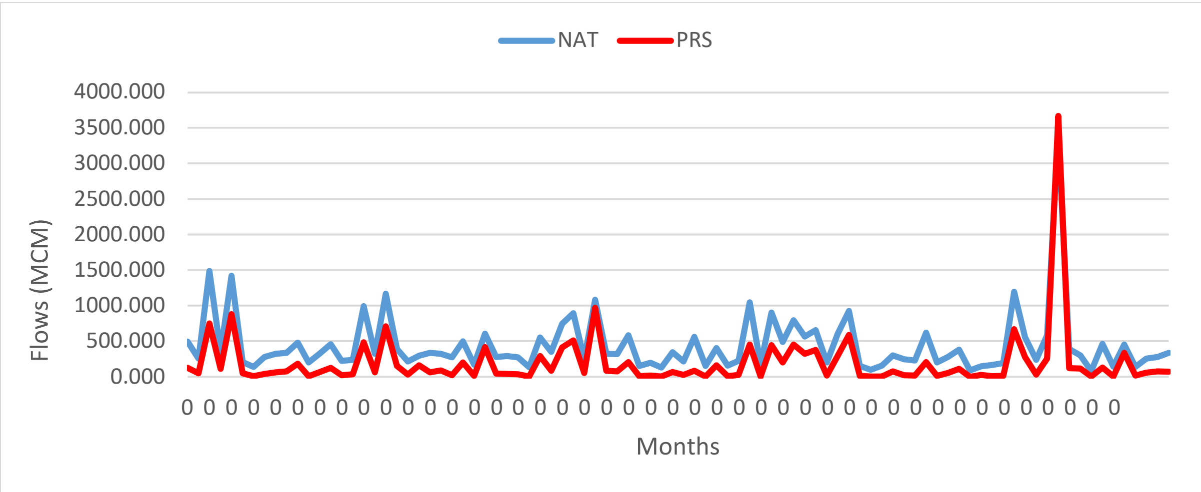

Figure 7-30: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Groot Letaba River GLET-B81J-LRANC).

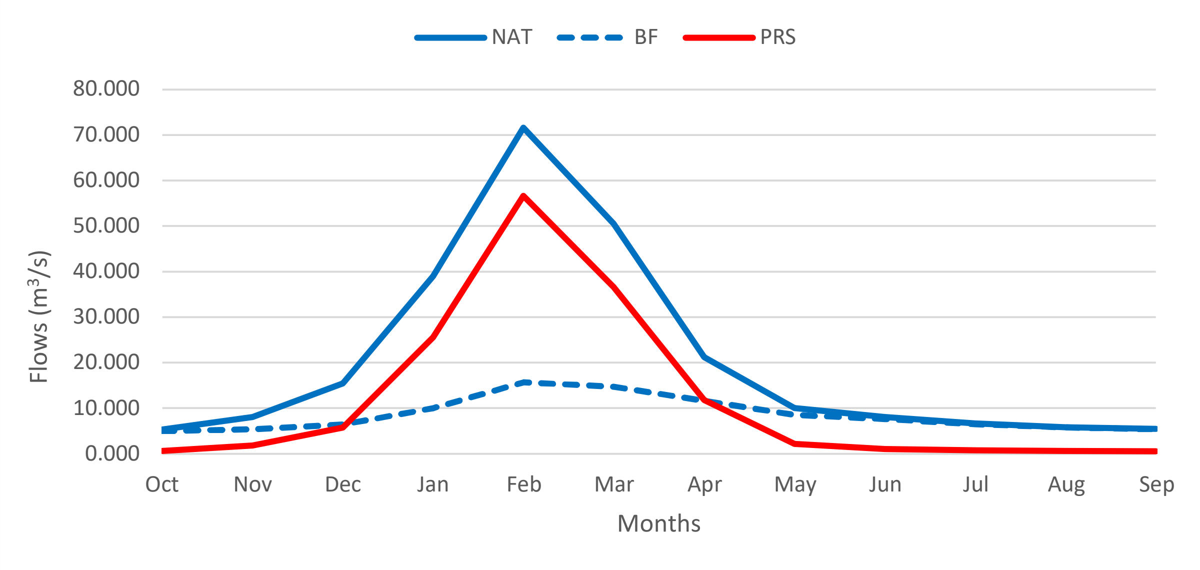

Figure 7-31: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Letaba River (LETA-B83A-LONEB).

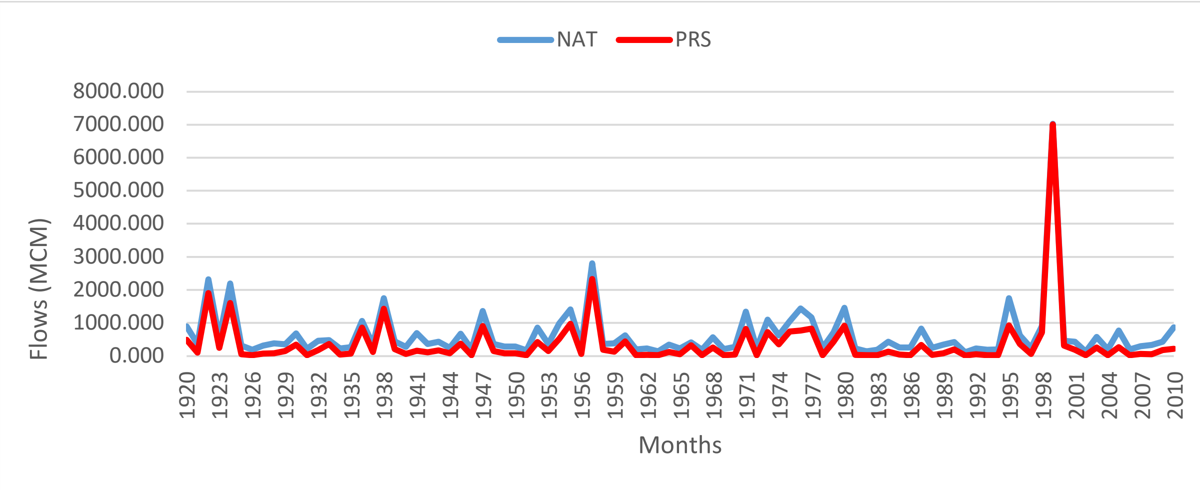

Figure 7-32: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Letaba River (LETA-B83A-LONEB).

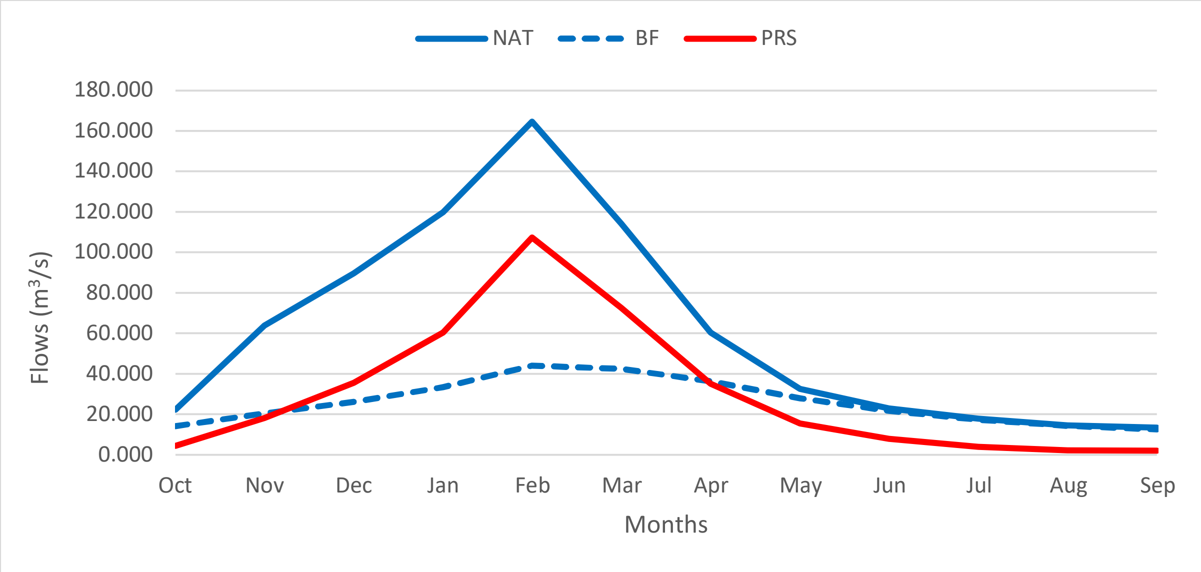

Figure 7-33: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Olifants River (OLIF-B73H-BALUL).

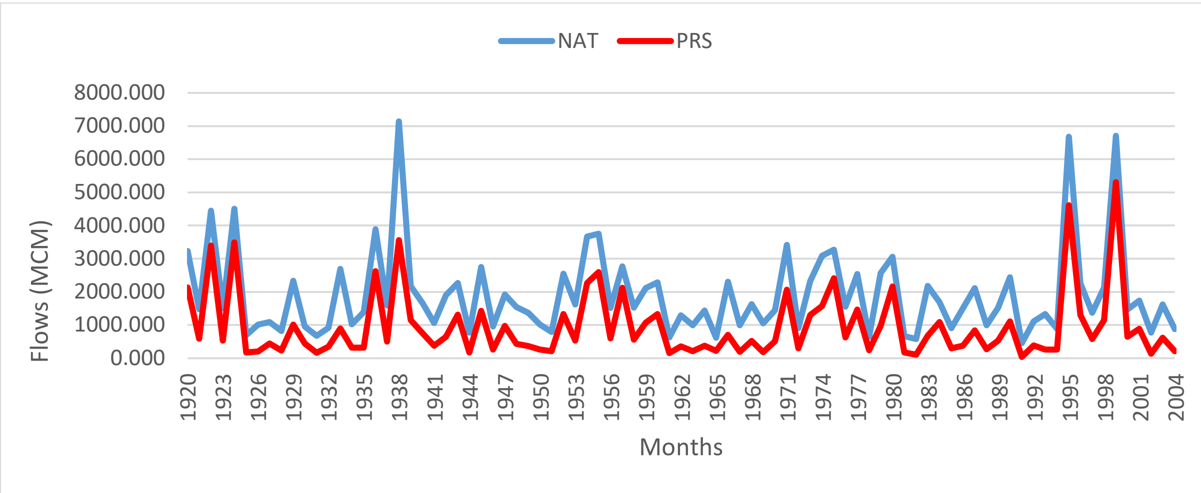

Figure 7-34: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Olifants River (OLIF-B73H-BALUL).

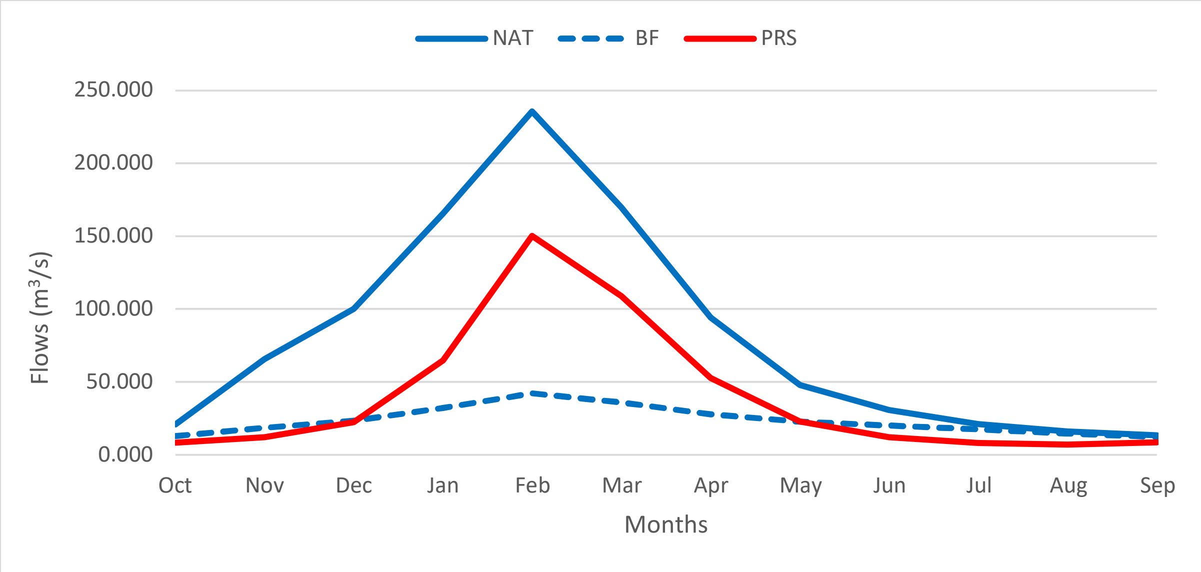

Figure 7-35: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Elephantes River (ELEP-Y30C-SINGU).

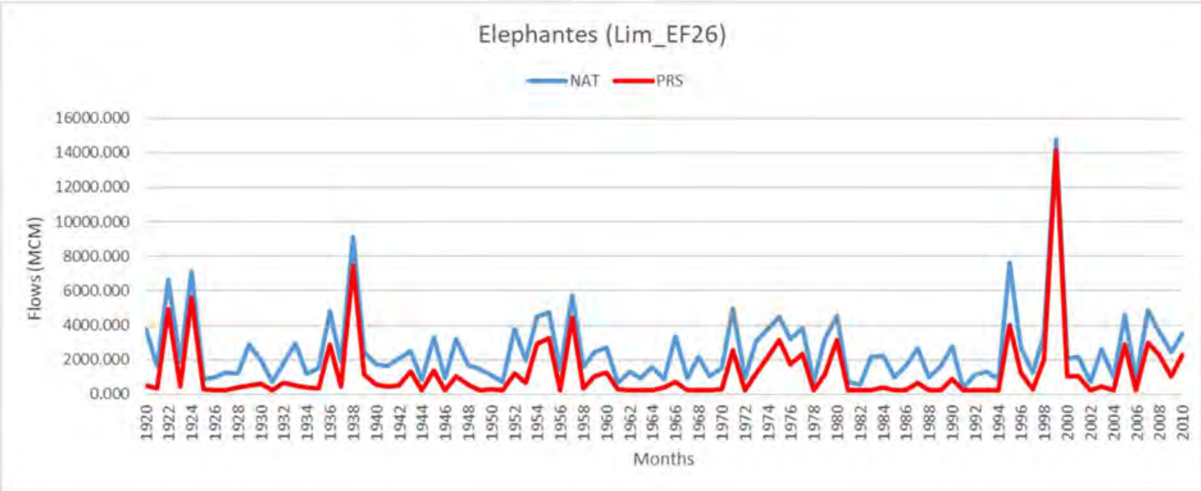

Figure 7-36: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Elephantes River (ELEP-Y30C-SINGU).

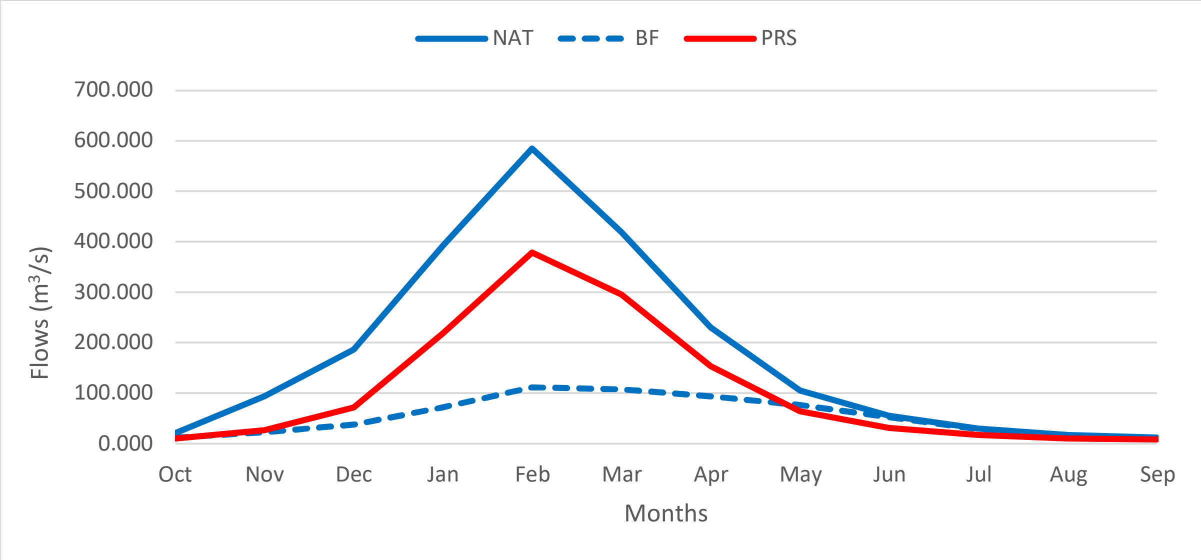

Figure 7-37: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Limpopo River at Chokwe (LIMP-Y30F-CHOKW).

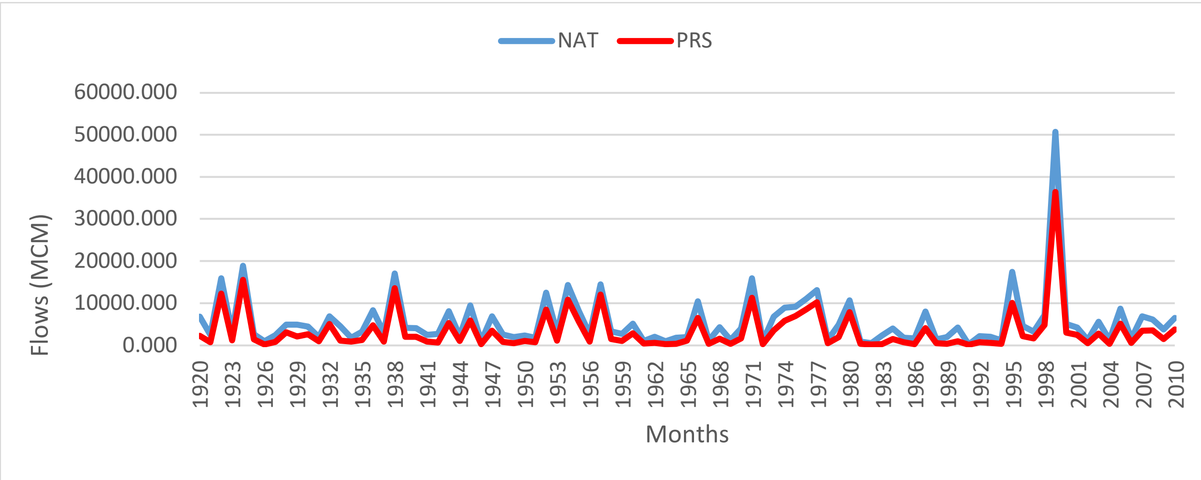

Figure 7-38: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Limpopo River at Chokwe (LIMP-Y30F-CHOKW).

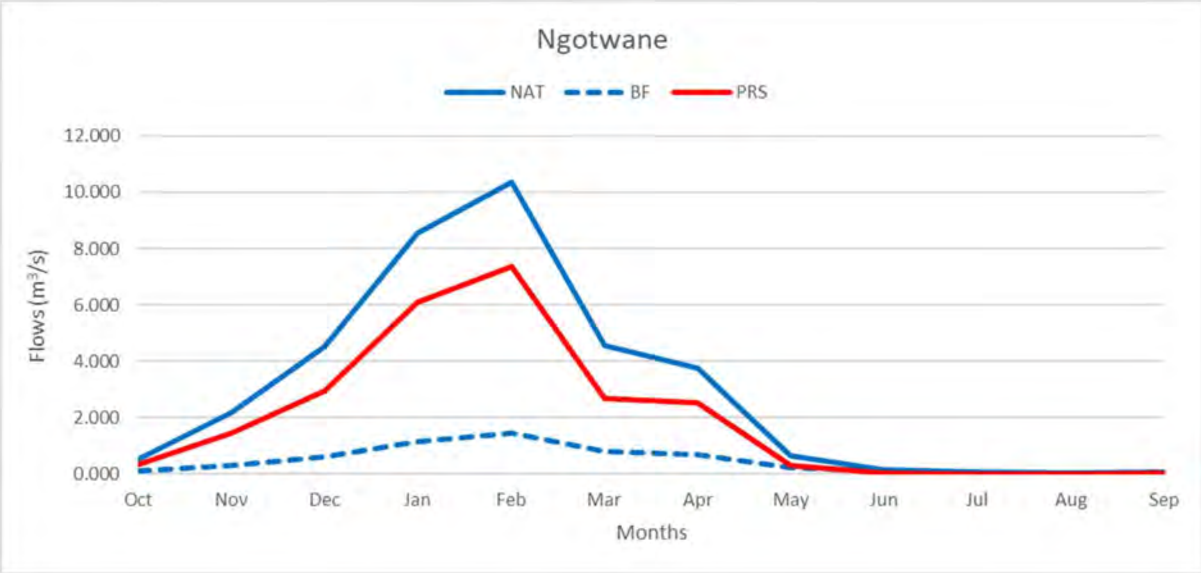

Figure 7-39: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Ngotwane River.

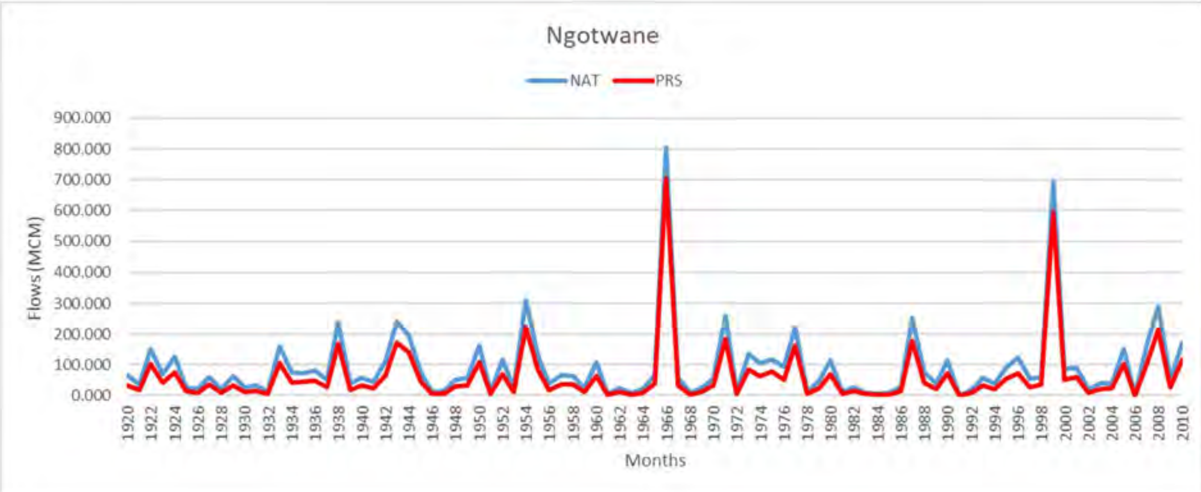

Figure 7-40: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Ngotwane River.

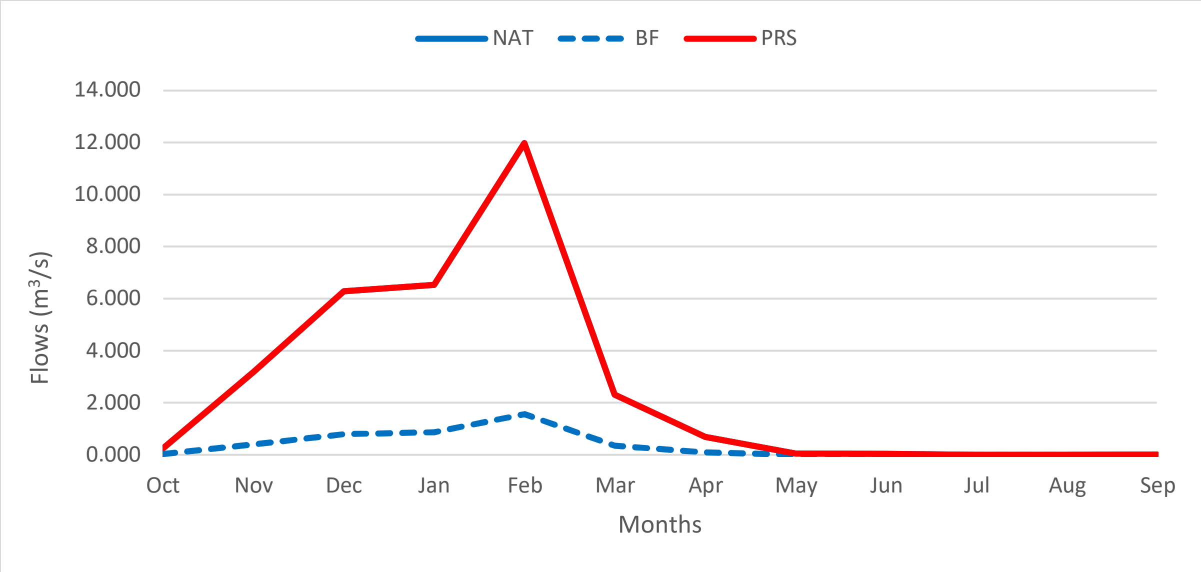

Figure 7-41: Mean monthly hydrology (discharge m³/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Bonwapitse River.

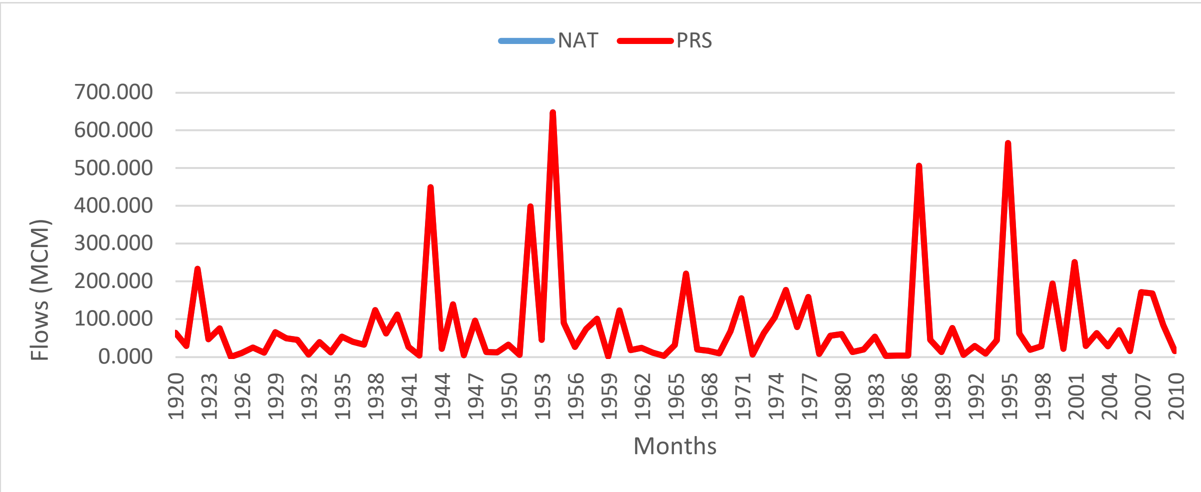

Figure 7-42: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Bonwapitse River.

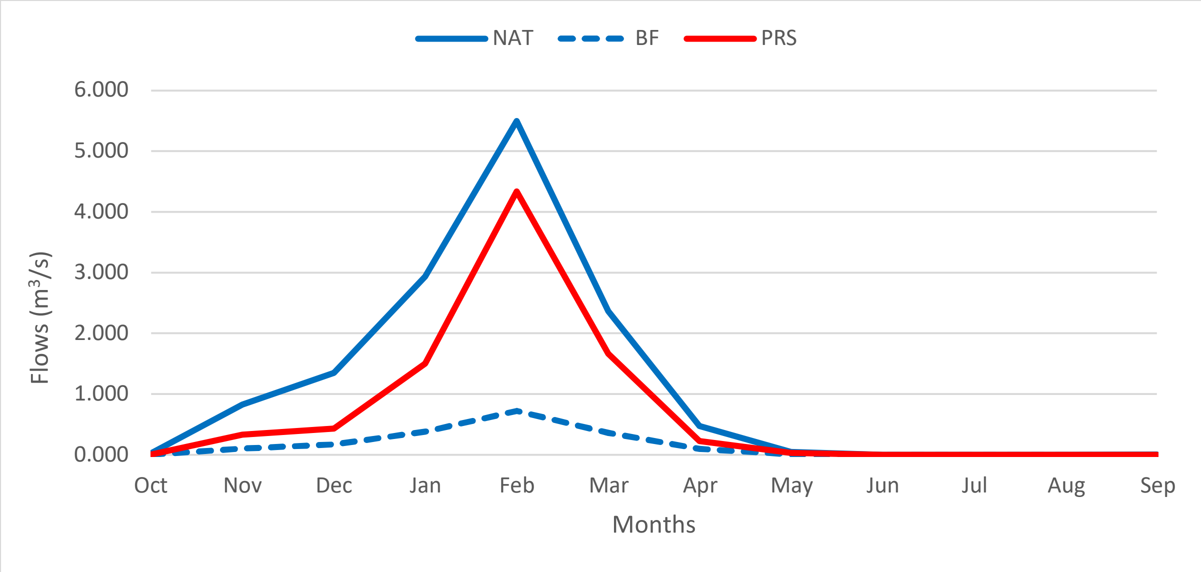

Figure 7-43: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Lostane River.

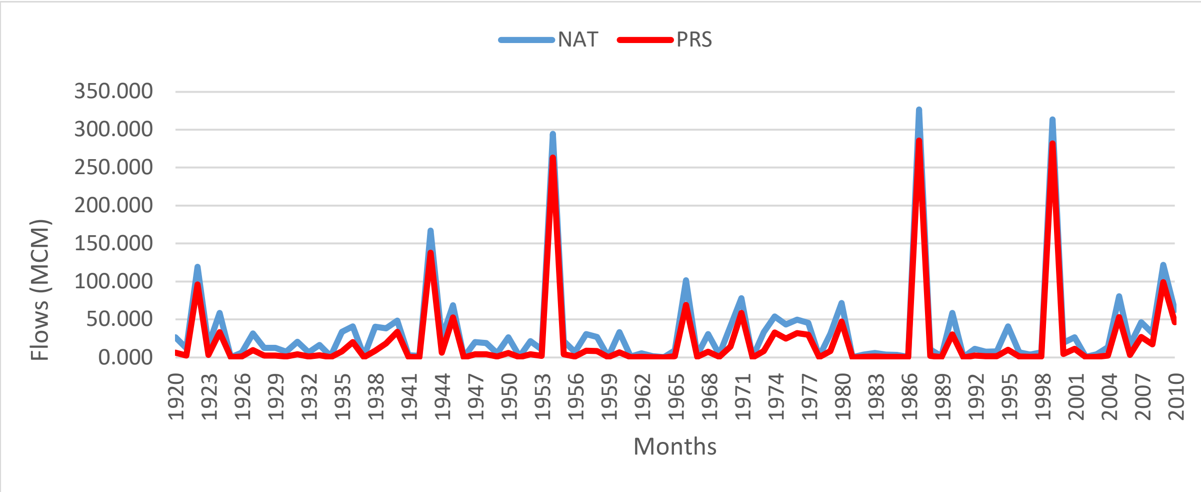

Figure 7-44: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Lostane River.

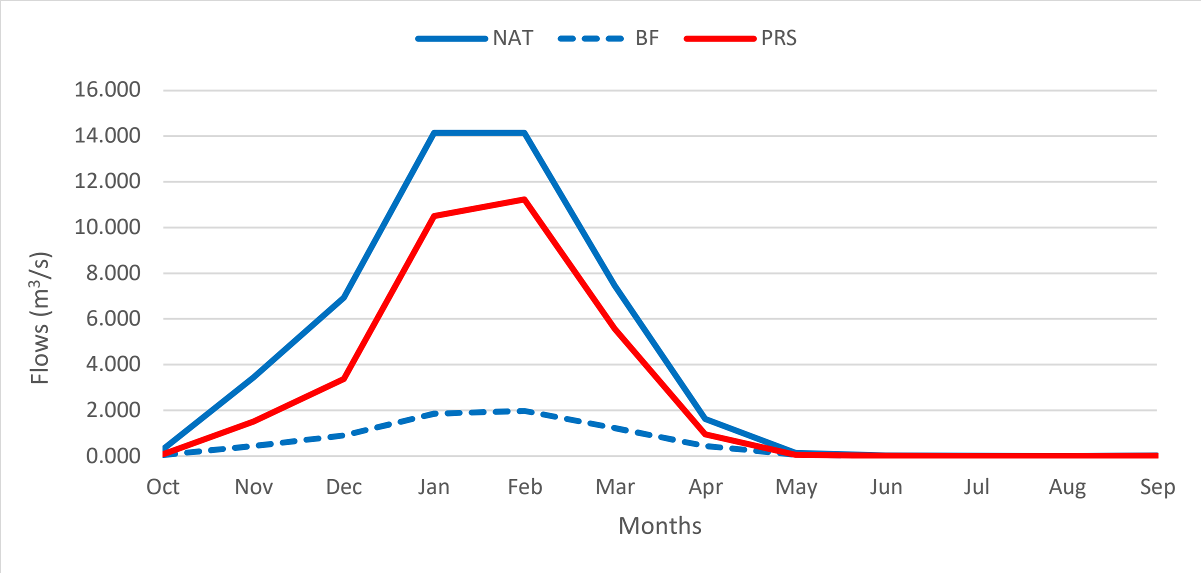

Figure 7-45: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Motloutse River.

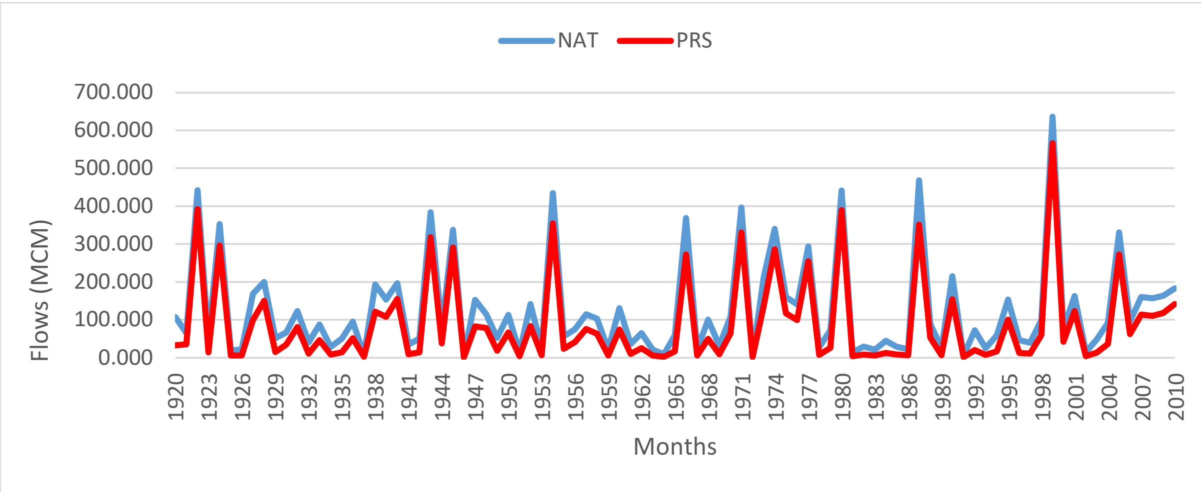

Figure 7-46: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Motloutse River.

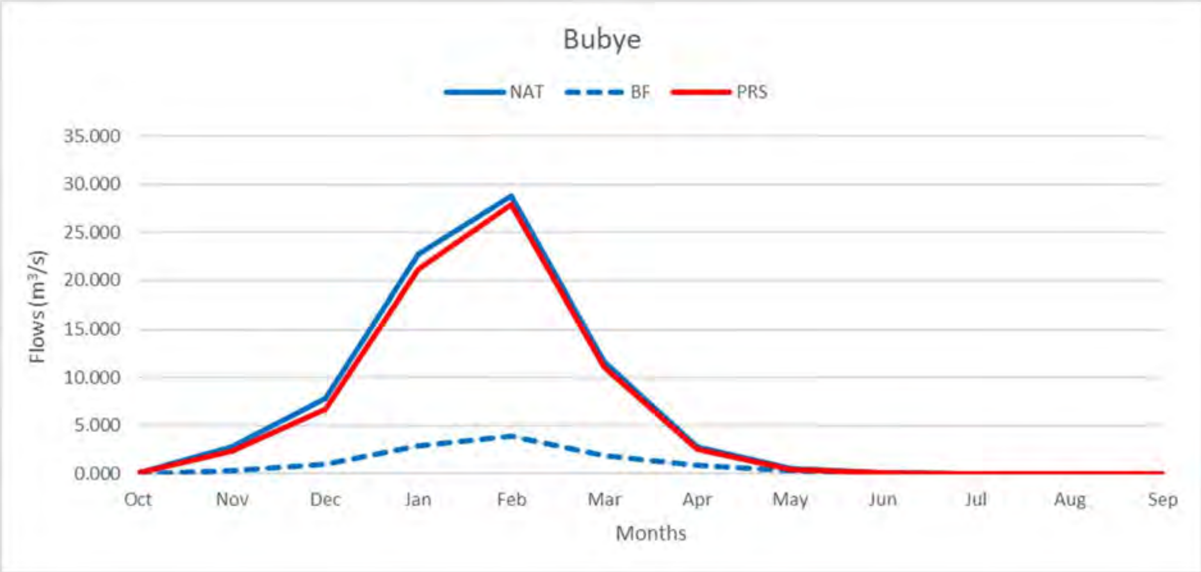

Figure 7-47: Mean monthly hydrology (discharge m^3/s) representing the natural (NAT), present day (PRS) and natural base flow separated (BF) for the Bubye River.

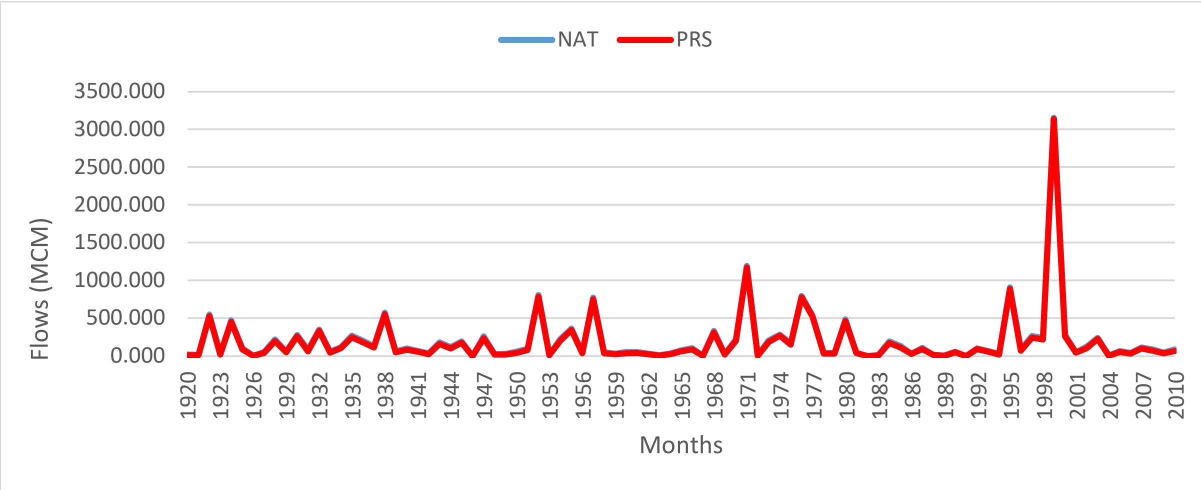

Figure 7-48: Mean monthly hydrology in million cubic meters per annum (MCM) for the flow record from 1920 to 2010 in the Bubye River.

8 APPENDIX C – Groundwater Contribution to E-flows

Groundwater contributions to river flows are especially important in over-utilised, water stressed catchments, and or during the dry and drought seasons, when ground water makes noticeable contributions to river flows. Groundwater can account for more than 90% of the surface river flows of perennial rivers during low flow and drought conditions (Rockström and Gordon, 2001). During the dry periods of seasonal and ephemeral rivers, groundwater also contributes to the maintenance of pools. Groundwater derived surface-flows have social and ecological importance, providing refuge areas for aquatic life and contributing to the overall resilience of the river ecosystems, particularly during low flow periods. In the Limpopo Basin, where many perennial rivers have been changed into seasonal rivers and seasonal rivers have been changed into ephemeral rivers, the groundwater contributions to the resilience of these systems, and their contribution to e-flows are especially important and have been considered in estimation of the e-flow requirements.

The contribution of ground water flows to the e-flow determination process of the Limpopo Basin consisted of two main activities and a series of experiments to validate these components including:

1. Characterization of the contribution of ground water to surface-river flows for all the reaches of rivers considered in the study.
2. Characterization of the presence and stability of isolated pools to evaluate the availability of refuge areas for aquatic biota and ecosystem services particularly in seasonal and ephemeral river reaches of the basin.

Experimentation included constraining the baseflow filter parameter using monitored isotope and chemical data to determine the optimal baseflow filter parameters that could be used to separate baseflow from total stream flow. This included the selection and monitoring of groundwater-surface-water interactions at two indicator locations (Limpopo River at Mapungubwe and Groot Letaba River at the Letaba Ranch) in the Limpopo Basin.

In addition, *routine* groundwater quality sampling and analysis (chemical and Isotope sampling for the Limpopo River (Mapungubwe site) and Letaba River (Letaba Ranch site)) and *once-off* random, basin-wide analysis of groundwater quality samples obtained at the e-flow sites was done. These data were used to characterise the potential threat of groundwater derived water quality stressors on surface flows during the dry season.

Detailed information is available in Report 4: Specialist Data and Literature Review as well as Report 5: Present Ecological State of the Limpopo River: Drivers of Ecosystem Change.

8.1.1 Conceptual model for groundwater contribution to E-flows

The contribution/s that groundwater resources make to the surface-water flows and the associated resilience of surface-water resources because of the groundwater contributions, have been evaluated and integrated into the assessment of e-flows for the Limpopo River. Initially, the probable interactions between ground and surface-water flows were hypothesized in conceptual models. This needed to be an evidence driven process and depended on historical data/literature and data derived from the study (Report 4, Specialist Literature and Data Review). The conceptual models are important for understanding the groundwater contribution to setting e-flows and include the hydrological process from groundwater recharge and depletion. The conceptual model showing the probable groundwater contribution to e-flow is shown in **Error! Reference source not found.**. This conceptual model demonstrates the relationship between groundwater recharge and abstraction and illustrates that groundwater levels subsequently have the potential to contribute to base river flows and e-flows and also support isolated pools within the rivers, thus expanding the resilience of the river to reduced flows.

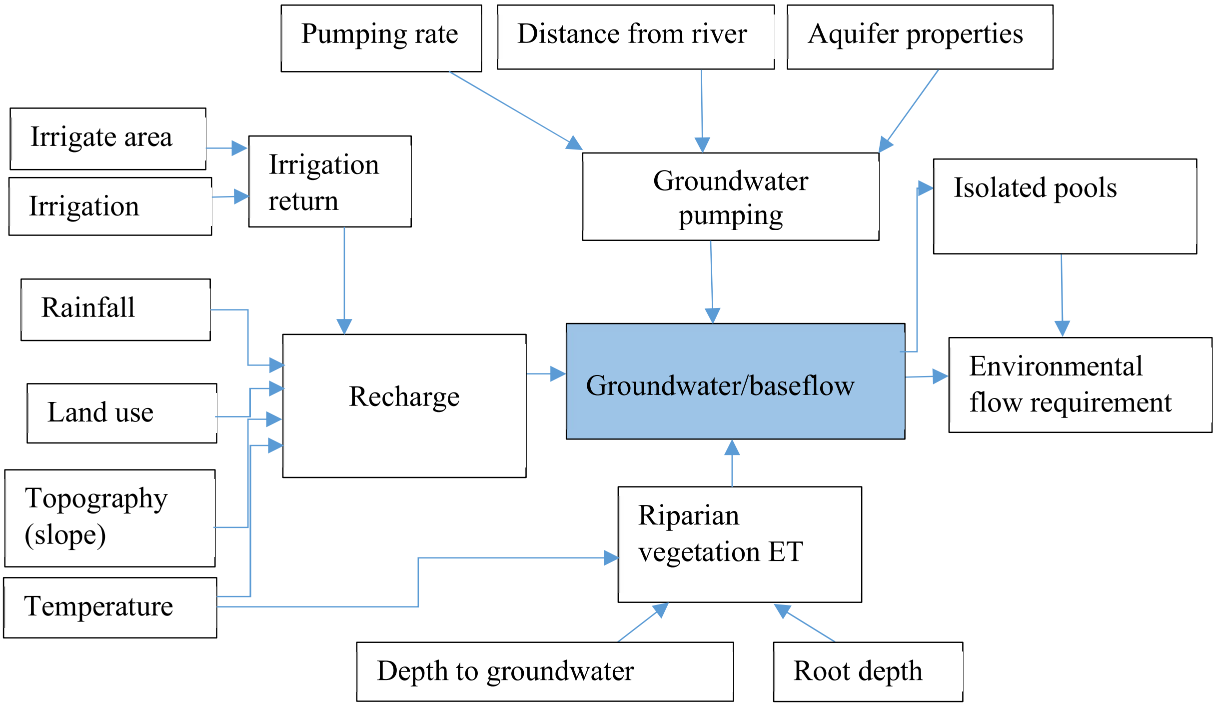

Figure 8-1: Preliminary cause and effect relationship of groundwater on e-flows

This groundwater focused conceptual model was integrated into the formal e-flows model and Bayesian Network used to determine e-flows for the Limpopo River. The overall e-flow determination conceptual model (**Error! Reference source not found.**) demonstrates how the groundwater base flow contributions have been integrated into base-low and drought flow contributions that affect all ecosystem service endpoints considered. Specific contributions of groundwater to social and ecological variables considered in the study include contributions to; the (a) velocity-depth habitat characteristic nodes, (2) riparian habitat for vegetation, (3) water input flows, (4) dilution/flushing flows, and (5-7) instream habitat characteristics for supporting services ecosystem variables *viz.* fish, invertebrates and riparian vegetation. The presence of and condition of groundwater pools that may contribute to resource resilience and affect e-flow estimates have been included in the conditional probability tables of supporting service variables (instream habitat availability nodes) in risk regions where pools are present. The groundwater contributions have also been included in the conditional probability tables of the habitat change node in the resource resilience endpoint. Finally, knowledge of how water abstractions are made from ground water ecosystems to increase resilience of human communities and the maintenance of water for domestic use endpoint was also considered.

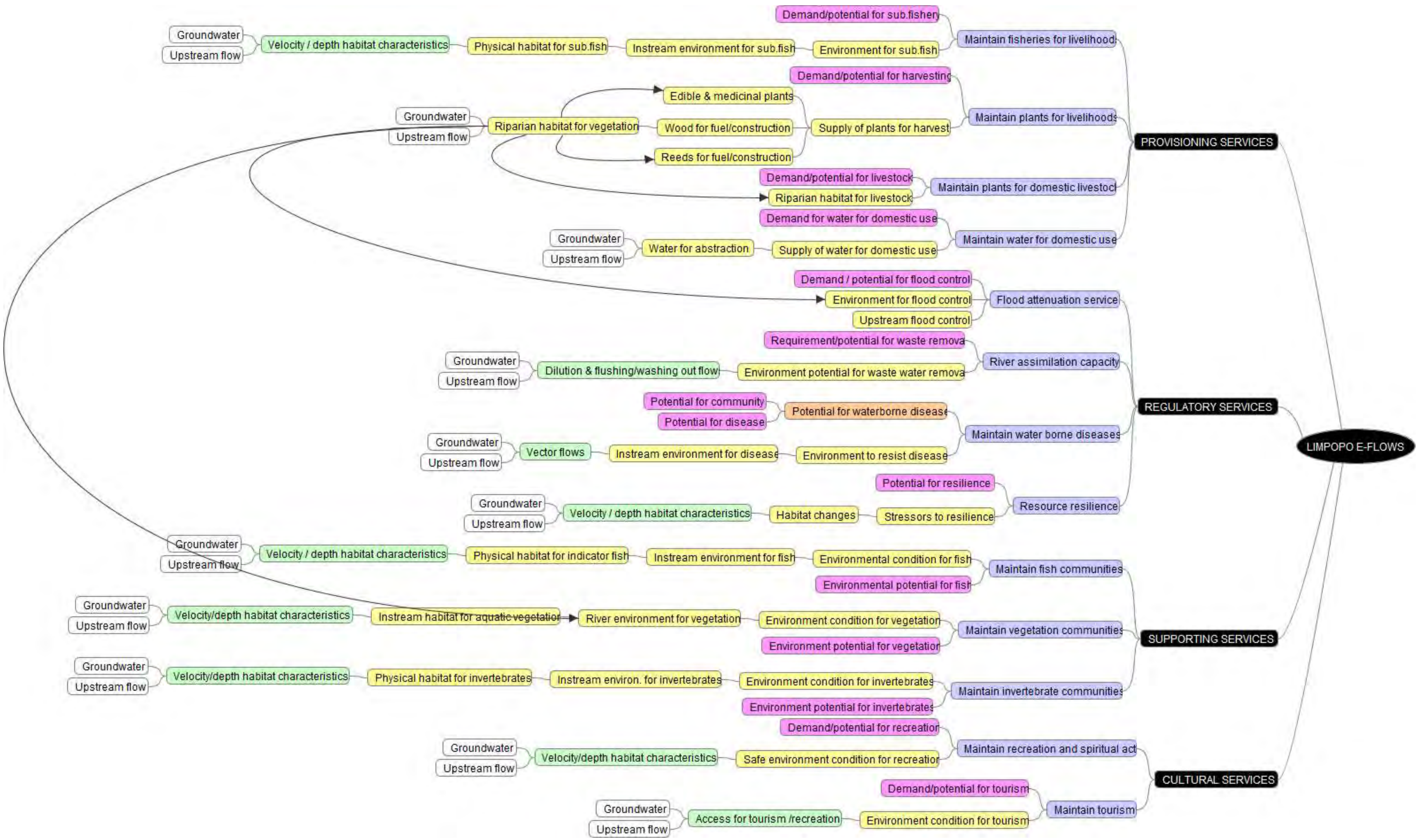

Figure 8-2: Simplified conceptual model for the socio-ecological systems considered in the Limpopo e-flow determination study with groundwater contributions to hydrology highlighted.

In addition to the contributions of groundwater to base low-flow hydrology, the availability of pools within the study area was used to evaluate the probability of instream habitat availability and the resilience of the ecosystem for supporting services ecosystem variables including fish, macroinvertebrates, and riparian vegetation. Here the conditional probability table response curves representing the velocity-depth flow-derived probable response of fish (as an example) to instream habitat availability are represented in **Error! Reference source not found.**A when instream pools are not considered and **Error! Reference source not found.**B when instream pools are considered. The two graphs indicate an increased probability of high risk (light blue shaded area) to instream habitat availability occurring at low discharges or drought conditions when the instream pools are <u>not</u> considered (**Error! Reference source not found.**A) compared to when they are (**Error! Reference source not found.**B). Arrows are included to demonstrate that in areas where pools are available maintenance critical flows of 0.8m^3/s probably provide the service required by 1.8m^3/s in the same reach if instream pools are not available.

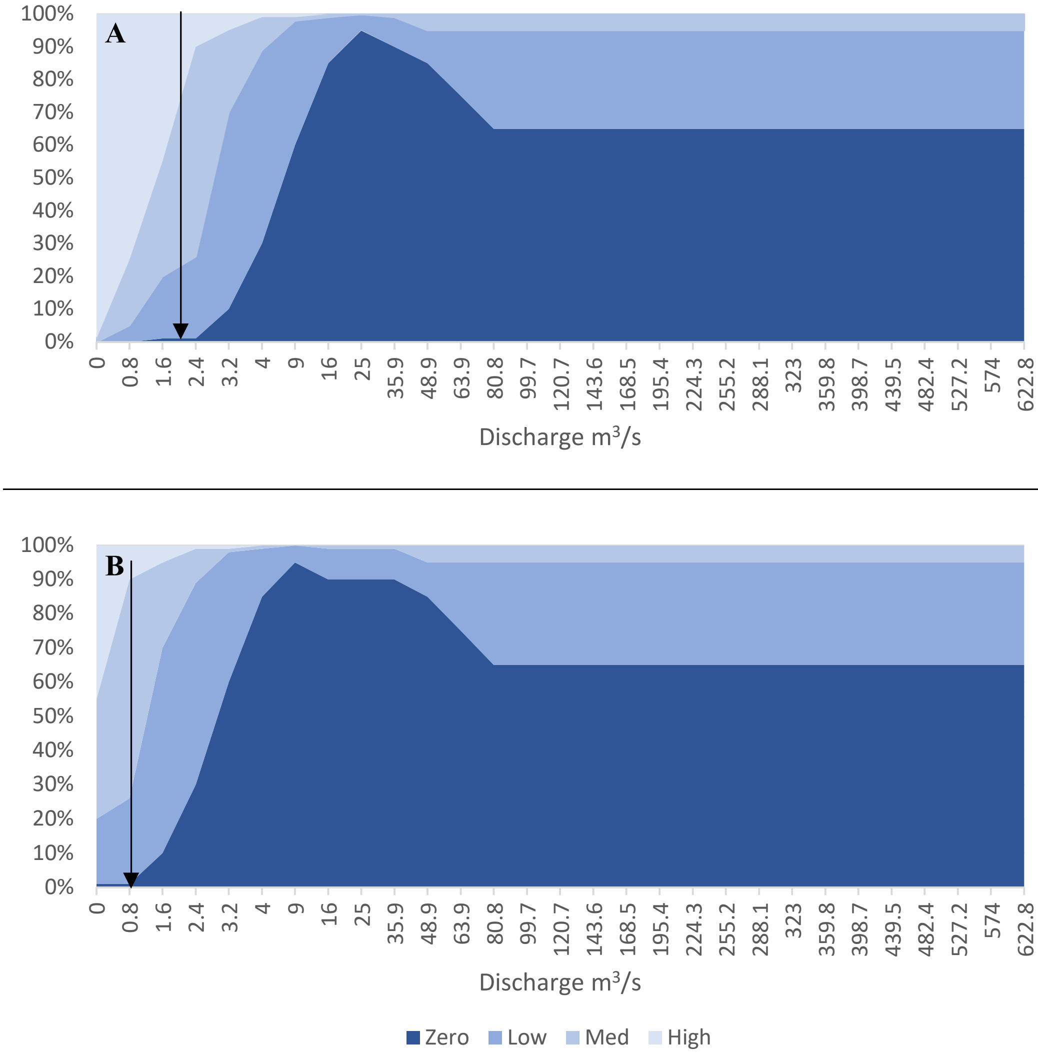

Figure 8-3: Conditional probability table response curves for velocity-depth habitat availability to demonstrate how the resilience of the ecosystem has been included to represent the availability of instream pools within a risk region. The top graph (A) represents the velocity-depth flow-derived probable response of fish to instream habitat availability without consideration of instream pools (Site CROC-A24J-ROOIB). The bottom graph (B) includes a shift of risk ranks towards lower discharge to account for the evidence of pools available.

8.1.2 Evidence for the groundwater contribution

Assessment of the contribution of groundwater to surface-water hydrology considered isotopic and chemical hydrograph separation techniques (eg. Sklash and Farvolden 1979), while the ecosystem resilience pertaining to the presence of instream pools was determined using historical satellite imagery, recognition software and spatial analysis tools (as per Kalbus et al., 2006).

Isotopic and chemical hydrograph separation techniques

The groundwater and river-water sampling occurred during the recession of high flows in early May 2021. Chemical analyses of the water samples were performed at the North West University, Potchefstroom, South Africa. The following anions and cations water quality parameters were selected for analysis: Total dissolved solids (TDS), salinity, silica (SiO_2), chloride (Cl^-) (can be used for recharge estimations), sulphate ($SO^{2-}{}_4$), alkalinity ($CO^{2-}{}_3$; $HCO^-{}_3$), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+) (O'Brien et al., 2022a). Stable isotope analyses (oxygen-18 and deuterium (^2H)) of the water samples were performed using Thermo Delta V mass spectrometer connected to a Gasbench at Environmental Isotope Group (EIG) at iThemba Laboratories in Johannesburg, South Africa. A piper diagram was constructed to identify chemical relationships among water samples from different sources and to reveal the similarities, dissimilarities, and different types of water and the origin of water in the study area (**Error! Reference source not found.**). The main objective of this work was to identify the source of water for isolated pools in non-perennial /ephemeral rivers based on the premise that surface and groundwater display different isotopic and chemical signatures. Two sites were selected for monitoring (Letaba catchment representing perennial rivers and the Shashe-Limpopo confluence at Mapungubwe, representing non-perennial rivers characterized by isolated pools of water). A detailed description of these two sites can be found in the specialist Report No.4 (Dickens et al., 2021).

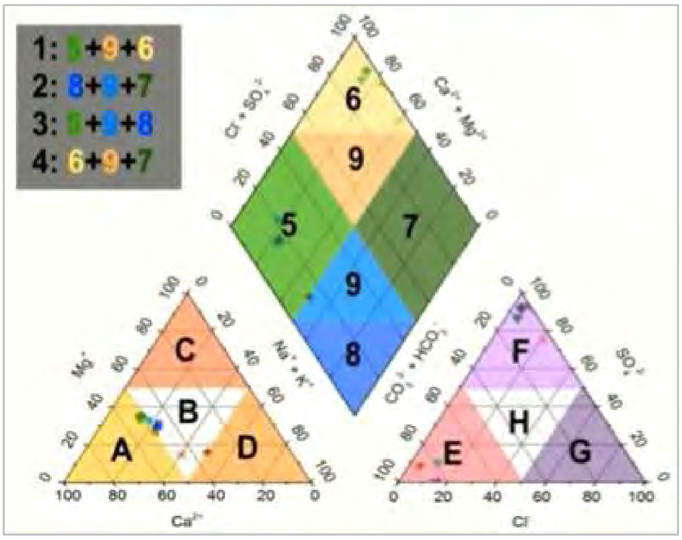

Figure 8-4: Piper diagram showing different water types (Sadashivaiah et al., 2008)

The surface-water team focused on the basin-wide water sample collection from both surface river flow and boreholes near the river, while the groundwater team collected surface-water and borehole water from Letaba and Mapungubwe sites. The surface-water team also collected basin-wide samples for the analysis of stable isotopes by the groundwater team.

The water samples collected throughout the Limpopo River Basin were used to analyse the proportion of groundwater in the surface-water for gaining rivers (perennial) and for losing sections of the rivers (ephemeral). The separation of the proportion of groundwater and surface-water assumed that groundwater and surface-water have different signatures. These signatures were used to assess the proportion of groundwater in surface-water flows and were assessed using chemical and isotope analysis of surface-water flow and groundwater near the rivers.

The groundwater type in the Letaba catchment during the recession of high flows was mixed Ca-Na-HCO_3 type (temporary hard water) and Na-CI type (saline water), while surface-water was Ca-HCO_3 type (**Error! Reference source not found.**). Water type evaluation is extremely useful in providing a preliminary idea about the complex hydrochemical processes in the subsurface. The saline water is likely coming from a shale geological formation with concentration of NaCI by evaporation. The data shows that there is a strong interaction between surface and groundwater and confirmed that the river baseflow evolved primarily from groundwater (O'Brien et al., 2022a).

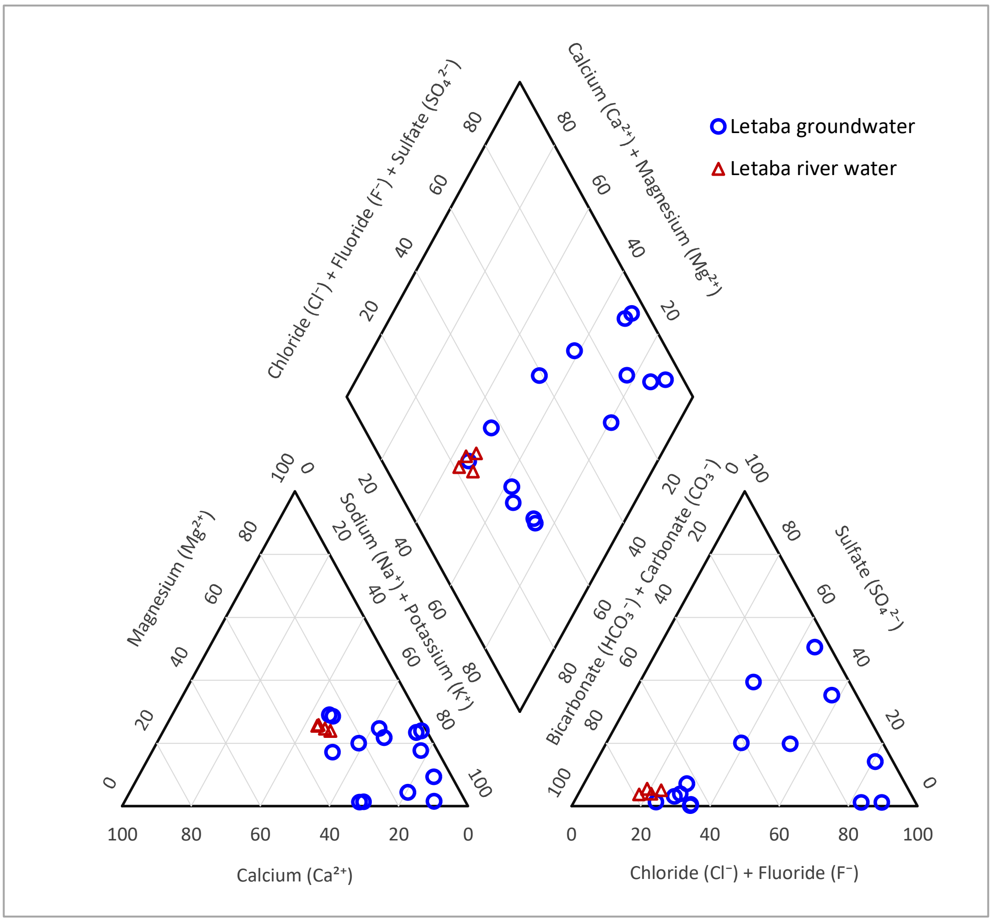

Figure 8-5: The Piper diagram for groundwater and river-water for Letaba sites

Groundwater in Mapungubwe during the same period was classified as Ca-HCO_3 type (shallow fresh groundwater, with temporary hardness) and mixed Ca-Na-HCO_3 type, while the surface-water was Ca-HCO_3 type (**Error! Reference source not found.**). The minority of groundwater samples (2) demonstrated Na-CI type (saline) and mixed Ca-Mg-CI type. At both sites, surface-water (Ca-HCO_3 type) and groundwater (Ca-HCO_3 type, mixed Ca-Na-HCO_3 type and Na-CI type) was similar. It is suggested that the chemistry of the groundwater was controlled by a mixing process and cation exchange process. Similar to the Letaba site, the chemical and isotope results indicate a strong interaction between surface and groundwater in the isolated pools and confirms that surface-water evolved from groundwater (O'Brien et al., 2022a).

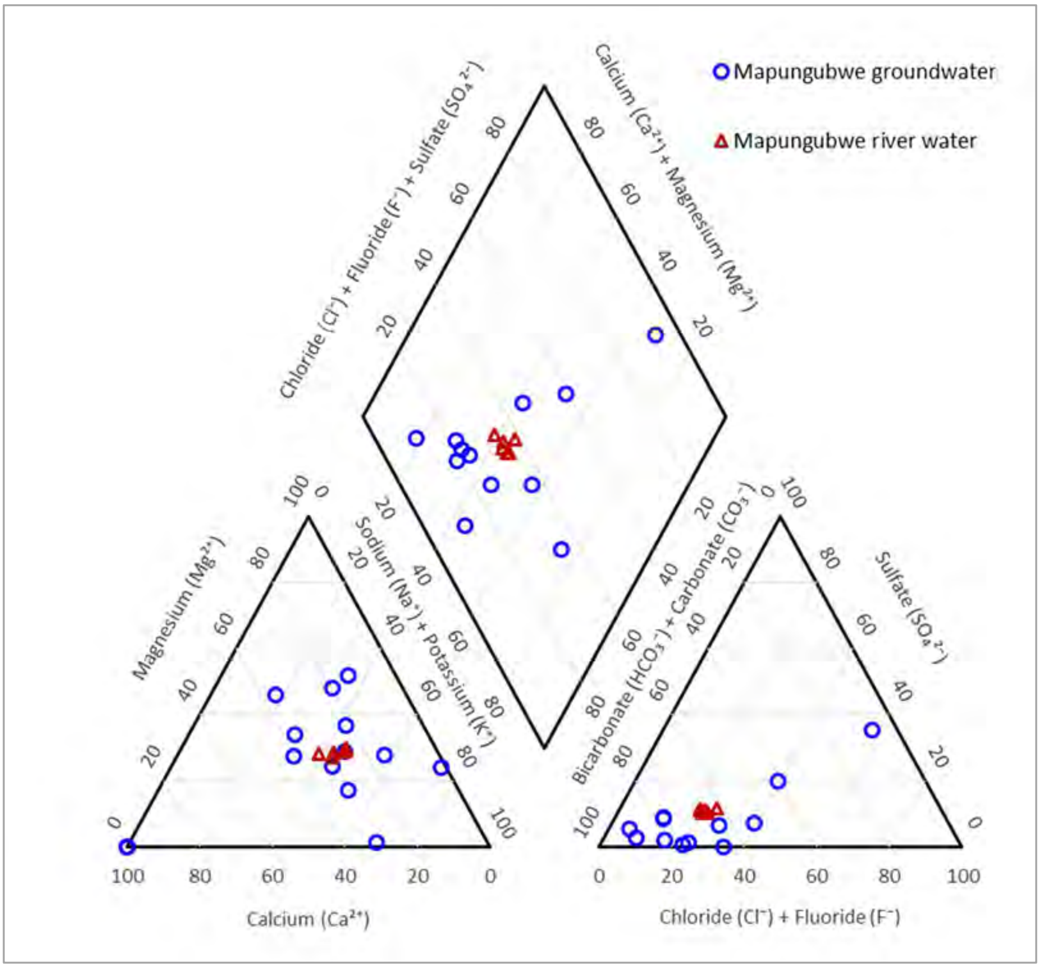

Figure 8-6: The Piper diagram for groundwater and river water for mapungubwe sites

Baseflow separation is a process to determine the amount of groundwater that makes up surface-water flows. For baseflow separation, two components are commonly determined that include (1) pre-event water (old water), consisting of unsaturated-zone water and groundwater and (2) event water (new water), consisting of surface runoff and lateral stormflow. In this study, old water was taken as groundwater, while event water was taken as rainfall. Water moving along different pathways picks up different minerals, organic matter and nutrients, depending on the characteristics of the geological pathway and the water residence time. Therefore, different parts of a catchment and selected components can contribute to different quality signatures (fingerprints). An isotopic signature is a ratio of non-radiogenic 'stable isotopes', stable radiogenic isotopes, or unstable radioactive isotopes of particular elements in sampled water (Kumar, 2013). The oxygen-18 and deuterium (^2H) analysis was used to assess groundwater and surface-water interaction (O'Brien et al., 2022a).

The isotope water characterization was based on plots of $\delta^{18}O$ vs. δ^2H from rainfall, river water and groundwater collected from boreholes, which were compared to the Local Meteoric Water Line (LMWL), which takes into account local climate variations by bivariate plot. However, in the absence of local isotopic precipitation data in this study area, a Global Meteoric Water Line, Pretoria Meteoric Water Line and Taaiboschgroet (Limpopo) Meteoric Water Line (O'Brien et al., 2022a) were used for comparison (**Error! Reference source not found.** and **Error! Reference source not found.**). Local climatic conditions affect the LMWL; hence, comparing the different water samples with the LMWL gives an understanding on the water sources and their isotopic fractionation for regional hydrology investigation. Similar isotopic signatures of the groundwater and surface-water or isolated pools along the river was observed, further indicating the groundwater contributions to river flow during dry and wet periods. This confirms that the source of water in isolated pools during the dry season is groundwater. Using the two component baseflow separation method, the proportion of groundwater to total river flow from isotope baseflow separation ranged from 0.19 (Mapungubwe, drier climate than Letaba) to 0.41 (Letaba). These proportions were used to constrain the baseflow filter parameters of baseflow separation method used in the study.

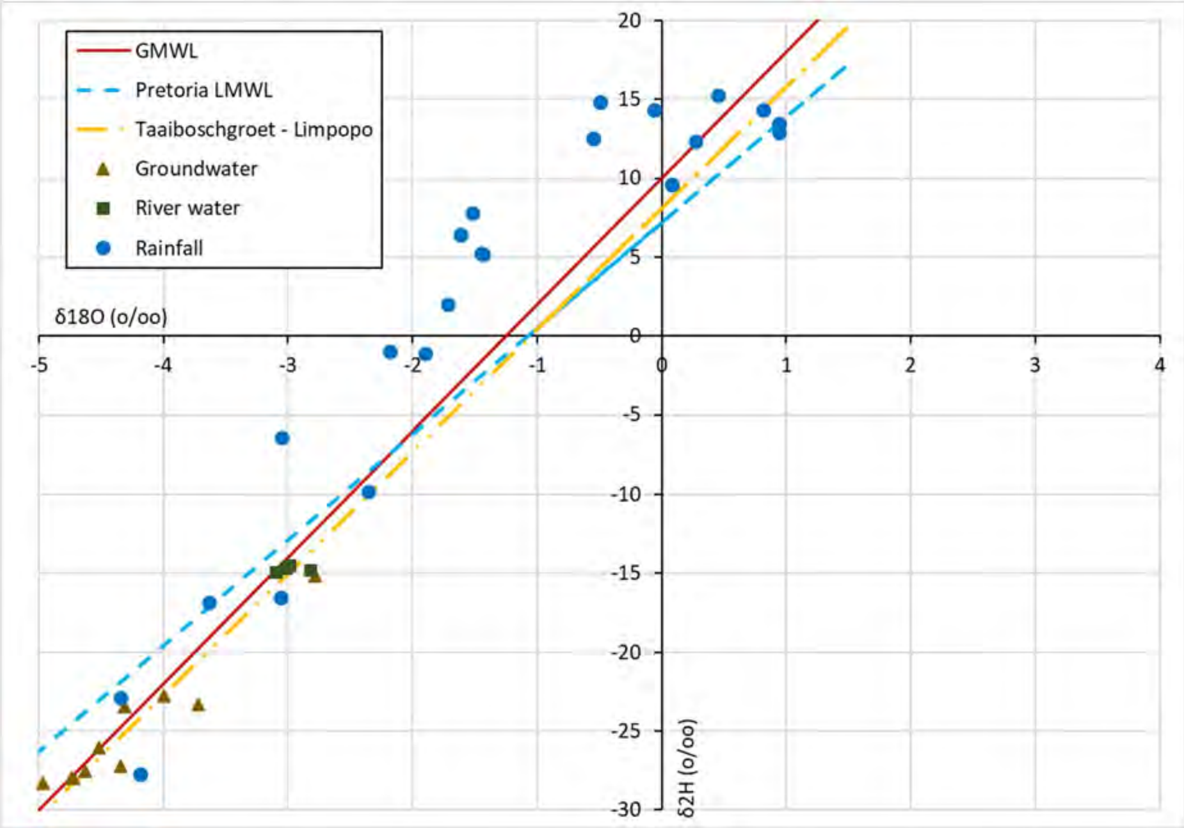

Figure 8-7: The variation of $\delta^{18}O$ and $\delta^{2}H$ for rainfall (2016-2018), river (2021), and groundwater (2021) for Letaba site.

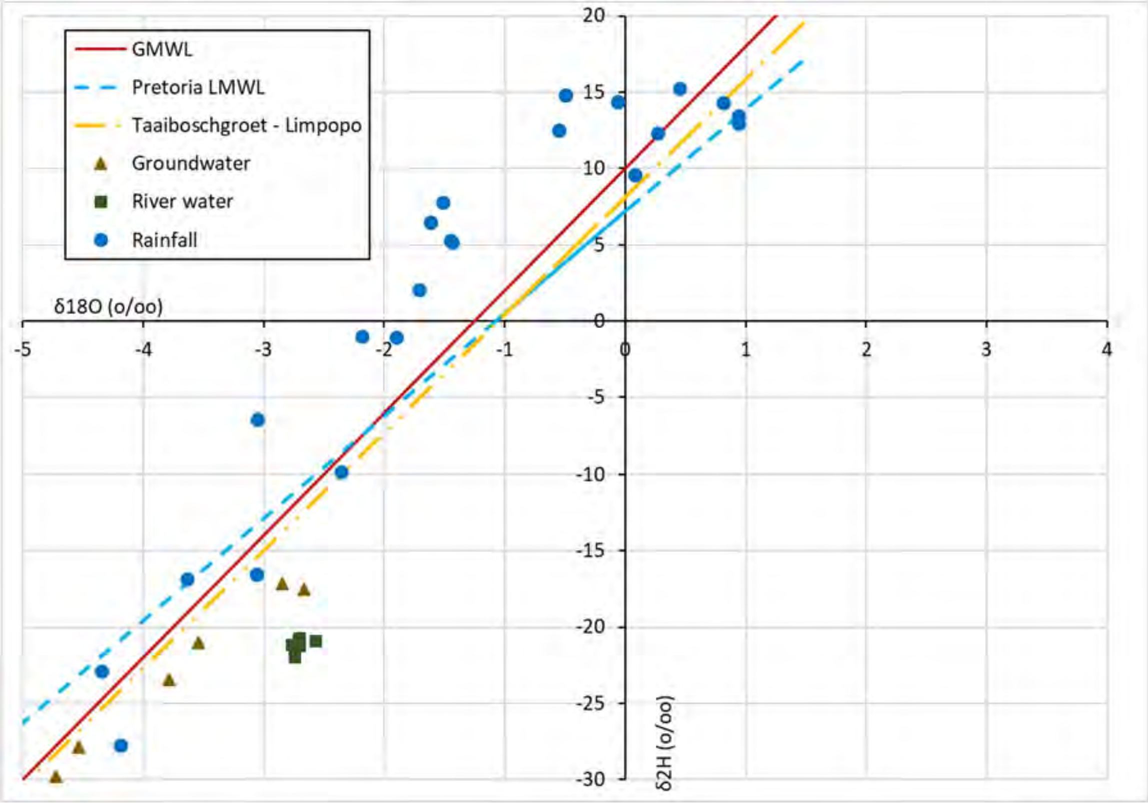

Figure 8-8: The variation of $\delta^{18}O$ and $\delta^{2}H$ for rainfall (2016-2018), river (2021), and groundwater (2021) for Mapungubwe.

8.1.3 Constraining baseflow filter parameter

The recursive digital filter method of Nathan and McMahon (1990) is the most widely used method for baseflow separation using daily streamflow data. However, this type of baseflow separation is not based on any real knowledge of the hydrological processes. Furthermore, the actual measurements of baseflow are difficult and were not available. Therefore, a separate evaluation of the filtering technique against hydro-chemical and isotopic methods were carried out to increase the validity of the results as well as the e-flow assessment. The constraining of baseflow filter parameters alpha and beta were carried out using stable isotope tracers (2H and 18O) collected from the Letaba and Mapungubwe sites (O'Brien et al., 2022a). **Error! Reference source not found.** (O'Brien et al., 2022a) presents the baseflow filter parameter used by the hydrology team (referred to here as Stassen (2021)) and the Isotope approach for three river flow gauging stations. It is clear that the filter parameters and the baseflow index varied from site to site. On average, the alpha and beta values estimated using the isotope approach were 0.43 and 0.96, respectively. The alpha and beta values used by the surface-water hydrology team for all risk regions were 0.44 and 0.97 respectively. Given that the hydrology team used naturalized flow for baseflow separation as opposed to the measured flow used for the isotope approach the difference in alpha and beta values used by the hydrology team and the isotopic approach were comparable. In conclusion, the filter parameters used by the hydrology team were in agreement with that found using the isotopic approach. The river flow regime classification of rivers in the basin could be used for upscaling filter parameters from the two sites to similar sites in the basin.

One of the limitations of the current approach of constraining baseflow index (BFI) based on isotope baseflow separation was that the sampling was done during the wet period and should have been done in the dry season as well to understand the changes of BFI with seasons.

Table 8-1: Comparison of alpha and beta parameters for BFI from recursive digital filter and baseflow isotope separation

Catchment ID	River gauge ID	BFI by Stassen (2021)			BFI from isotope separation			BFI difference (%) between isotope and Stassen (2021)
		Alpha	Beta	BFI	Alpha	Beta	BFI	
B81D	B8H010	0.44	0.97	0.422	0.420	0.919	0.38	-11
Outlet of Letaba	B8H018	0.44	0.97	0.327	0.417	0.941	0.41	20
Mapungubwe	A7H008	0.44	0.97	0.221	0.446	0.977	0.19	-16

BFI is the baseflow index

8.1.4 Isolated pool characterization

The spatial frequency of water occurrence map for the period January 2016 - June 2021 for the Limpopo River Basin was purchased from South Africa National Space Agency (SANSA). The water frequency map shows the number of times a given grid cell on the satellite image contained water. The total number of months for the data period January 2016- June 2021 was 66. For example, if a given cell was coded as 37, it means that water was detected and mapped in that cell in 37 months out of 66. We made a comparative analysis of isolated pool mapping using Sentinel -2 and SANSA datasets for the dry season (August 2020), see Figure 9. Results showed a good correlation between the two datasets. The number of pixels or grid cells for a given frequency of water occurrence per risk region was computed. Results showed that the Olifants risk region had the highest number of grid cells with permanent water features, while the Shashe and Shingwedzi did not have a single grid with permanent water features (O'Brien et al., 2022a). The results of these analyses were incorporated into the PROBFLO method to determine e-flows and evaluate the risk of altered flows and non-flow variables to the ecosystems services in the Limpopo Basin (O'Brien et al., 2022b).

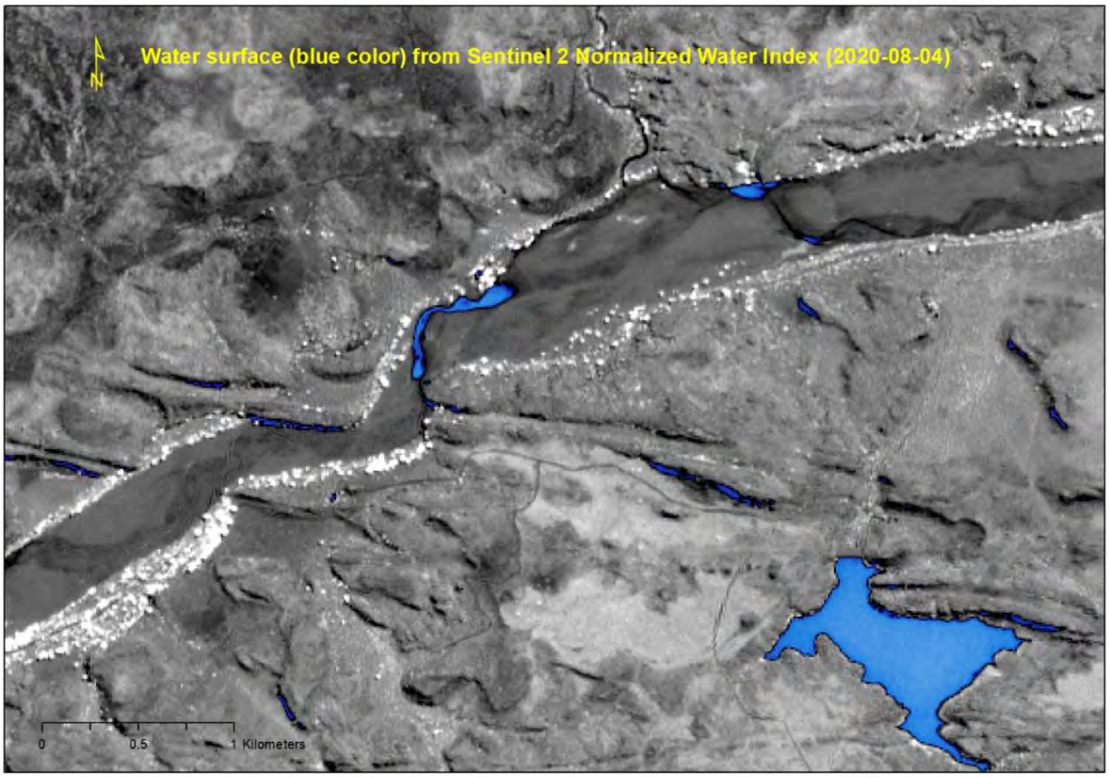

Figure 8-9: water surface feature mapping using sentinel 2 (August 2020 –dry season), the right bottom blue water feature is a dam reservoir

8.1.5 Conclusion

In the Limpopo River e-flow case study where many perennial rivers have been changed into seasonal rivers and seasonal rivers have been changed into ephemeral rivers, the groundwater contributions to the resilience of these systems, and their contribution to e-flows have been considered. The contribution of ground water flows to the e-flow determination process consisted of the characterization of the contribution of ground water derived river flows for all of the reaches of rivers considered in the study as well as the characterization of isolated pools using remote sensing data obtained from South Africa National Space Agency (SANSA) to consider the availability of refuge areas for aquatic biota and ecosystem services in the basin. Specific contributions of groundwater to social and ecological variables considered in the study include contributions to; the velocity-depth habitat characteristic nodes, the riparian habitat for vegetation, the water input flows, the dilution/flushing flows, and the instream habitat characteristics for supporting services ecosystem variables fish, invertebrates and riparian vegetation. The presence of and condition of groundwater pools that may contribute to resource resilience and affect e-flow estimates have been included in the conditional probability tables of supporting service variables in risk regions where pools are available. The groundwater contributions have also been included in the conditional probability tables of the habitat change node in the resource resilience endpoint. Finally, knowledge of how water abstractions are made from ground water ecosystems to increase resilience of human communities and the maintenance of water for domestic use endpoint was also considered.

8.1.6 References

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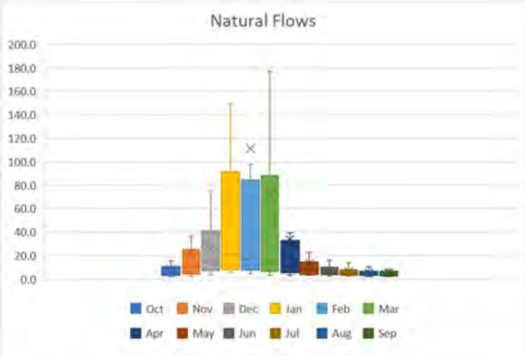
9 APPENDIX D – E-flow Tables

CROCODILE RIVER: CROC-A24J-ROOIB

Table 9-1: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the CROC-A24J-ROOIB site (The X in the box and whisker chart represents the mean).

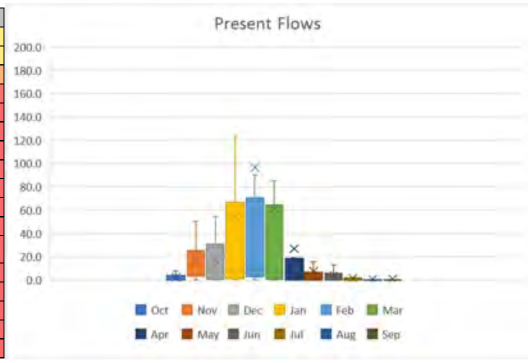
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	31.1	128.6	74.5	444.8	622.7	393.4	174.2	58.7	16.1	17.8	14.1	14.3
1	28.2	60.0	71.3	235.9	587.4	315.4	148.9	47.2	15.6	13.6	10.3	13.6
5	15.5	36.5	59.3	149.4	326.5	176.8	77.2	22.5	12.2	9.9	8.3	8.4
10	11.1	27.7	44.1	123.0	97.5	112.6	39.5	16.8	10.3	7.9	6.8	7.2
15	9.7	22.7	38.1	59.4	70.7	63.7	26.3	11.5	9.2	7.1	5.9	6.0
20	8.6	20.7	32.6	49.5	53.8	36.2	21.1	10.2	8.4	6.7	5.6	5.5
30	6.9	16.1	21.2	31.0	32.6	29.0	15.9	8.3	6.9	5.7	5.1	4.8
40	5.5	12.3	17.6	24.3	20.5	19.1	11.8	7.3	6.3	5.4	4.6	4.2
50	4.7	9.6	14.1	21.2	16.4	14.1	10.5	6.8	5.5	4.8	4.2	3.9
60	4.4	8.5	12.0	14.7	14.2	10.5	9.1	6.2	5.0	4.4	3.9	3.5
70	3.9	7.1	10.3	10.7	10.5	8.4	7.2	5.2	4.5	4.1	3.6	3.2
80	3.6	5.4	8.5	8.4	8.8	7.4	6.0	4.3	4.1	3.8	3.3	2.9
85	3.3	4.7	7.5	8.2	7.9	6.7	5.7	4.1	3.6	3.5	3.2	2.7
90	3.0	4.3	6.4	7.8	7.3	5.9	4.9	3.5	3.4	3.1	2.9	2.6
95	2.7	3.6	5.3	7.1	6.2	4.8	4.4	3.2	3.2	2.9	2.6	2.4
99	1.8	2.8	3.9	6.2	4.4	3.4	3.7	2.9	2.9	2.6	2.4	2.1
99.9	1.8	2.2	3.6	6.1	4.2	3.3	3.2	2.9	2.8	2.6	2.3	2.0



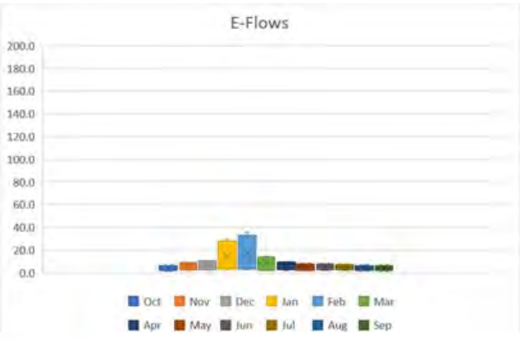
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	15.1	85.7	54.1	403.3	573.8	362.3	168.4	52.0	20.0	12.1	4.7	6.3
1	10.3	50.6	52.4	184.7	520.8	311.5	155.7	43.3	12.9	7.7	4.2	5.9
5	8.1	32.0	46.6	123.7	295.0	162.9	70.3	15.6	7.9	3.7	0.2	3.2
10	4.9	27.9	34.5	87.2	90.0	85.4	19.1	7.9	6.2	1.8	0.1	0.5
15	2.9	22.9	26.9	46.5	51.5	43.9	17.4	5.7	5.2	1.1	0.1	0.1
20	1.5	18.0	24.6	31.9	41.1	32.1	10.6	3.5	4.4	0.8	0.1	0.1
30	0.1	14.9	19.0	18.9	23.0	16.2	6.9	1.0	3.0	0.5	0.0	0.0
40	0.0	13.4	13.5	11.9	13.0	10.1	3.8	0.2	1.5	0.1	0.0	0.0
50	0.0	11.8	10.1	8.8	9.7	7.0	2.2	0.1	0.6	0.1	0.0	0.0
60	0.0	10.0	8.6	6.4	7.9	3.9	0.9	0.0	0.1	0.0	0.0	0.0
70	0.0	8.5	5.9	4.1	6.5	2.2	0.4	0.0	0.0	0.0	0.0	0.0
80	0.0	6.4	2.5	2.4	4.4	1.2	0.1	0.0	0.0	0.0	0.0	0.0
85	0.0	4.8	1.6	1.7	3.8	0.8	0.1	0.0	0.0	0.0	0.0	0.0
90	0.0	1.9	0.0	0.7	2.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	6.157	8.841	10.531	29.542	35.454	14.271	9.361	7.779	7.585	7.029	6.499	6.050
1	6.153	8.813	10.519	29.490	35.427	14.238	9.354	7.770	7.580	7.020	6.488	6.047
5	6.140	8.797	10.484	29.450	35.295	14.181	9.332	7.755	7.564	7.011	6.478	6.032
10	6.106	8.695	10.307	29.340	33.593	14.052	9.306	7.717	7.532	6.977	6.448	6.013
15	6.088	8.576	9.965	26.594	32.042	13.775	9.262	7.664	7.480	6.950	5.916	5.955
20	6.049	8.456	9.492	24.449	29.324	13.132	9.207	7.571	7.426	6.743	5.619	5.486
30	5.907	7.772	8.461	20.952	23.901	12.065	9.019	7.238	6.863	5.724	5.070	4.788
40	5.544	6.823	7.136	17.005	18.291	9.880	8.558	6.541	6.254	5.402	4.622	4.240
50	4.712	6.351	6.703	12.068	11.675	9.070	8.091	6.032	5.471	4.790	4.189	3.908
60	4.379	5.674	5.973	8.945	9.188	7.532	7.155	4.991	5.000	4.387	3.898	3.526
70	3.688	4.695	4.919	6.266	6.828	5.413	5.802	3.830	4.298	4.099	3.633	3.245
80	2.608	3.473	3.602	4.381	4.087	3.107	4.113	2.795	3.135	3.250	2.884	2.516
85	1.993	2.814	2.901	3.405	2.963	2.162	3.189	2.389	2.526	2.735	2.464	2.119
90	1.728	2.285	2.322	2.949	2.795	2.112	2.470	2.107	2.214	2.362	2.136	1.934
95	1.728	1.960	1.956	2.709	2.795	2.112	1.847	1.914	1.923	2.016	1.892	1.827
99	1.728	1.960	1.956	2.709	2.795	2.112	1.847	1.837	1.836	1.873	1.829	1.827
99.9	1.728	1.960	1.956	2.709	2.795	2.112	1.847	1.837	1.836	1.844	1.829	1.827



Summary of IFR estimate for: CROC-A24J-ROOIB site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	595.859
S.Dev.	=	583.5
CV	=	0.979
Q75	=	12.1
Q75/MMF	=	0.244
BFI Index	=	0.324
CV(JJA+JFM) Index	=	2.21
ERC	=	C/D
Total IFR	=	209.116 (35.09 %MAR)
Maint. Low flow	=	153.295 (25.73%MAR)
Drought Low flow	=	56.497 (9.48 %MAR)
Maint. High flow	=	55.821 (9.37 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-2: Summary of statistics for environmental flows (E-flows) for the CROC-A24-ROOIB site.

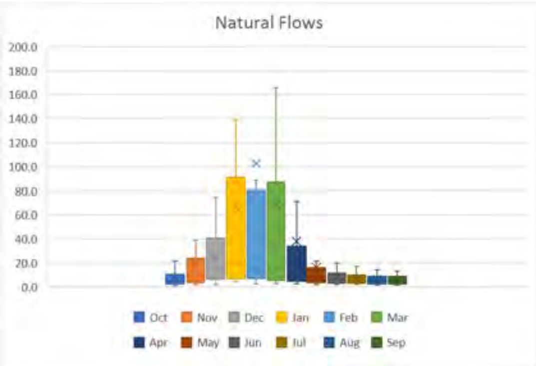
Month	Natural flows			Modified flows (E-flows)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	6.653	5.12	0.287	3.596	1.7	0	3.596
Nov	14.713	16.419	0.431	4.272	1.8	1.168	5.44
Dec	20.642	16.688	0.302	4.629	1.8	1.13	5.759
Jan	40.63	62.559	0.575	6.126	1.8	8.113	14.239
Feb	58.343	121.584	0.861	7.954	1.8	8.982	16.936
Mar	39.244	66.032	0.628	6.527	1.8	2.355	8.882
Apr	19.62	28.809	0.566	5.471	1.8	0	5.471
May	8.901	8.266	0.347	4.519	1.8	0	4.519
Jun	6.312	2.928	0.179	4.306	1.8	0	4.306
Jul	5.397	2.427	0.168	3.968	1.8	0	3.968
Aug	4.662	1.906	0.153	3.689	1.8	0	3.689
Sep	4.452	2.204	0.191	3.513	1.8	0	3.513

LIMPOPO RIVER: LIMP-A41D-SPANW

Table 9-3: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LIMP-A41D-SPANW site (The X in the box and whisker chart represents the mean)

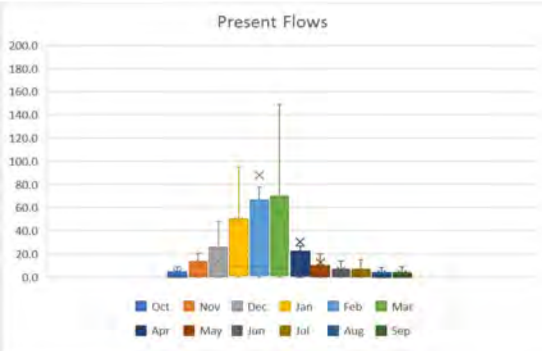
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	24.4	104.2	74.6	408.8	584.7	361.4	233.4	102.3	20.1	17.0	14.4	13.4
1	21.7	54.5	73.6	227.7	522.7	312.0	173.3	51.9	19.2	16.2	14.1	12.7
5	15.7	38.7	56.2	138.8	295.3	165.6	71.1	21.4	15.4	13.2	10.9	10.5
10	11.1	27.0	45.7	109.6	88.9	103.8	40.6	18.4	11.9	10.1	9.2	9.9
15	9.7	21.1	35.3	72.0	72.1	70.2	27.2	13.4	11.1	9.2	8.3	7.8
20	8.8	18.6	29.0	48.0	56.6	47.0	23.9	11.2	10.0	8.5	7.8	7.3
30	7.1	13.8	21.0	28.3	32.8	29.0	16.1	9.5	8.7	7.5	6.5	6.1
40	6.0	11.1	17.2	23.9	19.3	19.2	12.8	7.7	7.0	6.3	5.7	5.3
50	5.1	9.2	14.0	20.4	15.2	14.4	10.3	7.0	6.4	5.6	4.9	4.4
60	4.4	7.7	10.8	13.5	12.8	10.2	8.3	6.8	5.5	5.0	4.5	3.9
70	3.7	6.3	9.5	11.0	10.4	7.8	7.6	6.1	5.0	4.6	4.1	3.6
80	3.1	5.1	7.2	8.6	8.4	6.7	6.1	4.4	4.5	4.0	3.5	3.0
85	2.9	4.2	6.6	7.4	7.6	6.0	4.9	3.9	3.6	3.6	3.2	2.7
90	2.6	3.6	5.9	6.7	6.0	5.0	4.4	3.5	3.1	2.7	2.5	2.2
95	2.1	2.7	4.8	5.6	4.8	3.7	3.8	2.7	2.7	2.5	2.4	1.9
99	1.4	2.0	3.3	4.8	3.4	3.0	3.1	2.3	2.2	2.0	1.8	1.6
99.9	1.1	1.8	2.1	4.2	2.8	2.7	2.5	2.2	2.1	1.9	1.7	1.4



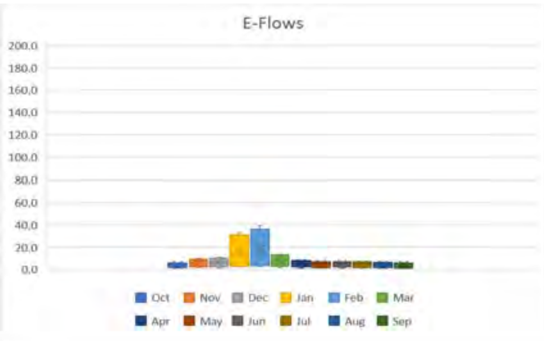
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	21.5	71.2	47.9	349.5	519.1	278.5	215.4	92.8	23.2	14.6	8.1	12.1
1	13.7	34.6	44.8	188.3	516.9	274.7	137.1	57.8	21.7	12.4	7.5	8.6
5	8.9	20.3	29.2	94.7	228.4	148.8	70.4	20.1	13.6	9.6	5.2	5.1
10	5.1	15.3	28.0	64.6	77.2	91.6	26.5	11.5	7.0	7.8	4.4	4.1
15	3.8	11.6	22.5	35.2	55.5	48.2	17.9	8.6	5.7	4.7	3.5	2.9
20	3.2	10.7	17.3	27.1	40.3	35.1	14.0	6.6	5.0	3.6	2.8	2.5
30	2.3	5.7	10.7	19.0	20.9	18.7	9.8	4.6	3.8	3.2	2.3	2.1
40	1.8	3.8	8.5	13.6	10.6	10.0	7.1	3.5	2.8	2.2	1.8	1.6
50	1.3	2.4	5.6	8.9	9.5	7.7	5.1	3.1	2.3	2.0	1.5	1.3
60	0.8	1.4	4.0	6.5	5.9	5.3	3.3	2.3	1.8	1.5	1.0	0.7
70	0.3	0.8	2.4	4.0	4.1	3.1	2.6	1.4	1.4	0.9	0.5	0.3
80	0.2	0.4	0.7	2.5	2.8	2.2	1.8	0.8	0.7	0.4	0.1	0.1
85	0.1	0.2	0.3	1.8	2.0	1.5	1.2	0.4	0.4	0.1	0.0	0.0
90	0.0	0.1	0.1	1.2	1.5	1.2	0.5	0.2	0.2	0.0	0.0	0.0
95	0.0	0.0	0.0	0.2	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	5.558	9.338	10.483	32.888	39.162	13.250	8.154	7.028	7.028	6.680	6.281	5.811
1	5.554	9.307	10.477	32.838	39.127	13.230	8.145	7.018	7.023	6.680	6.281	5.811
5	5.546	9.284	10.436	32.812	39.024	13.187	8.126	7.010	7.011	6.680	6.281	5.811
10	5.516	9.205	10.193	32.190	36.766	13.082	8.107	6.989	6.983	6.668	6.268	5.809
15	5.496	9.105	9.783	29.901	34.467	12.805	8.073	6.950	6.953	6.649	6.256	5.780
20	5.472	8.892	9.006	27.158	31.564	12.583	8.020	6.868	6.898	6.588	6.208	5.743
30	5.348	8.207	8.150	21.851	25.676	11.631	7.857	6.753	6.775	6.450	6.060	5.585
40	5.165	7.077	6.719	17.827	19.285	10.153	7.537	6.355	6.424	6.121	5.721	5.231
50	4.858	5.826	5.808	12.612	13.291	8.092	7.087	5.986	6.106	5.559	4.902	4.448
60	4.350	4.954	5.200	9.473	9.401	7.183	6.311	5.212	5.433	4.679	4.258	3.745
70	3.608	4.123	4.314	6.417	6.739	5.858	5.179	4.102	4.454	3.558	3.162	2.691
80	2.654	3.053	3.175	4.095	4.708	4.154	3.723	2.750	3.206	2.441	2.134	1.796
85	2.135	2.337	2.436	3.234	3.557	3.159	2.930	2.053	2.439	1.968	1.736	1.482
90	1.651	1.930	1.978	2.787	2.795	2.363	2.194	1.520	1.925	1.624	1.456	1.303
95	1.228	1.518	1.483	2.449	2.533	1.621	1.558	1.237	1.399	1.380	1.281	1.229
99	1.029	1.486	1.396	2.329	2.439	1.579	1.243	1.237	1.236	1.259	1.232	1.229
99.9	1.029	1.486	1.396	2.329	2.439	1.579	1.243	1.237	1.236	1.241	1.232	1.229



Summary of IFR estimate for: LIMP-A41D-SPANW site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	591.487
S.Dev.	=	579.474
CV	=	0.98
Q75	=	13
Q75/MMF	=	0.264
BFI Index	=	0.355
CV(JJA+JFM) Index	=	2.223
ERC	=	C
Total IFR	=	219.244 (37.07 %MAR)
Maint. Low flow	=	145.899 (24.67 %MAR)
Drought Low flow	=	37.308 (6.31 %MAR)
Maint. High flow	=	73.345 (12.40 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-4: Summary of statistics for environmental flows (E-flows) for the LIMP-A41D-SPANW site.

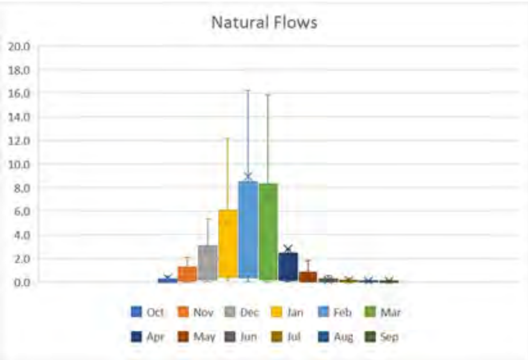
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	6.379	4.364	0.255	3.492	1	0	3.492
Nov	13.403	14.3	0.412	4.013	1.2	2.365	6.378
Dec	19.864	16.933	0.318	4.336	1.2	1.529	5.865
Jan	39.117	58.472	0.558	5.608	1.2	10.258	15.866
Feb	55.699	112.304	0.833	7.174	1.2	11.357	18.531
Mar	38.07	62.071	0.609	5.945	1.2	3.05	8.995
Apr	20.508	33.396	0.628	5.124	1.2	0	5.124
May	10.043	12.209	0.454	4.362	1.2	0	4.362
Jun	7.349	3.977	0.209	4.256	1.2	0	4.256
Jul	6.414	3.216	0.187	3.997	1.2	0	3.997
Aug	5.665	2.754	0.182	3.803	1.2	0	3.803
Sep	5.215	2.717	0.201	3.605	1.2	0	3.605

MATLABAS RIVER: MATL-A41D-WDRAAI

Table 9-5: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the MATL-A41D-WDRAAI site (The X in the box and whisker chart represents the mean)

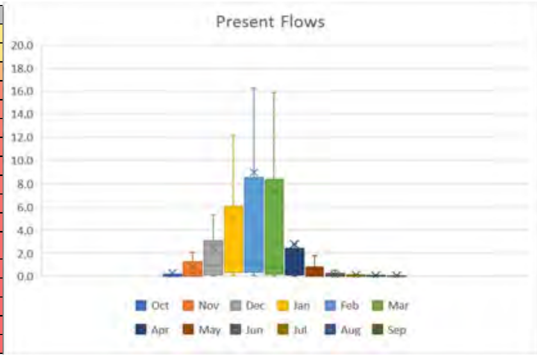
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	3.0	3.3	12.0	32.4	56.0	46.5	15.2	1.8	0.5	0.6	0.4	0.2
1	1.0	3.3	11.4	17.6	50.1	34.9	14.7	1.8	0.5	0.3	0.2	0.2
5	0.5	2.1	5.4	12.1	16.3	15.8	7.7	1.4	0.3	0.2	0.1	0.2
10	0.3	1.4	3.4	8.1	11.2	10.3	2.8	1.0	0.3	0.2	0.1	0.1
15	0.2	1.2	2.8	4.1	5.8	6.3	2.1	0.7	0.2	0.1	0.1	0.1
20	0.2	0.9	2.6	3.6	3.6	3.6	1.6	0.5	0.2	0.1	0.1	0.1
30	0.1	0.6	1.5	2.2	2.8	1.9	1.0	0.4	0.1	0.1	0.1	0.1
40	0.1	0.5	1.2	1.5	1.9	1.3	0.8	0.2	0.1	0.1	0.1	0.0
50	0.0	0.4	1.0	1.3	1.2	0.8	0.5	0.2	0.1	0.1	0.0	0.0
60	0.0	0.2	0.7	0.9	1.0	0.7	0.3	0.1	0.1	0.1	0.0	0.0
70	0.0	0.2	0.5	0.7	0.8	0.5	0.3	0.1	0.1	0.1	0.0	0.0
80	0.0	0.1	0.3	0.5	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0
85	0.0	0.1	0.2	0.5	0.4	0.2	0.2	0.1	0.0	0.0	0.0	0.0
90	0.0	0.1	0.2	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.2	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A



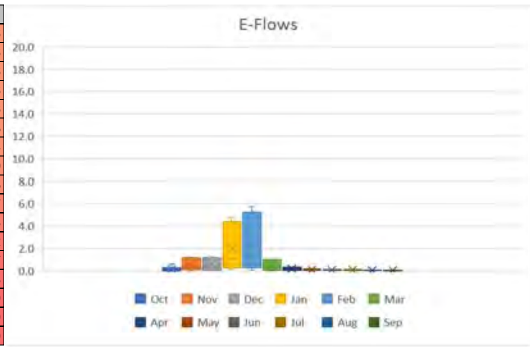
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	2.7	3.2	12.0	32.5	56.0	46.5	15.2	1.8	0.5	0.6	0.4	0.1
1	0.9	3.2	11.4	17.6	50.2	34.8	14.7	1.8	0.4	0.3	0.2	0.1
5	0.4	2.1	5.3	12.1	16.2	15.8	7.7	1.3	0.3	0.2	0.1	0.1
10	0.2	1.3	3.4	8.0	11.2	10.3	2.8	0.9	0.2	0.1	0.1	0.0
15	0.1	1.2	2.7	4.1	5.8	6.3	2.0	0.7	0.2	0.1	0.1	0.0
20	0.1	0.9	2.5	3.6	3.6	3.5	1.5	0.4	0.1	0.1	0.0	0.0
30	0.0	0.6	1.5	2.2	2.8	1.9	0.9	0.3	0.1	0.1	0.0	0.0
40	0.0	0.4	1.1	1.5	1.9	1.3	0.8	0.2	0.1	0.0	0.0	0.0
50	0.0	0.3	1.0	1.2	1.2	0.7	0.5	0.2	0.1	0.0	0.0	0.0
60	0.0	0.1	0.6	0.9	0.9	0.6	0.3	0.1	0.0	0.0	0.0	0.0
70	0.0	0.1	0.3	0.6	0.7	0.4	0.2	0.1	0.0	0.0	0.0	0.0
80	0.0	0.0	0.3	0.5	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.2	0.4	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.1	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

B



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	0.591	1.182	1.258	4.806	5.710	0.986	0.298	0.163	0.106	0.084	0.063	0.046
1	0.588	1.181	1.257	4.798	5.706	0.984	0.297	0.163	0.106	0.084	0.063	0.046
5	0.498	1.176	1.253	4.793	5.686	0.978	0.296	0.163	0.106	0.084	0.063	0.046
10	0.287	1.154	1.225	4.659	5.460	0.968	0.295	0.162	0.105	0.083	0.063	0.046
15	0.218	1.145	1.096	4.086	4.991	0.948	0.293	0.161	0.105	0.083	0.062	0.046
20	0.164	0.930	0.994	3.573	3.605	0.918	0.290	0.159	0.104	0.083	0.062	0.045
30	0.093	0.648	0.764	2.248	2.778	0.775	0.283	0.156	0.101	0.081	0.061	0.044
40	0.056	0.494	0.582	1.523	1.893	0.653	0.268	0.147	0.097	0.077	0.058	0.039
50	0.037	0.351	0.346	1.057	1.127	0.448	0.242	0.136	0.091	0.067	0.049	0.035
60	0.026	0.220	0.232	0.633	0.666	0.284	0.200	0.115	0.081	0.060	0.041	0.027
70	0.019	0.150	0.140	0.364	0.391	0.180	0.141	0.085	0.066	0.056	0.037	0.023
80	0.011	0.112	0.084	0.258	0.280	0.065	0.073	0.049	0.046	0.040	0.024	0.012
85	0.007	0.085	0.068	0.258	0.266	0.051	0.037	0.031	0.034	0.030	0.017	0.007
90	0.004	0.054	0.059	0.258	0.266	0.048	0.017	0.016	0.026	0.024	0.011	0.003
95	0.000	0.025	0.053	0.258	0.168	0.048	0.017	0.008	0.019	0.017	0.006	0.000
99	0.000	0.000	0.048	0.236	0.060	0.000	0.016	0.008	0.015	0.011	0.004	0.000
99.9	0.000	0.000	0.012	0.155	0.047	0.000	0.016	0.008	0.015	0.011	0.004	0.000

C



Summary of IFR estimate for: MATL-A41D-WDRAAI site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	40.146
S.Dev.	=	53.565
CV	=	1.334
Q75	=	0.15
Q75/MMF	=	0.045
BFI Index	=	0.16
CV(JJA+JFM) Index	=	2.834
ERC	=	B/C
Total IFR	=	20.017 (49.86 %MAR)
Maint. Low flow	=	4.27 (10.64 %MAR)
Drought Low flow	=	0.417 (1.04 %MAR)
Maint. High flow	=	15.748 (39.23 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-6: Summary of statistics for environmental flows (E-flows) for the MATL-A41D-WDRAAI site.

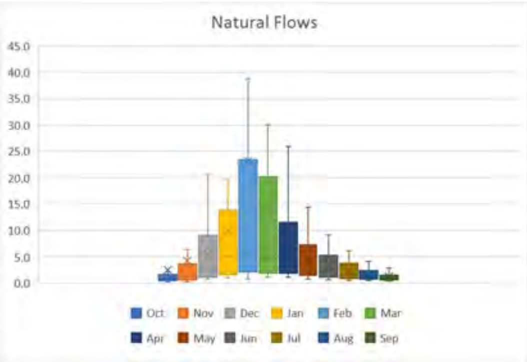
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	0.14	0.367	0.978	0.04	0	0.424	0.464
Nov	0.601	0.697	0.447	0.072	0	0.869	0.941
Dec	1.601	2.137	0.498	0.134	0.007	0.424	0.558
Jan	2.865	4.739	0.617	0.228	0.057	1.884	2.112
Feb	4.557	9.68	0.878	0.363	0.045	2.085	2.448
Mar	3.542	7.395	0.779	0.312	0	0.424	0.736
Apr	1.517	2.935	0.746	0.197	0.015	0	0.197
May	0.357	0.433	0.453	0.106	0.007	0	0.106
Jun	0.128	0.107	0.323	0.067	0.015	0	0.067
Jul	0.087	0.078	0.333	0.052	0.011	0	0.052
Aug	0.062	0.056	0.339	0.04	0.004	0	0.04
Sep	0.045	0.045	0.385	0.03	0	0	0.03

LEPHALALA RIVER: LEPH-A50H-SEEKO

Table 9-7: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LEPH-A50H-SEEKO site (The X in the box and whisker chart represents the mean)

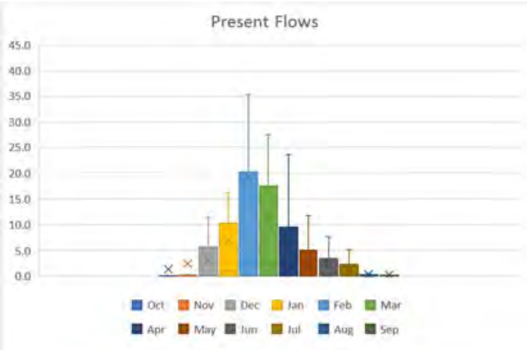
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	24.9	25.8	20.6	38.2	136.3	60.6	27.5	14.4	9.1	6.1	4.2	3.1
1	5.2	21.1	15.4	32.8	114.7	58.0	26.0	11.3	8.8	5.7	3.8	2.9
5	2.2	6.4	12.8	19.7	38.9	30.0	18.4	8.8	6.6	4.6	3.0	2.2
10	1.9	4.4	11.1	14.9	25.1	22.7	12.2	7.9	5.7	4.0	2.5	1.7
15	1.4	3.0	7.0	12.6	21.7	17.5	10.9	6.6	4.9	3.4	2.2	1.4
20	1.2	2.4	5.2	11.9	15.1	14.5	8.8	5.8	4.4	3.1	1.8	1.3
30	1.1	1.8	4.5	8.6	11.0	8.9	7.1	4.5	3.1	2.2	1.5	1.1
40	0.9	1.4	3.7	7.7	7.2	6.2	5.1	4.1	2.7	1.9	1.2	1.0
50	0.8	1.2	2.7	5.0	5.7	4.7	4.4	3.5	2.5	1.7	1.1	0.8
60	0.7	1.1	2.2	3.9	4.9	4.0	3.4	2.8	2.0	1.4	1.0	0.8
70	0.6	1.0	1.7	2.8	3.3	2.8	2.9	2.2	1.6	1.2	1.0	0.7
80	0.5	0.8	1.3	2.0	2.6	2.1	2.4	1.9	1.4	1.1	0.8	0.6
85	0.5	0.7	1.2	1.8	2.4	2.0	2.1	1.7	1.3	0.9	0.7	0.6
90	0.4	0.6	1.0	1.4	1.8	1.9	1.8	1.3	1.1	0.8	0.7	0.6
95	0.4	0.5	0.9	1.2	1.5	1.5	1.4	0.9	0.8	0.7	0.6	0.5
99	0.3	0.3	0.8	1.0	1.1	1.3	1.2	0.7	0.6	0.5	0.5	0.4
99.9	0.3	0.3	0.8	0.9	0.8	1.1	1.1	0.7	0.6	0.5	0.4	0.4



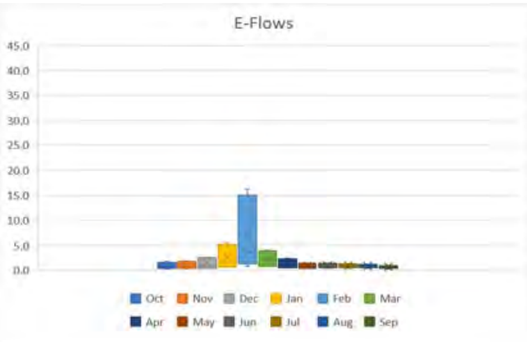
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	19.1	21.9	16.3	33.5	116.0	50.7	23.7	11.7	7.6	5.1	1.9	1.8
1	3.2	14.2	11.5	27.8	104.8	49.9	23.6	9.1	6.7	4.9	1.4	1.4
5	0.1	4.0	9.1	16.3	35.3	27.5	15.7	7.3	5.2	2.9	1.0	0.1
10	0.0	0.3	7.5	11.1	21.2	20.3	10.2	5.5	3.6	2.3	0.4	0.1
15	0.0	0.1	3.7	9.4	19.2	14.7	8.8	4.6	3.1	2.2	0.2	0.1
20	0.0	0.0	1.8	8.4	12.7	11.8	7.1	3.5	2.2	1.4	0.0	0.1
30	0.0	0.0	0.4	5.4	7.8	7.2	4.6	2.2	1.4	0.7	0.0	0.0
40	0.0	0.0	0.0	4.3	4.3	3.9	3.3	1.8	0.8	0.3	0.0	0.0
50	0.0	0.0	0.0	0.9	3.0	2.2	2.0	1.3	0.5	0.1	0.0	0.0
60	0.0	0.0	0.0	0.0	1.5	1.1	1.2	0.5	0.1	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	1.694	1.823	2.649	5.563	16.269	3.991	2.378	1.361	1.334	1.216	1.092	0.930
1	1.687	1.820	2.643	5.558	16.256	3.988	2.374	1.357	1.333	1.215	1.091	0.930
5	1.684	1.811	2.637	5.544	16.201	3.960	2.362	1.352	1.330	1.214	1.090	0.929
10	1.667	1.784	2.617	5.509	15.896	3.916	2.322	1.339	1.328	1.210	1.086	0.926
15	1.421	1.762	2.398	4.877	14.267	3.858	2.297	1.316	1.321	1.206	1.083	0.922
20	1.221	1.697	2.196	4.545	12.005	3.726	2.205	1.275	1.313	1.200	1.075	0.917
30	1.083	1.545	1.823	3.647	9.669	3.326	2.015	1.148	1.285	1.178	1.054	0.899
40	0.862	1.278	1.410	2.833	6.690	2.829	1.580	0.958	1.253	1.139	1.023	0.862
50	0.769	0.992	0.923	1.663	3.605	2.120	1.262	0.756	1.186	1.092	0.972	0.816
60	0.599	0.740	0.778	1.118	2.330	1.452	0.914	0.588	1.077	1.002	0.883	0.731
70	0.433	0.578	0.588	0.772	1.566	1.001	0.692	0.486	0.920	0.871	0.755	0.610
80	0.355	0.401	0.436	0.635	1.259	0.787	0.587	0.439	0.720	0.700	0.592	0.461
85	0.337	0.378	0.428	0.635	1.220	0.739	0.561	0.427	0.613	0.597	0.501	0.386
90	0.328	0.373	0.428	0.635	1.220	0.730	0.551	0.421	0.514	0.513	0.424	0.326
95	0.328	0.373	0.428	0.635	1.220	0.730	0.551	0.419	0.428	0.419	0.357	0.295
99	0.321	0.336	0.428	0.635	1.128	0.730	0.551	0.419	0.403	0.377	0.334	0.295
99.9	0.264	0.304	0.428	0.635	0.810	0.730	0.551	0.419	0.403	0.368	0.334	0.295



Summary of IFR estimate for: LEPH-A50H-SEEKO site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	142.231
S.Dev.	=	117.15
CV	=	0.824
Q75	=	3.01
Q75/MMF	=	0.254
BFI Index	=	0.304
CV(JJA+JFM) Index	=	1.896
ERC	=	C
Total IFR	=	55.623 (39.11 %MAR)
Maint. Low flow	=	25.727 (18.09 %MAR)
Drought Low flow	=	12.503 (8.79 %MAR)
Maint. High flow	=	29.896 (21.02 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-8: Summary of statistics for environmental flows (E-flows) for the LEPH-A50H-SEEKO site.

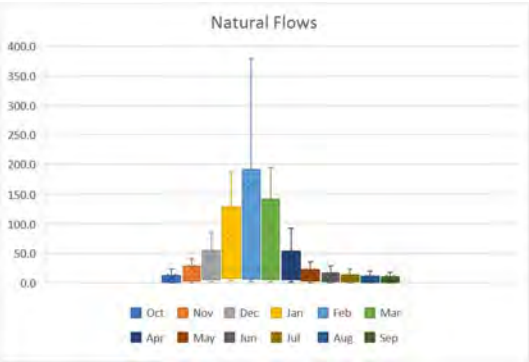
Month	Natural flows			Modified flows (IFR)			
				Low flows		High flows	Total flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.212	2.791	0.859	0.568	0.258	0.612	1.18
Nov	2.457	4.062	0.638	0.644	0.301	0.632	1.276
Dec	4.174	3.985	0.356	0.726	0.359	0.612	1.338
Jan	7.356	7.019	0.356	0.911	0.444	1.758	2.669
Feb	12.476	20.697	0.686	1.277	0.615	5.756	7.033
Mar	9.47	11.779	0.464	1.104	0.533	1.758	2.862
Apr	6.237	5.516	0.341	0.98	0.476	0.632	1.612
May	3.986	2.641	0.247	0.844	0.413	0	0.844
Jun	2.916	1.909	0.253	0.807	0.397	0	0.807
Jul	2.023	1.254	0.231	0.727	0.359	0	0.727
Aug	1.392	0.776	0.208	0.661	0.329	0	0.661
Sep	1.019	0.53	0.2	0.577	0.291	0	0.577

LIMPOPO RIVER: LIMP-A36C-LIMPK

Table 9-9: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LIMP-A36C-LIMPK site (The X in the box and whisker chart represents the mean)

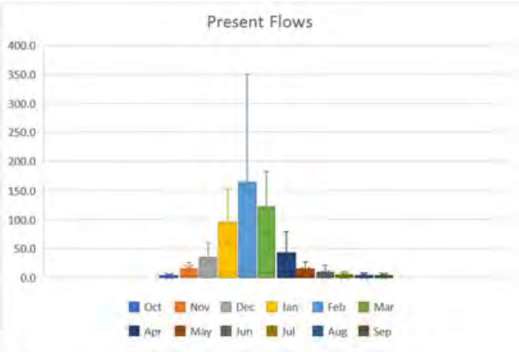
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	42.5	143.9	203.3	359.7	922.8	416.6	234.3	77.6	29.4	23.0	20.0	18.2
1	23.1	81.6	149.0	316.5	873.2	344.3	169.9	57.4	25.7	19.8	18.2	16.1
5	13.5	41.1	85.4	187.2	378.5	195.4	92.7	35.8	22.1	17.9	14.5	13.8
10	12.3	31.4	61.2	152.8	223.8	168.8	64.3	23.8	17.2	15.1	11.9	11.5
15	11.4	24.6	48.3	102.9	159.6	113.4	42.5	21.6	15.9	12.2	10.0	9.0
20	10.3	21.9	41.1	67.4	114.4	86.9	37.0	20.1	13.4	10.5	9.1	8.0
30	7.2	17.1	30.3	47.3	51.0	45.1	30.8	14.2	10.6	8.3	7.3	6.2
40	6.6	13.2	20.5	30.7	30.3	29.1	20.2	10.3	8.7	7.2	5.6	5.0
50	5.1	9.7	17.1	22.7	22.1	19.8	14.2	9.2	6.9	5.9	4.6	4.0
60	3.4	8.0	13.1	17.5	17.4	14.2	9.8	7.6	5.4	4.6	3.7	3.0
70	3.0	6.9	9.7	14.2	12.8	10.6	8.9	6.2	4.4	3.7	2.9	2.2
80	2.0	5.3	7.0	10.4	10.5	7.0	6.3	4.6	3.5	2.8	2.0	1.4
85	1.5	3.6	6.4	8.5	7.6	5.9	5.4	3.9	2.3	2.2	1.5	0.9
90	1.2	2.9	5.8	6.7	6.5	5.3	4.8	2.3	1.8	1.4	1.0	0.6
95	0.9	1.8	4.8	5.2	4.9	3.0	2.9	1.4	0.9	0.7	0.5	0.3
99	0.1	0.6	2.2	4.1	3.1	2.0	1.5	0.7	0.5	0.4	0.2	0.1
99.9	0.0	0.3	0.8	3.6	2.4	1.2	0.6	0.3	0.4	0.3	0.2	0.0



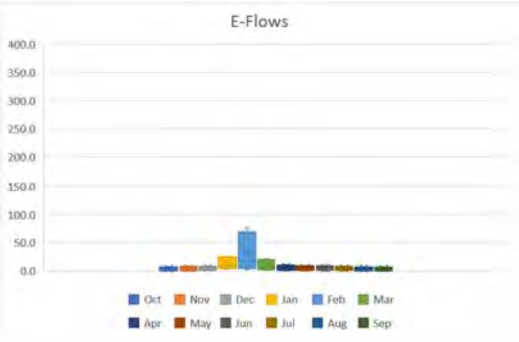
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	12.0	115.7	168.6	320.3	880.3	407.1	222.6	67.8	21.1	13.4	10.4	9.5
1	9.1	60.7	126.9	287.4	833.2	321.8	153.4	48.4	19.0	10.3	7.8	6.9
5	5.3	25.3	59.5	153.3	349.5	182.1	79.6	26.3	14.0	8.4	5.8	5.0
10	3.8	15.7	40.2	114.3	194.4	144.6	53.0	15.9	9.7	5.5	4.3	3.6
15	2.3	13.0	28.4	74.6	131.9	97.9	32.5	12.7	7.5	3.8	2.4	2.3
20	1.9	11.2	20.6	41.5	99.6	71.9	24.3	9.3	6.1	2.7	2.0	1.9
30	1.4	7.7	14.3	23.8	34.3	31.9	16.2	5.2	3.7	1.9	1.5	1.4
40	1.0	4.2	7.2	11.6	14.1	16.4	7.8	3.4	2.4	1.3	1.1	1.0
50	0.8	2.0	4.9	6.4	9.5	8.0	3.9	2.1	1.2	1.1	0.9	0.8
60	0.6	1.5	2.0	3.5	5.9	4.9	2.5	1.3	0.9	0.8	0.7	0.6
70	0.3	0.8	1.4	1.9	4.0	2.5	1.2	0.8	0.5	0.3	0.3	0.3
80	0.1	0.4	0.6	1.1	1.7	1.1	0.5	0.3	0.2	0.1	0.2	0.1
85	0.1	0.2	0.5	0.6	0.6	0.5	0.2	0.1	0.1	0.0	0.1	0.1
90	0.0	0.1	0.3	0.3	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0
95	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	6.295	7.434	8.421	25.835	75.535	20.863	10.697	8.884	8.605	7.983	7.221	6.460
1	6.283	7.421	8.408	25.808	75.491	20.816	10.683	8.871	8.587	7.963	7.208	6.443
5	6.273	7.403	8.389	25.724	75.284	20.732	10.668	8.851	8.569	7.951	7.173	6.425
10	6.247	7.361	8.345	25.581	72.506	20.519	10.620	8.791	8.468	7.909	7.102	6.374
15	6.206	7.322	8.285	23.156	65.554	20.082	10.556	8.762	8.421	7.818	7.042	6.286
20	6.153	7.253	8.170	20.985	58.990	19.169	10.430	8.691	8.322	7.730	6.882	6.149
30	5.920	7.033	7.932	18.336	46.063	17.229	10.155	8.478	7.914	7.335	6.421	5.568
40	5.635	6.591	7.238	14.189	30.318	13.415	9.471	7.882	7.154	6.690	5.429	4.902
50	5.062	5.869	6.456	9.440	17.832	10.333	8.687	7.350	6.153	5.852	4.564	3.777
60	3.427	4.684	4.961	6.531	10.908	8.371	7.177	6.210	4.700	4.570	3.201	2.466
70	2.831	3.051	2.989	4.683	6.765	5.669	5.049	4.576	3.098	3.108	1.894	1.290
80	1.315	1.274	1.103	3.955	5.099	2.728	2.578	2.587	1.696	1.756	0.924	0.502
85	0.593	0.528	0.676	3.955	4.885	1.845	1.342	1.587	1.120	1.120	0.568	0.263
90	0.080	0.311	0.676	3.955	4.885	1.800	0.566	0.777	0.798	0.802	0.395	0.134
95	0.080	0.311	0.676	3.955	4.843	1.800	0.566	0.360	0.550	0.508	0.264	0.079
99	0.055	0.306	0.671	3.918	3.058	1.726	0.560	0.354	0.482	0.362	0.197	0.066
99.9	0.042	0.270	0.632	3.614	2.374	1.127	0.507	0.311	0.441	0.295	0.188	0.041



Summary of IFR estimate for: LIMP-A36C-LIMPK site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	801.391
S.Dev.	=	824.435
CV	=	1.029
Q75	=	12.38
Q75/MMF	=	0.185
BFI Index	=	0.293
CV(JJA+JFM) Index	=	2.309
ERC	=	C
Total IFR	=	276.526 (34.51 %MAR)
Maint. Low flow	=	185.547 (23.15 %MAR)
Drought Low flow	=	24.26 (3.03 %MAR)
Maint. High flow	=	90.979 (11.35 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-10: Summary of statistics for environmental flows (E-flows) for the LIMP-A36C-LIMPK site.

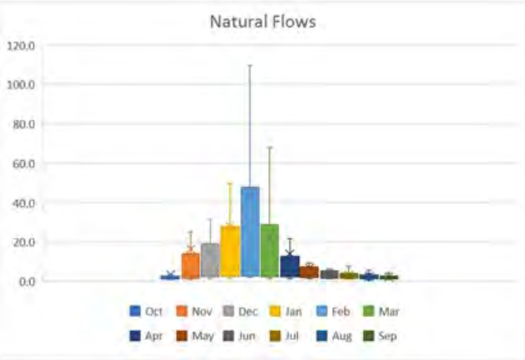
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	6.284	5.922	0.352	3.96	0.041	0	3.96
Nov	15.93	19.652	0.476	4.735	0.266	0	4.735
Dec	27.948	32.065	0.428	5.501	0.627	0	5.501
Jan	51.674	69.377	0.501	7.333	3.252	6.194	13.527
Feb	86.648	165.595	0.79	10.574	2.319	23.893	34.467
Mar	54.105	76.153	0.525	8.228	1.06	6.194	14.422
Apr	27.81	36.643	0.508	6.727	0.502	0	6.727
May	12.867	12.463	0.362	5.518	0.306	0	5.518
Jun	8.528	6.424	0.291	5.216	0.436	0	5.216
Jul	6.926	5.078	0.274	4.782	0.287	0	4.782
Aug	5.73	4.47	0.291	4.378	0.187	0	4.378
Sep	4.986	4.166	0.322	4.014	0.039	0	4.014

MOGALAKWENA RIVER: MOGA-A36D-LIMPK

Table 9-11: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the MOGA-A36D-LIMPK site (The X in the box and whisker chart represents the mean)

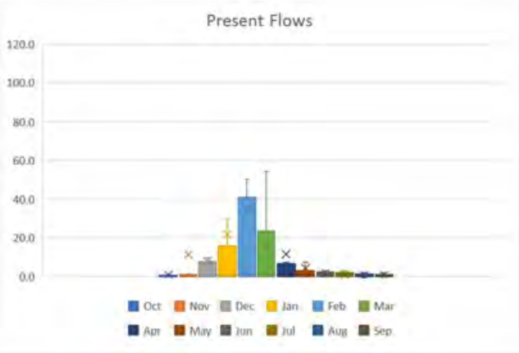
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	21.6	130.3	65.2	176.7	284.5	148.5	84.9	33.1	10.7	7.6	5.4	4.3
1	8.6	64.6	63.0	118.1	177.1	68.0	58.8	25.3	10.7	7.1	4.7	3.7
5	3.2	25.0	31.8	49.5	109.7	42.7	21.6	9.4	6.1	4.6	3.7	3.1
10	2.8	17.2	22.1	31.4	57.2	33.5	13.9	7.4	5.2	4.0	3.3	2.8
15	2.6	10.8	16.1	24.3	38.5	24.0	11.6	7.1	5.0	3.9	3.2	2.7
20	2.4	6.8	13.2	20.5	26.0	15.8	9.9	6.2	4.2	3.4	2.9	2.5
30	2.2	3.9	9.9	14.1	15.3	10.8	7.6	4.8	3.7	3.0	2.5	2.3
40	2.1	3.2	6.2	10.6	9.6	7.0	6.5	3.8	3.2	2.8	2.4	2.0
50	1.8	2.7	5.1	7.2	7.5	5.5	4.6	3.2	2.7	2.4	2.1	1.8
60	1.6	2.5	3.9	5.3	5.7	4.6	3.7	2.8	2.6	2.2	1.9	1.7
70	1.5	2.2	3.2	3.4	4.1	3.9	3.1	2.3	2.0	1.9	1.7	1.5
80	1.3	1.9	2.5	3.0	3.1	2.6	2.4	2.0	1.8	1.6	1.5	1.3
85	1.2	1.7	2.1	2.6	2.7	2.5	2.2	1.8	1.7	1.5	1.4	1.3
90	1.1	1.6	2.0	2.4	2.5	2.2	2.1	1.8	1.6	1.4	1.4	1.2
95	1.0	1.3	1.7	2.0	2.1	1.9	1.8	1.6	1.5	1.3	1.2	1.1
99	1.0	1.0	1.3	1.7	1.8	1.6	1.6	1.4	1.3	1.2	1.1	1.1
99.9	1.0	0.9	1.3	1.6	1.7	1.4	1.3	1.2	1.2	1.2	1.1	1.0



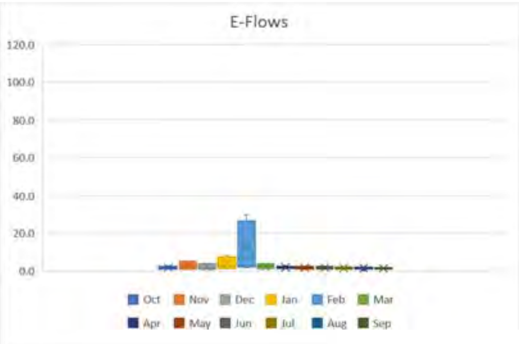
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	9.6	123.2	53.0	176.0	222.3	113.4	81.4	28.7	8.4	3.2	2.0	2.0
1	3.6	62.1	42.5	115.5	152.8	54.3	73.1	24.9	6.9	3.1	1.9	1.9
5	1.1	4.1	19.1	29.9	107.6	35.4	16.7	7.3	3.0	2.6	1.8	1.5
10	0.8	1.3	9.7	18.4	50.1	30.2	7.3	3.7	2.5	2.2	1.6	1.3
15	0.7	1.0	5.5	13.0	31.9	16.6	6.0	2.6	2.2	1.6	1.3	1.0
20	0.6	0.8	2.9	8.7	14.1	11.4	4.0	1.9	1.7	1.4	1.2	0.9
30	0.3	0.4	1.4	5.9	5.6	5.2	2.7	1.5	1.2	1.0	0.9	0.5
40	0.1	0.3	0.5	2.0	3.2	2.4	1.9	1.3	1.0	0.8	0.7	0.4
50	0.0	0.1	0.1	0.8	1.4	1.5	1.4	0.8	0.7	0.6	0.5	0.3
60	0.0	0.0	0.0	0.3	0.8	0.9	0.9	0.5	0.4	0.2	0.3	0.2
70	0.0	0.0	0.0	0.0	0.3	0.3	0.5	0.3	0.2	0.1	0.1	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	2.615	5.204	3.948	8.081	29.894	3.657	2.564	2.270	2.267	2.145	1.989	1.823
1	2.607	5.188	3.946	8.070	29.846	3.646	2.560	2.267	2.266	2.144	1.986	1.819
5	2.597	5.175	3.933	8.053	29.819	3.642	2.555	2.260	2.256	2.137	1.982	1.815
10	2.573	5.130	3.861	7.824	27.746	3.605	2.535	2.237	2.233	2.119	1.955	1.788
15	2.537	5.037	3.669	7.275	25.557	3.564	2.505	2.219	2.220	2.099	1.944	1.776
20	2.423	4.873	3.435	6.726	22.940	3.485	2.443	2.163	2.157	2.056	1.893	1.733
30	2.188	3.866	2.882	5.420	15.286	3.230	2.284	2.004	2.044	1.921	1.782	1.601
40	1.953	3.210	2.266	4.300	9.554	2.658	2.046	1.709	1.842	1.724	1.634	1.420
50	1.616	2.674	1.735	2.824	6.611	2.295	1.767	1.581	1.620	1.530	1.443	1.234
60	1.303	2.057	1.358	2.042	4.258	1.809	1.518	1.390	1.422	1.360	1.275	1.071
70	1.104	1.498	1.132	1.546	2.850	1.481	1.359	1.274	1.291	1.253	1.163	0.972
80	1.011	1.233	1.041	1.350	2.284	1.325	1.284	1.219	1.223	1.198	1.106	0.925
85	0.989	1.176	1.030	1.350	2.212	1.291	1.266	1.206	1.204	1.182	1.090	0.914
90	0.978	1.161	1.030	1.350	2.212	1.283	1.258	1.199	1.194	1.174	1.082	0.908
95	0.978	1.161	1.030	1.350	2.134	1.283	1.258	1.197	1.188	1.169	1.077	0.906
99	0.976	1.013	1.030	1.350	1.763	1.283	1.256	1.194	1.186	1.165	1.074	0.906
99.9	0.958	0.903	1.030	1.350	1.740	1.283	1.237	1.175	1.181	1.155	1.065	0.906



Summary of IFR estimate for: MOGA-A36D-LIMPK site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	242.551
S.Dev.	=	221.975
CV	=	0.915
Q75	=	5.26
Q75/MMF	=	0.26
BFI Index	=	0.341
CV(JJA+JFM) Index	=	2.143
ERC	=	C
Total IFR	=	89.884 (37.06 %MAR)
Maint. Low flow	=	46.671 (19.24 %MAR)
Drought Low flow	=	33.901 (13.98 %MAR)
Maint. High flow	=	43.214 (17.82 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-12: Summary of statistics for environmental flows (E-flows) for the MOGA-A36D-LIMPK site.

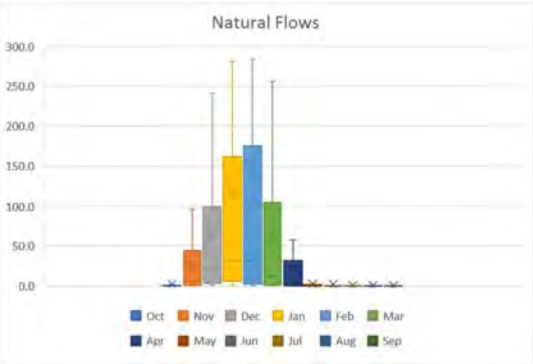
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	2.15	2.356	0.409	1.091	0.9	0.677	1.768
Nov	7.478	16.335	0.843	1.388	0.9	2.356	3.744
Dec	9.8	12.575	0.479	1.464	0.95	0.677	2.141
Jan	15.048	24.097	0.598	1.754	1.1	2.28	4.034
Feb	23.734	44.437	0.774	2.366	1.1	10.565	12.931
Mar	12.657	20.061	0.592	1.772	1.2	0.677	2.449
Apr	7.967	11.598	0.562	1.608	1.25	0	1.608
May	4.594	4.568	0.371	1.406	1.19	0	1.406
Jun	3.231	1.777	0.212	1.37	1.18	0	1.37
Jul	2.651	1.18	0.166	1.281	1.16	0	1.281
Aug	2.251	0.844	0.14	1.202	1.07	0	1.202
Sep	1.961	0.665	0.131	1.129	0.9	0	1.129

SHASHE RIVER: SHAS-Y20B-TULIB

Table 9-13: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the SHAS-Y20B-TULIB site (The X in the box and whisker chart represents the mean)

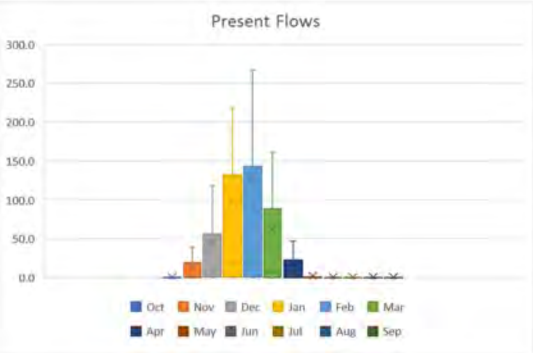
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	11.3	115.3	302.1	588.0	927.3	357.8	119.4	19.0	23.8	6.7	0.0	2.1
1	10.3	96.5	241.1	417.7	482.7	256.4	103.5	14.0	6.9	0.8	0.0	0.8
5	5.1	67.1	153.0	281.0	283.9	172.1	58.0	4.5	0.1	0.0	0.0	0.0
10	1.1	47.5	107.1	177.7	186.5	137.0	40.0	1.6	0.0	0.0	0.0	0.0
15	0.8	40.8	90.0	144.9	163.8	72.6	23.9	1.2	0.0	0.0	0.0	0.0
20	0.4	26.6	74.0	124.3	124.2	61.7	13.8	0.6	0.0	0.0	0.0	0.0
30	0.1	17.8	42.1	84.9	81.4	36.3	7.5	0.1	0.0	0.0	0.0	0.0
40	0.0	8.8	28.4	49.7	40.9	28.6	4.0	0.0	0.0	0.0	0.0	0.0
50	0.0	5.6	21.8	31.6	31.5	12.0	2.4	0.0	0.0	0.0	0.0	0.0
60	0.0	3.9	14.6	22.1	19.6	8.5	1.2	0.0	0.0	0.0	0.0	0.0
70	0.0	2.5	9.7	14.0	13.5	2.2	0.4	0.0	0.0	0.0	0.0	0.0
80	0.0	0.9	5.9	7.5	6.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.4	3.9	6.0	3.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.1	1.7	4.4	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	1.0	2.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A



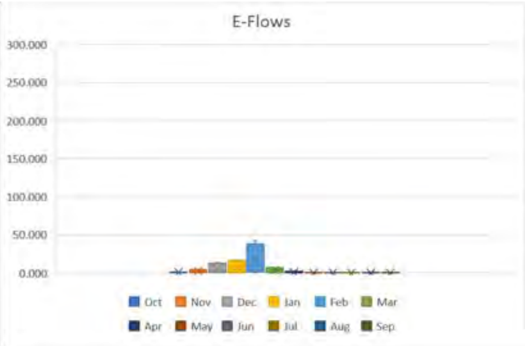
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	1.6	72.4	268.7	537.5	945.0	362.0	111.5	13.5	2.6	3.0	0.0	0.2
1	1.5	67.2	165.9	389.0	440.4	250.9	94.0	11.2	2.1	0.4	0.0	0.1
5	0.6	38.7	118.1	218.8	266.9	161.7	46.9	2.6	0.0	0.0	0.0	0.0
10	0.1	22.6	62.3	143.2	165.3	116.4	31.9	0.7	0.0	0.0	0.0	0.0
15	0.0	14.8	49.9	121.7	120.1	61.5	13.5	0.2	0.0	0.0	0.0	0.0
20	0.0	8.9	40.0	102.6	109.2	50.4	7.4	0.0	0.0	0.0	0.0	0.0
30	0.0	4.9	22.5	69.3	73.2	26.7	3.4	0.0	0.0	0.0	0.0	0.0
40	0.0	1.1	13.2	30.6	26.4	20.1	1.5	0.0	0.0	0.0	0.0	0.0
50	0.0	0.9	7.9	18.2	16.3	5.3	0.4	0.0	0.0	0.0	0.0	0.0
60	0.0	0.4	4.3	9.6	10.0	2.3	0.1	0.0	0.0	0.0	0.0	0.0
70	0.0	0.2	2.6	4.6	5.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.8	1.7	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.4	1.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

B



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	3.535	4.735	14.163	17.257	42.355	7.260	1.807	0.361	0.084	0.010	0.000	0.003
1	3.529	4.723	14.141	17.223	42.270	7.235	1.803	0.359	0.084	0.010	0.000	0.003
5	3.506	4.704	14.112	17.197	42.209	7.214	1.792	0.357	0.084	0.006	0.000	0.003
10	1.090	4.601	13.978	16.751	39.523	7.139	1.769	0.352	0.008	0.000	0.000	0.003
15	0.773	4.551	12.386	15.337	37.335	6.954	1.730	0.342	0.002	0.000	0.000	0.000
20	0.388	4.370	11.000	13.959	32.428	6.676	1.650	0.327	0.000	0.000	0.000	0.000
30	0.119	3.954	8.005	11.441	24.832	5.874	1.421	0.067	0.000	0.000	0.000	0.000
40	0.037	2.964	5.678	8.370	16.684	4.628	1.022	0.019	0.000	0.000	0.000	0.000
50	0.011	2.193	3.072	4.571	8.605	3.274	0.711	0.004	0.000	0.000	0.000	0.000
60	0.004	1.286	1.690	2.447	4.839	1.851	0.368	0.000	0.000	0.000	0.000	0.000
70	0.000	0.674	0.864	1.097	2.586	0.891	0.150	0.000	0.000	0.000	0.000	0.000
80	0.000	0.383	0.531	0.565	1.679	0.435	0.023	0.000	0.000	0.000	0.000	0.000
85	0.000	0.317	0.488	0.565	1.563	0.331	0.012	0.000	0.000	0.000	0.000	0.000
90	0.000	0.112	0.488	0.565	1.123	0.273	0.004	0.000	0.000	0.000	0.000	0.000
95	0.000	0.010	0.488	0.565	0.344	0.050	0.000	0.000	0.000	0.000	0.000	0.000
99	0.000	0.000	0.225	0.549	0.019	0.003	0.000	0.000	0.000	0.000	0.000	0.000
99.9	0.000	0.000	0.170	0.418	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000

C



Summary of IFR estimate for: SHAS-Y20B-TULIB site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	686.791
S.Dev.	=	719.6
CV	=	1.048
Q75	=	0
Q75/MMF	=	0
BFI Index	=	0.127
CV(JJA+JFM) Index	=	9.814
ERC	=	C
Total IFR	=	118.78 (17.29 %MAR)
Maint. Low flow	=	36.627 (5.33 %MAR)
Drought Low flow	=	0 (0 %MAR)
Maint. High flow	=	82.153 (11.96 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-14: Summary of statistics for environmental flows (E-flows) for the SHAS-Y20B-TULIB site.

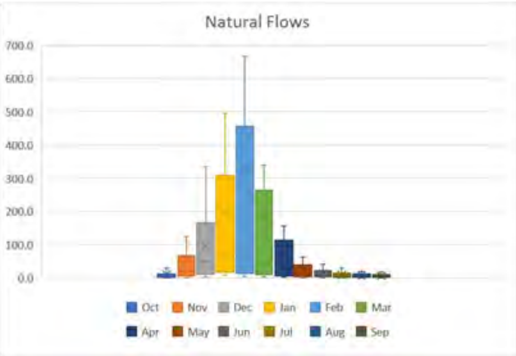
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	0.688	1.983	1.076	0.049	0	2.676	2.725
Nov	16.848	24.347	0.558	0.758	0	2.765	3.523
Dec	42.695	55.175	0.482	1.957	0	4.447	6.404
Jan	73.879	101.819	0.515	3.49	0	5.037	8.527
Feb	78.507	130.599	0.688	4.012	0	14.571	18.583
Mar	39.456	62.475	0.591	2.44	0	2.676	5.116
Apr	11.47	22.016	0.741	1.137	0	0	1.137
May	0.907	2.901	1.194	0.224	0	0	0.224
Jun	0.373	2.735	2.829	0.051	0	0	0.051
Jul	0.084	0.771	3.439	0.006	0	0	0.006
Aug	0	0	0	0	0	0	0
Sep	0.035	0.247	2.73	0.002	0	0	0.002

LIMPOPO RIVER: LIMP-A71L-MAPUN

Table 9-15: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LIMP-A71L-MAPUN site (The X in the box and whisker chart represents the mean)

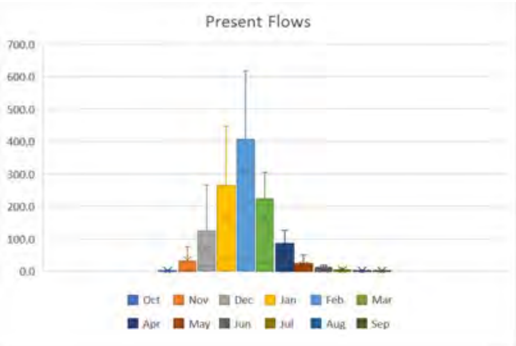
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	63.1	333.1	335.5	863.0	2009.0	1039.5	303.6	110.2	52.9	28.6	20.3	16.6
1	28.5	199.1	323.3	750.4	1327.8	735.1	293.1	108.5	40.8	22.0	17.8	14.9
5	14.5	125.0	231.2	495.7	667.0	339.6	156.8	63.2	29.8	19.7	14.4	13.0
10	12.9	70.9	179.2	344.7	522.9	289.7	131.3	43.4	25.3	16.1	12.6	11.5
15	11.7	60.9	151.1	269.4	389.3	238.1	94.7	32.7	18.1	13.0	10.3	9.9
20	11.1	53.5	131.6	216.9	232.4	198.1	77.0	26.2	15.0	11.0	9.0	7.8
30	9.5	40.2	84.8	136.7	150.4	128.7	58.6	20.6	12.2	9.3	7.2	6.5
40	6.9	25.3	64.9	95.1	85.1	82.8	40.2	15.8	9.3	7.4	6.0	5.2
50	6.1	20.0	47.9	68.2	65.7	40.8	23.4	10.6	7.7	6.2	5.1	4.5
60	3.9	13.4	31.9	47.2	44.9	24.7	14.4	8.8	6.0	5.2	4.1	3.3
70	3.3	10.4	23.9	33.6	29.5	19.3	10.4	7.0	5.0	4.1	3.5	2.7
80	2.0	8.5	17.2	21.4	23.0	13.7	9.0	5.5	4.2	3.7	2.7	2.0
85	1.6	7.4	13.9	18.7	16.5	10.0	7.9	4.5	3.7	3.0	2.2	1.7
90	1.3	4.0	9.3	15.0	12.4	8.4	5.7	3.5	2.5	1.9	1.6	1.1
95	1.0	2.7	7.6	12.9	9.3	4.5	4.2	2.1	1.4	1.1	0.9	0.7
99	0.5	1.1	3.3	8.1	5.4	2.9	2.3	1.6	0.9	0.9	0.6	0.3
99.9	0.2	0.4	1.5	7.1	4.5	2.4	1.3	0.6	0.9	0.8	0.6	0.2



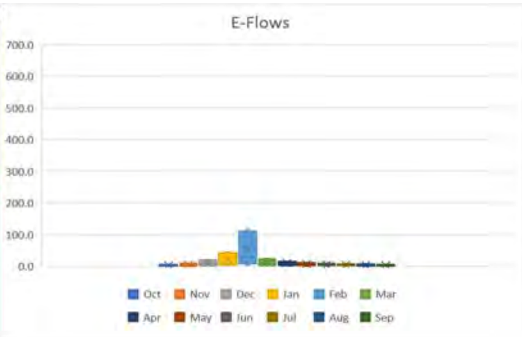
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	16.7	256.6	266.6	752.3	1985.9	995.9	267.4	88.3	36.8	16.9	8.8	6.4
1	7.4	150.4	262.4	663.4	1280.6	683.3	250.4	82.4	36.5	12.4	5.7	4.4
5	3.6	76.2	180.6	445.6	618.2	303.2	127.5	50.9	19.5	10.0	4.0	2.9
10	1.8	34.6	137.9	308.8	458.3	248.1	101.3	27.9	13.0	5.8	2.7	2.0
15	1.2	29.4	110.8	220.8	352.1	198.5	69.8	19.8	9.8	3.8	1.1	1.0
20	0.6	24.0	79.5	169.0	210.6	152.7	61.5	13.3	6.3	3.0	0.7	0.4
30	0.2	12.2	48.0	98.4	126.5	90.2	36.4	8.1	3.5	1.5	0.2	0.0
40	0.0	8.8	30.1	57.3	60.3	62.2	17.8	4.7	2.1	1.0	0.0	0.0
50	0.0	4.2	16.5	37.3	36.8	26.0	8.6	2.4	0.6	0.2	0.0	0.0
60	0.0	1.3	8.3	17.7	18.3	10.8	3.1	0.8	0.4	0.0	0.0	0.0
70	0.0	0.7	4.9	8.3	12.1	5.1	1.5	0.6	0.2	0.0	0.0	0.0
80	0.0	0.2	2.4	3.7	5.5	2.0	0.6	0.1	0.0	0.0	0.0	0.0
85	0.0	0.1	1.6	2.4	3.6	1.0	0.2	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.6	1.7	1.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.2	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	6.158	9.222	21.671	44.761	119.344	24.766	15.343	11.712	10.412	8.867	7.344	6.303
1	6.146	9.184	21.651	44.699	119.150	24.701	15.335	11.708	10.374	8.841	7.327	6.289
5	6.138	9.146	21.565	44.547	118.994	24.617	15.303	11.676	10.309	8.830	7.298	6.271
10	6.102	9.010	20.922	43.848	117.347	24.371	15.242	11.625	10.196	8.745	7.260	6.219
15	6.069	8.849	19.862	40.754	104.426	23.899	15.159	11.571	9.921	8.666	7.154	6.163
20	6.004	8.538	18.642	36.904	89.975	23.259	14.963	11.483	9.505	8.432	7.036	6.059
30	5.846	7.520	15.354	31.103	69.961	20.850	14.631	11.152	8.438	8.004	6.473	5.749
40	5.497	5.546	11.668	24.686	47.118	16.583	13.725	10.649	6.414	7.171	5.730	5.043
50	4.984	4.135	10.123	15.201	28.875	12.192	12.612	9.724	4.745	6.035	4.789	4.274
60	3.887	2.318	7.912	9.624	17.933	7.702	10.563	8.247	3.005	4.540	3.480	3.105
70	2.858	1.093	4.994	6.080	11.384	4.674	7.674	6.131	1.853	3.044	2.223	1.881
80	1.414	0.510	2.204	4.685	8.750	3.234	4.319	3.554	1.256	1.859	1.290	0.906
85	0.740	0.382	1.935	4.685	8.413	2.924	2.672	2.057	1.100	1.417	0.938	0.561
90	0.237	0.353	1.935	4.685	8.413	2.845	1.587	1.210	1.009	1.148	0.782	0.373
95	0.237	0.353	1.935	4.685	7.744	2.845	1.587	0.669	0.954	0.953	0.658	0.288
99	0.227	0.347	1.876	4.685	5.389	2.797	1.542	0.654	0.922	0.856	0.603	0.282
99.9	0.140	0.302	1.391	4.685	4.473	2.407	1.182	0.533	0.887	0.798	0.584	0.233



Summary of IFR estimate for: LIMP-A71L-MAPUN site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	1683.978
S.Dev.	=	1720.63
CV	=	1.022
Q75	=	14.82
Q75/MMF	=	0.106
BFI Index	=	0.221
CV(JJA+JFM) Index	=	2.238
ERC	=	B/C
Total IFR	=	408.764 (24.27 %MAR)
Maint. Low flow	=	271.946 (16.15 %MAR)
Drought Low flow	=	43.735 (2.6 %MAR)
Maint. High flow	=	136.819 (8.12 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-16: Summary of statistics for environmental flows (E-flows) for the LIMP-A71L-MAPUN site.

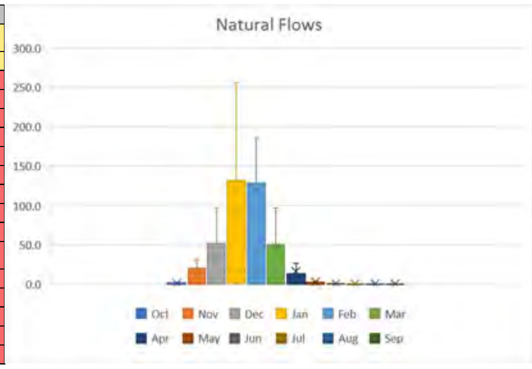
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	7.176	7.905	0.411	4.077	0.2	0	4.077
Nov	36.037	48.602	0.52	6.23	0.297	0	6.23
Dec	74.785	76.841	0.384	9.038	1.5	3.44	12.478
Jan	136.79	174.49	0.476	13.862	3.472	10.524	24.386
Feb	184.29	309.331	0.694	18.56	4.411	37.286	55.846
Mar	112.077	162.849	0.542	13.846	2.363	3.44	17.286
Apr	49.637	61.533	0.478	10.152	1.5	0	10.152
May	19.003	21.515	0.423	7.602	0.6	0	7.602
Jun	10.861	9.76	0.347	6.589	0.883	0	6.589
Jul	7.77	5.574	0.268	5.507	0.792	0	5.507
Aug	6.141	4.239	0.258	4.647	0.582	0	4.647
Sep	5.276	3.903	0.285	4.092	0.25	0	4.092

UMZINGWANI RIVER: UMZI-Y20C-BEITB

Table 9-17: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the UMZI-Y20C-BEITB site (The X in the box and whisker chart represents the mean)

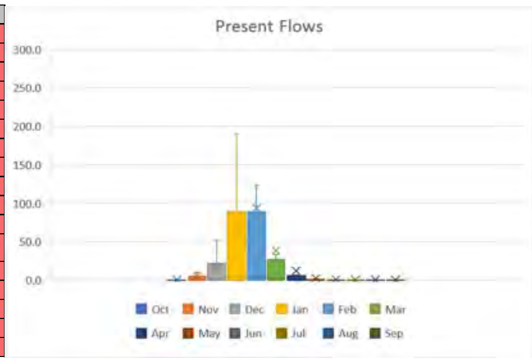
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	4.3	60.4	148.0	492.1	956.3	274.2	109.6	22.3	5.5	1.5	0.0	0.2
1	4.1	52.2	142.7	397.3	441.8	252.2	91.6	17.2	5.1	1.2	0.0	0.1
5	2.8	30.7	96.7	256.2	184.6	96.7	26.9	6.0	1.6	0.0	0.0	0.0
10	1.8	23.7	58.2	173.2	135.6	58.6	17.4	3.0	0.3	0.0	0.0	0.0
15	0.2	16.6	44.9	89.8	120.9	40.5	8.3	1.6	0.0	0.0	0.0	0.0
20	0.0	11.9	35.5	61.7	97.7	30.7	7.0	1.0	0.0	0.0	0.0	0.0
30	0.0	7.4	20.3	34.3	41.3	22.7	4.9	0.2	0.0	0.0	0.0	0.0
40	0.0	4.1	10.8	24.1	19.7	13.4	2.5	0.0	0.0	0.0	0.0	0.0
50	0.0	1.8	6.8	15.9	13.3	7.3	1.8	0.0	0.0	0.0	0.0	0.0
60	0.0	1.3	5.2	11.2	8.8	2.3	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.3	3.4	5.9	4.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	1.5	2.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.1	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



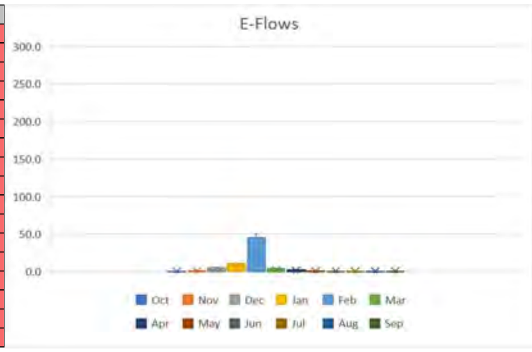
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	0.7	28.4	92.5	392.2	872.0	260.9	92.0	16.8	4.9	1.3	0.0	0.0
1	0.7	28.1	91.4	295.6	340.0	234.9	81.2	15.2	4.6	1.0	0.0	0.0
5	0.3	10.2	52.6	189.7	122.5	71.3	15.5	4.2	0.9	0.0	0.0	0.0
10	0.0	6.1	26.6	129.4	103.4	33.0	6.5	1.1	0.0	0.0	0.0	0.0
15	0.0	3.3	16.4	47.3	72.9	19.3	3.9	0.3	0.0	0.0	0.0	0.0
20	0.0	1.6	9.0	33.1	54.2	13.8	2.3	0.0	0.0	0.0	0.0	0.0
30	0.0	0.7	3.8	12.2	16.8	9.7	1.2	0.0	0.0	0.0	0.0	0.0
40	0.0	0.4	1.7	6.0	7.5	4.8	0.3	0.0	0.0	0.0	0.0	0.0
50	0.0	0.2	0.7	3.9	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0
60	0.0	0.0	0.5	1.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	0.0	0.5	5.6	10.9	49.6	4.3	2.3	0.4	0.1	0.0	0.0	0.0
1	0.0	0.4	5.6	10.9	49.5	4.3	2.3	0.4	0.1	0.0	0.0	0.0
5	0.0	0.4	5.6	10.8	49.4	4.2	2.3	0.4	0.1	0.0	0.0	0.0
10	0.0	0.4	5.3	10.7	47.4	4.2	2.3	0.4	0.1	0.0	0.0	0.0
15	0.0	0.4	4.9	10.3	42.8	4.2	2.2	0.4	0.0	0.0	0.0	0.0
20	0.0	0.4	4.3	9.9	37.8	4.2	2.2	0.4	0.0	0.0	0.0	0.0
30	0.0	0.4	3.4	9.0	27.7	4.1	2.2	0.2	0.0	0.0	0.0	0.0
40	0.0	0.3	2.0	8.1	18.2	3.9	2.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.2	1.2	7.0	9.4	3.7	1.8	0.0	0.0	0.0	0.0	0.0
60	0.0	0.1	0.7	5.0	5.4	2.3	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.3	3.1	3.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.2	0.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.1	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



Summary of IFR estimate for: UMZI-Y20C-BEITB site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	437.807
S.Dev.	=	597.163
CV	=	1.364
Q75	=	0
Q75/MMF	=	0
BFI Index	=	0.129
CV(JJA+JFM) Index	=	6.522
ERC	=	C
Total IFR	=	88.58 (20.23 %MAR)
Maint. Low flow	=	20.73 (4.74 %MAR)
Drought Low flow	=	0 (0 %MAR)
Maint. High flow	=	67.85 (15.50 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-18: Summary of statistics for environmental flows (E-flows) for the UMZI-Y20C-BEITB site.

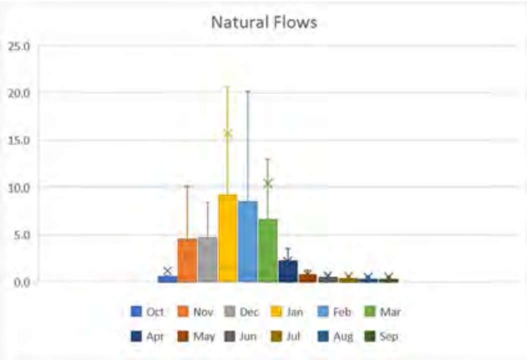
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	0.346	0.958	1.035	0.013	0	0	0.013
Nov	7.482	11.881	0.613	0.287	0	0	0.287
Dec	21.442	33.028	0.575	0.845	0	1.716	2.561
Jan	51.209	90.446	0.659	2.053	0	4.365	6.418
Feb	56.476	125.61	0.919	2.439	0	18.439	20.878
Mar	24.034	46.498	0.722	1.311	0	1.716	3.027
Apr	6.943	16.906	0.939	0.69	0	0.91	1.6
May	1.181	3.542	1.12	0.277	0	0	0.277
Jun	0.239	0.912	1.472	0.08	0	0	0.08
Jul	0.041	0.214	1.971	0.015	0	0	0.015
Aug	0	0	0	0	0	0	0
Sep	0.004	0.025	2.195	0	0	0	0

SAND RIVER: SAND-A71K-R508B

Table 9-19: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the SAND-A71K-R508B site (The X in the box and whisker chart represents the mean)

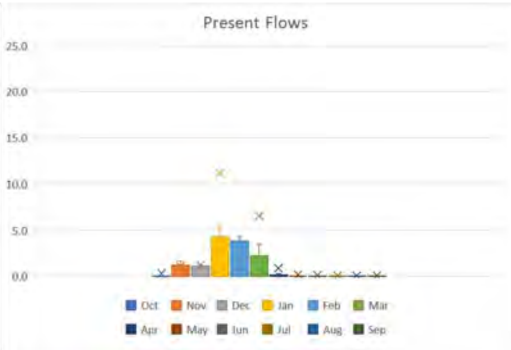
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	11.3	15.1	15.1	128.0	662.3	105.6	16.8	6.5	6.2	5.6	5.2	4.9
1	5.5	10.1	12.2	85.0	201.4	38.3	9.0	3.1	2.9	2.5	2.3	2.1
5	1.4	7.6	8.4	20.7	20.2	13.0	3.5	1.2	0.7	0.6	0.6	0.5
10	0.7	5.3	4.8	10.9	9.3	9.6	2.7	0.8	0.5	0.4	0.3	0.3
15	0.4	3.7	4.5	7.5	7.7	3.7	1.8	0.6	0.4	0.3	0.2	0.3
20	0.3	2.2	3.3	6.3	6.0	2.8	1.3	0.5	0.3	0.2	0.2	0.1
30	0.1	1.5	2.5	3.6	3.4	1.7	0.9	0.4	0.2	0.1	0.1	0.1
40	0.1	0.8	1.7	1.9	2.2	1.0	0.6	0.3	0.1	0.1	0.0	0.0
50	0.0	0.4	1.2	1.5	0.8	0.7	0.4	0.2	0.1	0.0	0.0	0.0
60	0.0	0.2	0.8	0.9	0.5	0.5	0.3	0.1	0.0	0.0	0.0	0.0
70	0.0	0.1	0.3	0.4	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



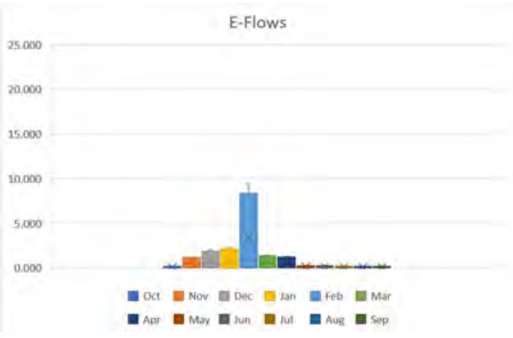
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	4.3	7.6	8.8	107.2	544.8	70.8	10.2	2.4	1.8	1.3	1.1	1.0
1	1.4	5.4	6.0	59.0	163.2	29.1	3.7	0.5	0.4	0.2	0.2	0.1
5	0.0	3.1	3.0	11.5	13.1	7.1	0.8	0.0	0.0	0.0	0.0	0.0
10	0.0	1.7	1.3	5.6	4.3	3.5	0.3	0.0	0.0	0.0	0.0	0.0
15	0.0	0.8	1.0	2.9	3.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.5	2.5	2.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.1	0.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	0.165	1.179	2.038	2.220	9.365	1.395	1.240	0.227	0.196	0.165	0.142	0.125
1	0.165	1.174	2.035	2.217	9.346	1.390	1.235	0.226	0.195	0.164	0.141	0.125
5	0.164	1.171	2.031	2.209	9.337	1.384	1.226	0.224	0.194	0.164	0.141	0.125
10	0.161	1.158	1.875	2.172	8.830	1.372	1.211	0.221	0.192	0.161	0.138	0.121
15	0.158	1.133	1.796	1.965	7.733	1.341	1.189	0.214	0.187	0.157	0.133	0.119
20	0.152	1.086	1.553	1.805	6.039	1.297	1.131	0.204	0.179	0.145	0.131	0.111
30	0.097	0.970	1.163	1.414	3.376	1.152	0.907	0.177	0.155	0.119	0.093	0.066
40	0.052	0.753	0.823	1.040	2.192	0.898	0.571	0.128	0.119	0.060	0.030	0.000
50	0.000	0.428	0.413	0.563	0.787	0.640	0.444	0.082	0.062	0.000	0.000	0.000
60	0.000	0.239	0.233	0.305	0.467	0.370	0.285	0.042	0.008	0.000	0.000	0.000
70	0.000	0.058	0.124	0.142	0.246	0.188	0.135	0.007	0.000	0.000	0.000	0.000
80	0.000	0.000	0.081	0.077	0.074	0.101	0.019	0.000	0.000	0.000	0.000	0.000
85	0.000	0.000	0.069	0.056	0.029	0.011	0.000	0.000	0.000	0.000	0.000	0.000
90	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
95	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000



Summary of IFR estimate for: SAND-A71K-R508B site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	74.191
S.Dev.	=	231.002
CV	=	3.114
Q75	=	0
Q75/MMF	=	0
BFI Index	=	0.192
CV(JJA+JFM) Index	=	7.399
ERC	=	C
Total IFR	=	24.061 (32.43 %MAR)
Maint. Low flow	=	6.689 (9.02 %MAR)
Drought Low flow	=	0 (0 %MAR)
Maint. High flow	=	17.372 (23.41 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-20: Summary of statistics for environmental flows (E-flows) for the SAND-A71K-R508B site.

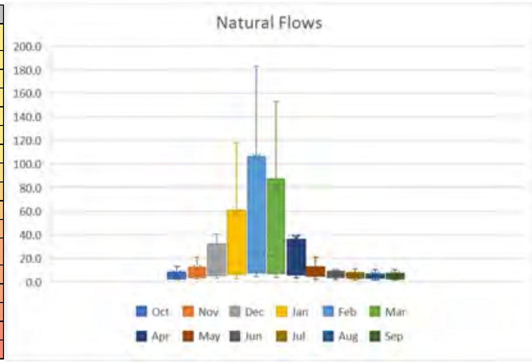
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	0.39	1.418	1.357	0.104	0	0	0.104
Nov	1.618	2.735	0.652	0.163	0	0.72	0.883
Dec	2.147	2.754	0.479	0.188	0	0.697	0.885
Jan	6.078	17.105	1.051	0.372	0	0.697	1.069
Feb	12.955	76.681	2.447	0.72	0	3.324	4.044
Mar	3.614	12.492	1.291	0.32	0	0.697	1.017
Apr	1.06	2.201	0.801	0.195	0	0.72	0.915
May	0.405	0.857	0.789	0.141	0	0	0.141
Jun	0.262	0.757	1.114	0.119	0	0	0.119
Jul	0.199	0.675	1.266	0.099	0	0	0.099
Aug	0.167	0.623	1.393	0.086	0	0	0.086
Sep	0.158	0.596	1.451	0.078	0	0	0.078

LUVUVHU RIVER: LUVU-A91K-OUTPO

Table 9-21: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LUVU-A91K-OUTPO site (The X in the box and whisker chart represents the mean)

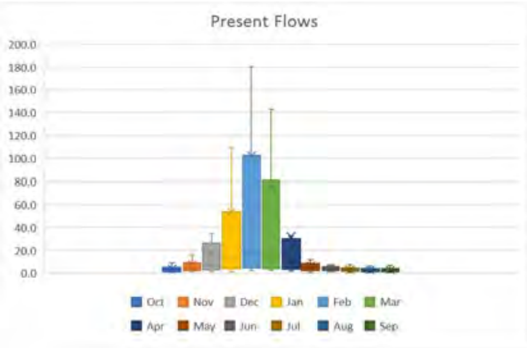
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	20.4	38.1	82.8	331.4	775.9	493.0	190.9	31.6	16.6	10.9	10.3	10.3
1	13.0	30.1	74.1	258.2	357.9	306.7	138.4	21.0	16.2	10.1	9.2	9.7
5	9.2	21.3	40.5	117.6	183.0	152.8	100.7	16.7	10.6	9.0	7.8	8.2
10	8.5	12.9	34.2	67.9	124.1	92.8	39.3	13.8	9.3	7.9	6.9	7.3
15	7.6	11.4	30.2	53.6	88.2	81.3	33.1	11.8	8.3	7.0	6.3	6.5
20	7.2	10.3	23.4	39.2	79.1	67.7	25.5	11.0	7.9	6.6	6.1	6.2
30	6.2	9.1	16.7	30.2	59.0	47.1	17.3	9.8	7.3	6.1	5.5	5.4
40	5.3	7.5	11.3	20.7	32.2	26.6	14.4	9.2	6.8	5.4	4.8	4.9
50	5.0	6.8	9.7	16.6	23.2	22.2	12.3	8.0	6.3	5.1	4.5	4.3
60	4.5	6.2	8.3	13.0	16.3	11.2	10.4	6.9	5.5	4.6	4.0	4.0
70	3.5	5.4	6.9	10.3	12.1	9.7	8.3	6.1	4.7	4.2	3.8	3.4
80	3.1	4.7	6.2	7.6	9.1	7.6	6.9	5.1	4.3	3.6	3.2	3.0
85	2.9	4.1	5.6	6.9	8.5	7.2	6.4	4.8	4.1	3.4	3.1	2.9
90	2.7	3.6	5.1	6.4	7.0	6.6	5.9	4.5	3.7	3.3	2.9	2.7
95	2.5	3.3	3.4	5.1	5.9	5.7	5.1	3.8	3.3	2.8	2.7	2.4
99	2.0	2.7	3.0	3.3	4.0	4.6	3.8	2.6	2.4	1.9	2.2	1.9
99.9	2.0	2.7	3.0	2.8	4.0	3.9	3.2	2.0	2.3	1.6	1.6	1.6



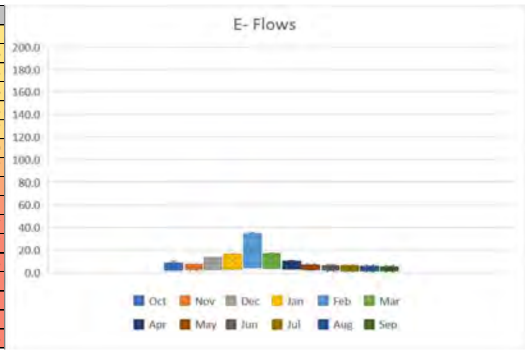
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	16.9	32.6	78.0	328.8	785.5	485.5	184.2	27.5	11.6	7.6	6.1	7.0
1	9.3	22.3	66.8	250.5	357.7	305.1	129.2	17.2	11.1	6.7	6.1	6.6
5	5.9	16.2	34.5	109.3	180.3	143.2	91.8	11.8	7.2	5.4	4.5	4.7
10	5.5	9.8	29.5	61.7	122.1	86.7	32.4	8.5	5.9	4.8	4.0	4.2
15	4.6	7.8	23.7	45.1	83.4	75.6	27.8	7.8	5.1	4.2	3.6	3.9
20	4.2	7.2	19.4	31.6	70.0	60.1	20.1	7.3	4.8	3.8	3.4	3.4
30	3.6	6.0	12.6	23.2	54.9	42.0	13.5	6.1	4.5	3.3	3.0	3.0
40	2.9	4.6	8.3	15.6	27.4	22.6	10.2	5.8	4.0	3.1	2.5	2.6
50	2.8	4.2	6.5	13.0	17.6	15.4	8.2	4.8	3.7	2.8	2.4	2.3
60	2.4	3.4	5.1	9.2	11.1	8.6	7.1	4.2	3.1	2.5	2.1	2.1
70	1.8	3.1	4.3	6.1	8.3	6.4	5.2	3.6	2.7	2.2	1.9	1.7
80	1.6	2.5	3.4	4.8	5.8	4.6	4.1	3.0	2.3	2.0	1.6	1.4
85	1.5	2.3	3.2	4.0	5.2	4.2	3.8	2.7	2.2	1.7	1.5	1.3
90	1.2	1.9	2.8	3.7	4.1	3.7	3.4	2.5	2.0	1.7	1.4	1.2
95	1.0	1.6	1.8	2.7	3.4	3.3	2.8	2.1	1.6	1.3	1.2	1.0
99	0.8	1.3	1.5	1.6	2.2	2.7	2.0	1.3	1.2	0.8	0.9	0.7
99.9	0.7	1.2	1.4	1.5	2.1	2.1	1.6	0.8	1.1	0.7	0.6	0.6



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	9.991	7.267	13.476	16.331	35.511	16.907	10.136	6.519	6.340	5.838	5.381	5.134
1	9.956	7.250	13.469	16.324	35.468	16.889	10.119	6.510	6.334	5.823	5.368	5.125
5	9.246	7.232	13.453	16.310	35.425	16.872	10.105	6.506	6.302	5.803	5.352	5.106
10	8.486	7.123	13.218	16.221	35.141	16.813	10.065	6.487	6.242	5.737	5.305	5.035
15	7.598	7.058	12.794	15.872	33.250	16.750	9.993	6.462	6.132	5.614	5.209	4.923
20	7.213	6.888	12.120	15.433	31.504	16.664	9.872	6.396	5.975	5.414	5.045	4.787
30	6.243	6.340	11.147	14.758	28.405	16.381	9.541	6.294	5.267	4.884	4.558	4.259
40	5.324	5.337	9.910	13.880	24.698	15.805	9.072	6.063	4.383	3.908	3.878	3.537
50	4.992	4.426	8.737	13.056	21.157	15.018	8.171	5.707	3.640	3.198	3.121	2.860
60	3.775	3.412	6.573	10.990	14.887	11.152	6.873	5.104	2.811	2.469	2.426	2.230
70	2.833	2.728	4.772	8.871	10.019	9.659	5.338	4.239	2.262	2.007	1.967	1.847
80	2.389	2.403	3.049	3.345	5.363	6.873	3.946	3.187	1.978	1.772	1.729	1.667
85	2.280	2.331	2.659	3.345	4.310	4.383	3.386	2.626	1.904	1.709	1.659	1.623
90	2.234	2.315	2.659	3.345	4.310	3.588	3.118	2.229	1.860	1.672	1.630	1.601
95	2.234	2.315	2.659	3.345	4.310	3.588	3.118	2.008	1.834	1.648	1.609	1.592
99	2.022	2.315	2.659	3.262	4.045	3.588	3.118	1.999	1.828	1.632	1.597	1.590
99.9	2.013	2.315	2.659	2.830	4.025	3.588	3.118	1.920	1.828	1.588	1.537	1.576



Summary of IFR estimate for: LUVU-A91K-OUTPO site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	559.847
S.Dev.	=	544.563
CV	=	0.973
Q75	=	12.62
Q75/MMF	=	0.271
BFI Index	=	0.32
CV(JJA+JFM) Index	=	1.993
ERC	=	C
Total IFR	=	224.297 (40.06 %MAR)
Maint. Low flow	=	134.904 (24.10 %MAR)
Drought Low flow	=	68.792 (12.29 %MAR)
Maint. High flow	=	89.393 (15.97 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-22: Summary of statistics for environmental flows (E-flows) for the LUVU-A91K-OUTPO site.

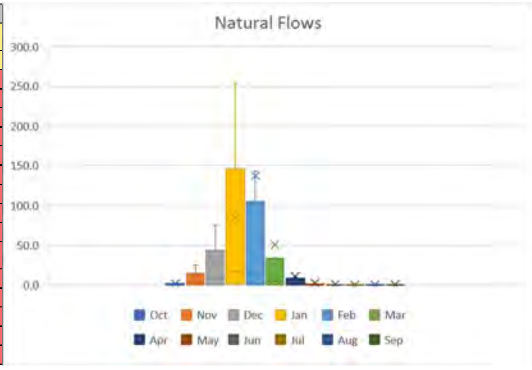
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	5.363	2.72	0.189	3.07	1.79	3.948	7.018
Nov	8.402	5.878	0.27	3.363	2.13	1.54	4.903
Dec	15.559	14.613	0.351	3.786	2.22	3.948	7.734
Jan	32.726	49.397	0.564	5.018	2.74	5.439	10.457
Feb	55.759	99.984	0.741	7.075	2.94	12.866	19.941
Mar	45.31	70.986	0.585	6.315	2.96	5.439	11.754
Apr	22.865	32.278	0.545	5.113	2.92	1.54	6.653
May	8.66	4.446	0.192	4.042	1.98	0	4.042
Jun	6.414	2.555	0.154	3.837	1.8	0	3.837
Jul	5.301	1.902	0.134	3.492	1.61	0	3.492
Aug	4.717	1.659	0.131	3.257	1.58	0	3.257
Sep	4.711	1.879	0.154	3.184	1.57	0	3.184

MWENEDZI RIVER: MWEN-Y20H-MALAP

Table 9-23: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the MWEN-Y20H-MALAP site (The X in the box and whisker chart represents the mean)

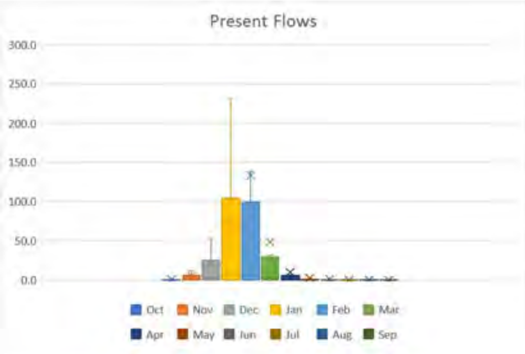
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	11.6	40.6	141.1	373.1	1354.0	405.3	77.6	25.2	10.3	2.5	0.2	2.9
1	10.6	38.2	111.2	371.2	465.1	230.7	53.9	11.0	3.5	0.5	0.0	1.3
5	3.9	24.7	76.4	252.7	143.1	96.0	26.2	5.7	1.0	0.0	0.0	0.0
10	2.1	15.9	53.0	179.5	120.8	33.9	9.2	1.5	0.0	0.0	0.0	0.0
15	0.9	13.2	34.3	111.5	89.6	32.3	7.0	0.8	0.0	0.0	0.0	0.0
20	0.3	11.7	27.7	71.5	64.9	25.0	5.7	0.5	0.0	0.0	0.0	0.0
30	0.0	6.9	17.4	35.3	33.4	16.0	3.9	0.0	0.0	0.0	0.0	0.0
40	0.0	4.9	10.4	23.4	24.0	10.7	1.9	0.0	0.0	0.0	0.0	0.0
50	0.0	3.0	7.5	16.7	14.5	5.4	0.9	0.0	0.0	0.0	0.0	0.0
60	0.0	1.9	3.8	7.0	9.2	3.3	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.6	2.1	4.2	5.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	1.0	2.2	1.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.3	1.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



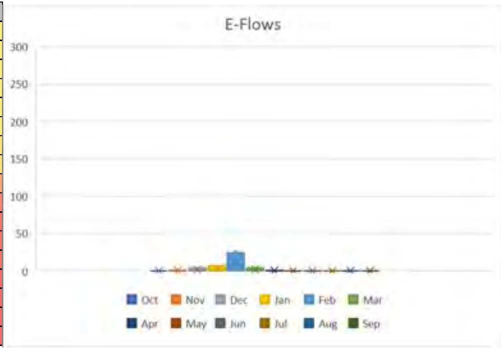
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	4.4	33.2	120.0	356.5	1357.9	403.1	78.0	25.3	9.1	2.6	0.2	2.5
1	3.9	21.8	90.7	356.1	466.9	231.4	51.8	11.2	3.4	0.5	0.0	0.5
5	0.8	11.7	53.9	231.0	138.7	84.8	17.3	4.0	0.6	0.0	0.0	0.0
10	0.1	6.3	28.7	130.3	113.4	31.6	6.5	1.3	0.1	0.0	0.0	0.0
15	0.1	5.3	20.7	78.6	84.7	26.8	5.5	0.8	0.0	0.0	0.0	0.0
20	0.1	3.9	12.6	52.1	54.9	20.3	4.8	0.5	0.0	0.0	0.0	0.0
30	0.0	1.9	6.7	24.4	24.6	13.3	2.5	0.0	0.0	0.0	0.0	0.0
40	0.0	1.2	4.4	12.8	13.2	6.6	1.2	0.0	0.0	0.0	0.0	0.0
50	0.0	0.8	2.5	7.5	6.6	2.6	0.5	0.0	0.0	0.0	0.0	0.0
60	0.0	0.3	1.3	3.4	3.7	1.6	0.1	0.0	0.0	0.0	0.0	0.0
70	0.0	0.1	0.8	1.3	2.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.4	0.8	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.2	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	0.307	0.931	4.518	7.223	27.16	4.335	0.841	0.353	0.344	0.299	0.25	0.293
1	0.306	0.928	4.511	7.219	27.1	4.332	0.839	0.352	0.343	0.279	0.247	0.291
5	0.304	0.925	4.499	7.186	27.03	4.298	0.835	0.349	0.331	0.25	0.246	0.274
10	0.298	0.916	4.435	6.998	25.75	4.223	0.82	0.343	0.301	0.243	0.246	0.266
15	0.292	0.899	3.99	6.685	23.09	4.18	0.809	0.315	0.295	0.243	0.246	0.258
20	0.283	0.867	3.565	6.207	21.06	4.037	0.783	0.306	0.293	0.243	0.246	0.258
30	0.236	0.76	2.824	4.9	15.83	3.646	0.695	0.299	0.293	0.243	0.246	0.201
40	0.189	0.622	2.012	3.897	8.686	2.589	0.475	0.228	0.293	0.243	0.209	0.201
50	0.122	0.467	1.08	2.466	5.891	1.904	0.336	0.228	0.293	0.243	0.209	0.106
60	0.064	0.301	0.614	1.365	3.357	0.963	0.267	0.228	0.293	0.061	0.209	0.054
70	0.027	0.19	0.334	0.665	1.841	0.426	0.179	0.079	0.053	0.061	0.03	0.023
80	0.027	0.137	0.222	0.389	0.619	0.276	0.154	0.064	0.014	0.018	0.019	0.014
85	0.027	0.125	0.208	0.389	0.377	0.256	0.154	0.061	0.009	0.018	0.019	0.014
90	0.004	0.122	0.208	0.389	0.25	0.246	0.124	0.059	0.005	0.004	0.004	0.003
95	0.004	0.122	0.208	0.338	0.223	0.239	0.124	0.059	0.003	0.003	0.002	0.002
99	0	0.122	0.193	0.238	0.204	0.22	0.124	0.058	0.002	0	0	0
99.9	0	0.122	0.076	0.229	0.197	0.213	0.124	0.058	0	0	0	0



Summary of IFR estimate for: MWEN-Y20H-MALAP site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	595.859
S.Dev.	=	583.5
CV	=	0.979
Q75	=	12.1
Q75/MMF	=	0.244
BFI Index	=	0.324
CV(JJA+JFM) Index	=	2.21

ERC	=	C/D
Total IFR	=	209.116 (35.09 %MAR)
Maint. Low flow	=	153.295 (25.73%MAR)
Drought Low flow	=	56.497 (9.48 %MAR)
Maint. High flow	=	55.821 (9.37 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-24: Summary of statistics for environmental flows (E-flows) for the MWEN-Y20H-MALAP site.

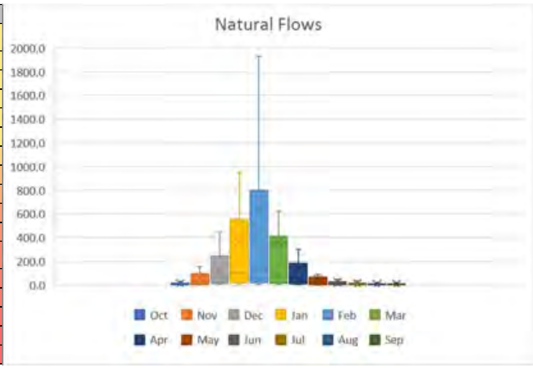
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	6.653	5.12	0.287	3.596	1.7	0	3.596
Nov	14.713	16.419	0.431	4.272	1.8	1.168	5.44
Dec	20.642	16.688	0.302	4.629	1.8	1.13	5.759
Jan	40.63	62.559	0.575	6.126	1.8	8.113	14.239
Feb	58.343	121.584	0.861	7.954	1.8	8.982	16.936
Mar	39.244	66.032	0.628	6.527	1.8	2.355	8.882
Apr	19.62	28.809	0.566	5.471	1.8	0	5.471
May	8.901	8.266	0.347	4.519	1.8	0	4.519
Jun	6.312	2.928	0.179	4.306	1.8	0	4.306
Jul	5.397	2.427	0.168	3.968	1.8	0	3.968
Aug	4.662	1.906	0.153	3.689	1.8	0	3.689
Sep	4.452	2.204	0.191	3.513	1.8	0	3.513

LIMPOPO RIVER: LIMP-Y30D-PAFUR

Table 9-25: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LIMP-Y30D-PAFUR site (The X in the box and whisker chart represents the mean)

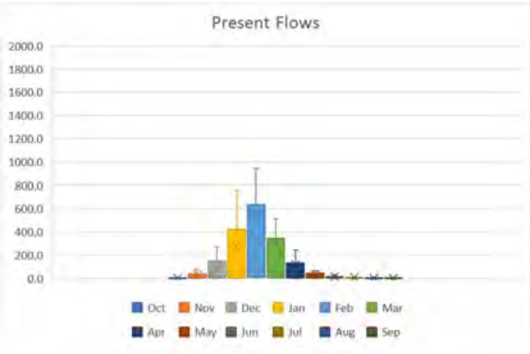
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	72.1	332.1	445.4	1575.1	5063.0	2417.0	695.6	242.9	111.6	52.8	27.5	19.3
1	33.1	228.1	402.9	1562.0	1931.6	1274.5	681.2	190.6	83.6	36.5	22.3	18.7
5	20.1	153.8	358.9	955.0	1129.8	626.1	297.4	89.9	46.7	24.3	15.9	12.9
10	15.8	103.9	263.4	678.9	887.1	441.6	201.3	66.0	31.3	16.8	12.0	11.1
15	14.4	79.5	222.4	420.8	707.0	384.0	168.3	58.9	25.2	15.7	9.9	9.8
20	11.8	64.1	178.1	329.2	498.6	347.8	146.6	49.2	21.3	11.6	9.3	8.6
30	9.7	50.9	127.4	182.5	299.5	231.3	91.7	31.6	17.2	9.4	6.8	5.5
40	7.2	39.6	93.0	157.4	167.7	146.5	69.8	23.3	11.6	7.3	5.6	4.3
50	4.4	24.9	61.8	102.1	120.0	75.1	44.4	18.7	8.7	5.9	4.0	3.6
60	3.3	18.2	44.1	75.5	74.3	50.2	29.9	12.6	7.3	4.6	3.1	2.5
70	2.8	10.6	34.0	54.0	46.6	35.0	17.3	9.3	5.7	3.9	2.6	2.1
80	1.6	8.9	21.2	33.0	32.6	19.9	11.6	6.5	3.8	2.7	1.8	1.5
85	1.4	6.9	15.7	23.6	26.3	13.6	10.7	4.4	2.6	2.0	1.5	1.1
90	1.1	4.5	11.9	19.5	19.4	11.2	8.1	3.2	2.2	1.5	1.0	0.9
95	0.8	1.9	6.6	13.1	10.7	7.4	6.5	2.4	1.7	1.0	0.8	0.5
99	0.1	1.1	2.2	4.9	3.1	3.7	2.4	1.1	0.4	0.0	0.3	0.0
99.9	0.1	0.8	1.2	4.1	3.0	2.1	1.3	0.1	0.3	0.0	0.0	0.0

A



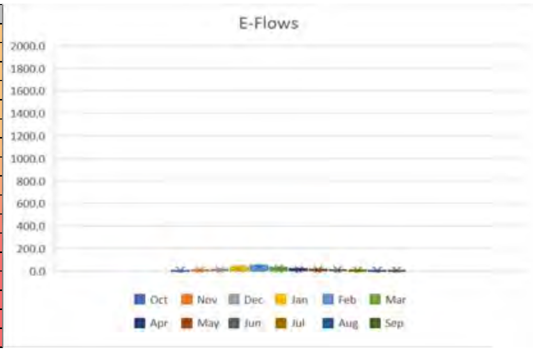
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	20.7	227.4	272.8	1351.9	4676.8	2253.6	638.7	210.2	89.5	33.8	10.3	6.1
1	17.3	142.2	270.2	1263.3	1732.5	1168.4	612.5	157.0	57.7	17.1	5.8	5.6
5	5.0	76.0	228.5	755.7	944.6	514.3	245.7	63.3	29.2	11.6	3.8	4.3
10	4.6	47.9	161.6	554.6	686.8	369.4	141.4	43.9	18.1	6.4	3.1	3.3
15	3.8	31.1	136.7	288.5	584.2	320.8	122.6	36.2	12.1	4.4	2.7	3.0
20	3.4	23.6	100.8	242.7	385.4	274.3	108.0	30.2	10.6	3.8	2.4	2.5
30	2.7	14.8	64.0	112.3	210.6	176.9	57.0	16.3	6.6	2.7	2.1	2.0
40	2.1	10.1	36.8	91.2	110.0	94.2	39.9	10.2	4.1	2.3	1.6	1.7
50	1.8	5.3	21.4	50.4	69.4	45.8	23.0	6.4	3.4	1.9	1.5	1.3
60	1.5	3.2	10.1	29.4	34.0	26.4	11.5	4.5	2.6	1.6	1.2	1.1
70	0.9	2.5	6.6	16.7	17.3	18.8	6.5	3.1	1.8	1.3	1.0	0.7
80	0.6	1.7	4.1	7.9	10.4	7.4	4.3	2.4	1.4	1.0	0.6	0.4
85	0.5	1.3	2.9	4.3	7.8	4.4	3.8	2.1	1.3	0.8	0.5	0.4
90	0.2	0.9	2.1	3.3	6.7	3.6	2.9	1.7	1.0	0.8	0.5	0.2
95	0.1	0.6	1.2	1.8	3.3	2.5	2.0	1.1	0.8	0.4	0.2	0.0
99	0.0	0.3	0.6	0.7	1.2	1.7	1.1	0.4	0.2	0.0	0.0	0.0
99.9	0.0	0.3	0.5	0.5	1.1	1.2	0.7	0.0	0.1	0.0	0.0	0.0

B



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	4.684	8.050	13.222	38.194	51.402	34.358	18.940	13.450	11.237	8.000	5.693	4.625
1	4.674	8.023	13.180	38.173	51.211	34.232	18.922	13.435	11.220	7.982	5.682	4.620
5	4.669	8.003	13.142	38.040	51.139	34.123	18.808	13.406	11.201	7.971	5.670	4.601
10	4.633	7.876	12.959	37.537	50.426	33.539	18.430	13.347	11.139	7.882	5.633	4.574
15	4.620	7.778	12.689	35.564	48.034	32.958	18.000	13.272	11.062	7.844	5.567	4.525
20	4.573	7.439	12.184	32.941	44.177	32.109	17.298	13.173	10.948	7.703	5.500	4.454
30	4.452	6.764	10.702	26.835	37.296	28.579	14.597	12.755	10.569	7.274	5.196	4.134
40	4.186	5.335	8.250	23.149	28.714	22.343	12.061	11.818	9.611	6.478	4.635	3.665
50	3.785	3.895	5.664	15.330	18.057	16.201	8.166	11.049	8.719	5.784	3.984	3.054
60	3.111	2.411	3.259	9.733	10.438	9.717	4.803	9.264	7.117	4.452	2.972	2.181
70	2.159	1.410	1.819	6.177	5.879	5.343	2.661	6.707	5.019	2.932	1.855	1.246
80	1.055	0.934	1.240	4.777	4.045	3.264	1.651	3.592	2.818	1.527	0.879	0.501
85	0.500	0.829	1.166	4.777	3.810	2.797	1.421	1.547	1.846	0.943	0.499	0.235
90	0.156	0.806	1.166	4.777	3.810	2.703	1.299	0.760	1.077	0.535	0.252	0.095
95	0.156	0.806	1.166	4.777	3.810	2.703	1.299	0.106	0.534	0.231	0.085	0.029
99	0.144	0.801	1.158	4.704	3.097	2.626	1.288	0.098	0.355	0.017	0.032	0.000
99.9	0.129	0.764	1.097	4.116	2.965	2.007	1.198	0.030	0.299	0.002	0.003	0.000

C



Summary of IFR estimate for: LIMP-Y30D-PAFUR site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	2792.125
S.Dev.	=	3384.242
CV	=	1.212
Q75	=	13.71
Q75/MMF	=	0.059
BFI Index	=	0.182
CV(JJA+JFM) Index	=	2.677
ERC	=	C
Total IFR	=	337.39 (12.08 %MAR)
Maint. Low flow	=	291.978 (10.46 %MAR)
Drought Low flow	=	32.368 (1.16 %MAR)
Maint. High flow	=	45.412 (1.63 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-26: Summary of statistics for environmental flows (E-flows) for the LIMP-Y30D-PAFUR site.

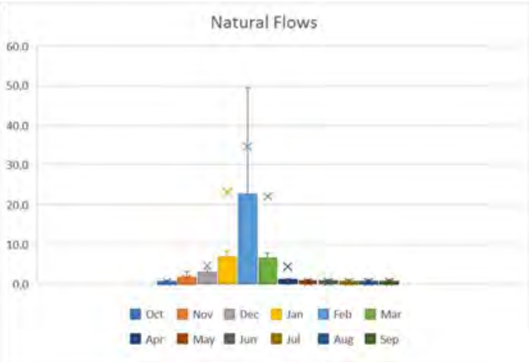
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	7.668	9.488	0.462	2.946	0.127	0	2.946
Nov	44.627	55.35	0.479	5.126	0.76	0	5.126
Dec	104.655	107.84	0.385	8.639	1.09	0	8.639
Jan	232.031	324.844	0.523	16.366	4.051	5.652	22.018
Feb	332.167	649.14	0.808	23.62	2.976	6.257	29.877
Mar	203.647	328.744	0.603	17.268	1.938	5.652	22.92
Apr	90.181	122.164	0.523	11.909	1.188	0	11.909
May	30.905	38.846	0.469	8.356	0.022	0	8.356
Jun	14.704	17.206	0.451	6.812	0.293	0	6.812
Jul	8.437	8.422	0.373	4.793	0	0	4.793
Aug	5.697	5.092	0.334	3.452	0	0	3.452
Sep	4.864	4.305	0.342	2.873	0	0	2.873

SHINGWEDZI RIVER: SHIN-B90H-POACH

Table 9-27: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the SHIN-B90H-POACH site (The X in the box and whisker chart represents the mean)

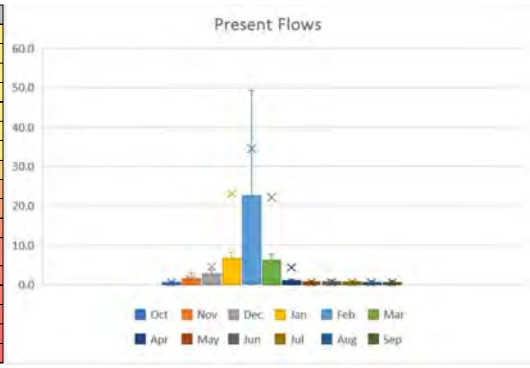
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	2.5	7.2	33.9	170.4	347.3	213.5	46.3	2.1	2.0	1.9	1.9	1.8
1	1.7	6.3	27.1	152.0	135.1	125.6	19.9	2.1	2.0	1.9	1.8	1.7
5	1.0	3.1	7.8	51.5	49.5	20.9	3.9	1.2	1.2	1.2	1.1	1.1
10	0.7	2.1	3.9	8.4	35.0	7.9	1.4	0.9	0.8	0.8	0.8	0.7
15	0.6	1.3	2.0	5.4	10.5	5.0	1.1	0.7	0.7	0.7	0.7	0.7
20	0.5	0.9	1.4	3.0	5.6	2.3	0.8	0.6	0.6	0.5	0.5	0.5
30	0.3	0.4	0.9	1.4	2.1	1.1	0.6	0.4	0.4	0.3	0.3	0.3
40	0.2	0.3	0.7	0.9	0.9	0.5	0.4	0.3	0.3	0.3	0.2	0.2
50	0.2	0.2	0.5	0.5	0.5	0.3	0.3	0.2	0.2	0.2	0.2	0.2
60	0.1	0.1	0.3	0.3	0.4	0.2	0.2	0.2	0.2	0.1	0.1	0.1
70	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
80	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
85	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
90	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
95	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A



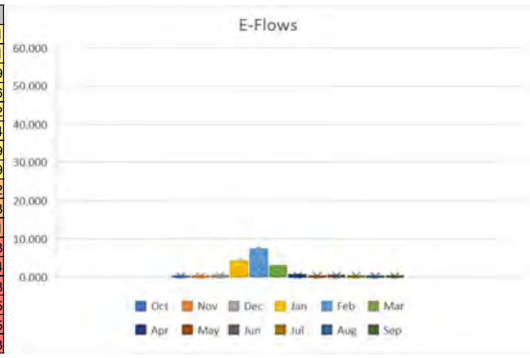
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	2.1	7.0	33.7	170.2	347.1	213.4	46.1	1.9	1.9	1.8	1.7	1.6
1	1.5	6.1	26.9	151.8	134.9	125.4	19.8	1.9	1.9	1.7	1.6	1.5
5	0.8	2.9	7.5	51.3	49.2	20.7	3.7	1.1	1.1	1.0	1.0	0.9
10	0.6	1.9	3.7	8.2	34.8	7.7	1.3	0.7	0.7	0.7	0.6	0.6
15	0.5	1.1	1.8	5.1	10.3	4.8	0.9	0.6	0.6	0.6	0.5	0.5
20	0.4	0.8	1.2	2.7	5.4	2.1	0.6	0.5	0.5	0.5	0.4	0.4
30	0.2	0.4	0.8	1.2	1.9	0.9	0.5	0.3	0.3	0.3	0.3	0.2
40	0.2	0.3	0.6	0.7	0.7	0.5	0.3	0.2	0.2	0.2	0.2	0.2
50	0.1	0.2	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.1
60	0.1	0.1	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1
70	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
80	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
85	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
90	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
95	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

B



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	0.346	0.378	0.484	4.726	7.781	3.021	0.623	0.422	0.431	0.414	0.389	0.371
1	0.345	0.377	0.484	4.722	7.764	3.013	0.621	0.422	0.431	0.413	0.388	0.371
5	0.345	0.377	0.483	4.705	7.751	2.998	0.619	0.421	0.430	0.412	0.387	0.369
10	0.343	0.375	0.481	4.297	7.688	2.964	0.615	0.417	0.426	0.409	0.383	0.366
15	0.342	0.372	0.478	4.161	6.863	2.911	0.612	0.414	0.421	0.403	0.379	0.362
20	0.338	0.368	0.475	2.961	5.613	2.263	0.604	0.408	0.414	0.396	0.373	0.354
30	0.287	0.355	0.465	1.449	2.102	1.120	0.556	0.381	0.370	0.347	0.325	0.309
40	0.224	0.305	0.442	0.874	0.889	0.530	0.413	0.276	0.255	0.254	0.243	0.239
50	0.161	0.208	0.409	0.504	0.545	0.336	0.258	0.205	0.204	0.190	0.179	0.162
60	0.127	0.135	0.344	0.306	0.352	0.213	0.201	0.168	0.158	0.149	0.146	0.143
70	0.101	0.120	0.183	0.228	0.242	0.157	0.147	0.134	0.131	0.119	0.111	0.091
80	0.082	0.076	0.081	0.149	0.156	0.116	0.104	0.089	0.086	0.074	0.060	0.048
85	0.052	0.039	0.029	0.125	0.152	0.112	0.063	0.054	0.055	0.054	0.044	0.034
90	0.024	0.029	0.029	0.093	0.123	0.097	0.035	0.035	0.041	0.039	0.033	0.028
95	0.024	0.029	0.029	0.069	0.080	0.084	0.035	0.025	0.029	0.029	0.026	0.025
99	0.024	0.027	0.028	0.040	0.040	0.037	0.034	0.024	0.025	0.025	0.024	0.025
99.9	0.023	0.027	0.026	0.031	0.030	0.031	0.031	0.023	0.023	0.023	0.023	0.023

C



Summary of IFR estimate for: SHIN-B90H-POACH site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	86.618
S.Dev.	=	200.484
CV	=	2.315
Q75	=	0.32
Q75/MMF	=	0.044
BFI Index	=	0.214
CV(JJA+JFM) Index	=	4.722
ERC	=	B/C
Total IFR	=	27.639 (31.91 %MAR)
Maint. Low flow	=	13.487 (15.57 %MAR)
Drought Low flow	=	0.806 (0.93 %MAR)
Maint. High flow	=	14.152 (16.34 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-28: Summary of statistics for environmental flows (E-flows) for the SHIN-B90H-POACH site.

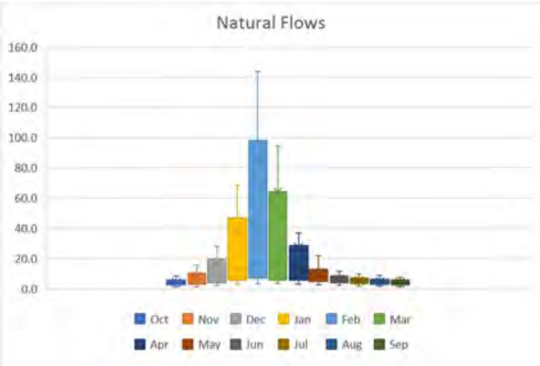
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	0.32	0.404	0.472	0.229	0.022	0	0.229
Nov	0.721	1.27	0.68	0.255	0.027	0	0.255
Dec	2.035	5.284	0.969	0.336	0.026	0	0.336
Jan	8.595	27.053	1.175	0.797	0.03	1.51	2.307
Feb	11.65	43.043	1.527	1.079	0.029	2.507	3.586
Mar	7.07	28.174	1.488	0.779	0.03	1.51	2.289
Apr	1.441	5.594	1.498	0.412	0.031	0	0.412
May	0.375	0.409	0.408	0.274	0.022	0	0.274
Jun	0.366	0.407	0.429	0.273	0.023	0	0.273
Jul	0.343	0.381	0.415	0.257	0.022	0	0.257
Aug	0.325	0.364	0.417	0.246	0.022	0	0.246
Sep	0.318	0.355	0.432	0.241	0.023	0	0.241

GROOT LETABA RIVER: GLET-B81J-LRANC

Table 9-29: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the GLET-B81J-LRANC site (The X in the box and whisker chart represents the mean)

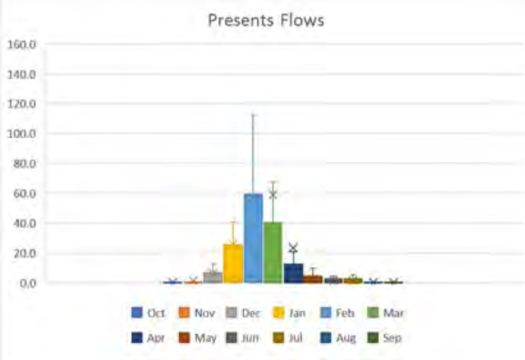
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	8.4	30.9	71.8	219.1	593.3	451.2	137.9	21.6	11.4	9.6	8.8	7.4
1	7.6	23.4	61.1	133.9	340.8	254.7	118.0	18.8	11.3	8.9	8.0	7.3
5	6.5	15.3	28.1	68.4	143.7	94.1	37.1	16.1	9.3	7.6	6.6	6.1
10	6.1	10.8	21.1	52.7	110.9	69.8	31.7	13.5	8.5	7.4	6.2	5.7
15	5.3	9.1	17.7	40.8	84.5	57.7	25.2	12.5	8.3	6.5	5.7	5.4
20	5.0	8.4	15.3	36.0	55.8	43.7	23.0	11.0	7.9	6.3	5.3	5.0
30	4.6	7.2	12.8	24.1	36.2	30.9	19.4	9.8	7.1	5.9	5.0	4.7
40	4.2	5.9	10.9	15.9	22.6	19.5	15.4	8.9	6.7	5.5	4.8	4.4
50	3.8	5.3	9.0	12.8	17.2	15.3	11.7	7.6	6.2	5.1	4.6	4.1
60	3.4	4.8	7.2	10.5	12.9	11.1	8.6	6.6	5.7	4.6	4.0	3.5
70	2.9	4.1	5.9	8.1	9.9	7.8	7.6	5.8	5.0	4.2	3.7	3.2
80	2.6	3.3	4.7	7.0	7.8	6.5	6.7	5.4	4.5	3.7	3.3	2.7
85	2.4	3.1	4.2	6.4	7.3	6.1	5.7	4.9	4.2	3.5	3.0	2.6
90	2.3	2.7	3.6	5.1	6.5	5.4	5.4	4.4	3.8	3.3	2.8	2.5
95	2.0	2.2	2.9	3.8	4.6	4.8	4.4	3.7	3.3	2.7	2.4	2.1
99	1.6	1.7	2.1	3.1	3.4	3.4	3.3	2.6	2.2	2.0	1.7	1.6
99.9	1.3	1.4	1.9	2.9	3.2	3.3	3.2	2.4	2.1	1.8	1.6	1.4



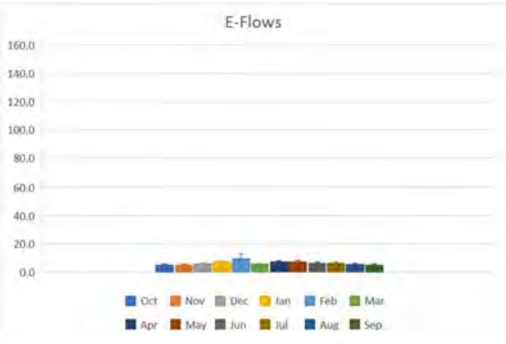
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	1.0	9.3	38.5	209.9	492.4	588.0	206.9	9.7	6.1	5.1	0.8	0.2
1	0.9	7.4	28.1	99.5	192.2	210.2	114.1	9.0	4.4	4.7	0.2	0.1
5	0.4	2.9	13.0	40.9	112.4	67.4	20.7	5.9	3.5	3.5	0.1	0.1
10	0.1	0.7	7.2	28.8	74.1	45.4	13.4	4.8	2.6	2.8	0.1	0.1
15	0.1	0.3	5.5	21.7	44.5	35.1	11.5	4.0	2.2	2.5	0.1	0.1
20	0.1	0.1	4.4	15.4	36.6	28.3	9.9	3.5	1.7	2.3	0.1	0.1
30	0.1	0.1	2.9	8.2	12.0	16.9	8.4	2.8	1.1	1.6	0.0	0.1
40	0.0	0.1	2.1	5.4	5.9	7.4	4.9	1.9	0.8	0.8	0.0	0.0
50	0.0	0.0	1.2	2.9	4.2	4.4	3.2	1.4	0.5	0.0	0.0	0.0
60	0.0	0.0	0.6	2.1	2.5	1.6	1.3	0.5	0.1	0.0	0.0	0.0
70	0.0	0.0	0.1	1.2	1.6	0.9	0.6	0.2	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.8	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	5.6	5.7	6.7	8.6	13.1	5.8	8.1	8.4	7.3	7.1	6.4	5.6
1	5.6	5.7	6.7	8.6	13.1	5.8	8.1	8.4	7.3	7.1	6.4	5.6
5	5.6	5.7	6.7	8.6	13.1	5.8	8.1	8.4	7.3	7.1	6.4	5.6
10	5.6	5.7	6.7	8.6	13.1	5.8	8.1	8.4	7.3	7.1	6.4	5.6
15	4.1	4.2	5.0	5.9	5.5	5.6	5.8	6.0	5.3	5.1	4.6	4.1
20	4.1	4.2	5.0	5.9	5.5	5.6	5.8	6.0	5.3	5.1	4.6	4.1
30	3.2	3.2	3.8	4.5	4.5	5.1	4.8	4.7	4.2	4.0	3.6	3.2
40	2.4	2.4	2.9	3.7	3.7	4.3	4.4	4.0	3.4	3.3	2.9	2.5
50	1.7	1.8	2.1	2.6	2.7	3.3	3.2	3.0	2.7	2.5	2.2	1.8
60	1.3	1.3	1.6	1.8	1.8	2.2	2.1	2.1	1.9	1.7	1.5	1.3
70	0.9	0.9	1.1	1.2	1.2	1.3	1.4	1.4	1.2	1.2	1.1	0.9
80	0.7	0.7	0.8	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.7
85	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
90	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
95	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4
99	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4
99.9	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4



Summary of IFR estimate for: GLET-B81J-LRANC site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	595.859
S.Dev.	=	583.5
CV	=	0.979
Q75	=	12.1
Q75/MMF	=	0.244
BFI Index	=	0.324
CV(JJA+JFM) Index	=	2.21

ERC	=	C/D
Total IFR	=	209.116 (35.09 %MAR)
Maint. Low flow	=	153.295 (25.73%MAR)
Drought Low flow	=	56.497 (9.48 %MAR)
Maint. High flow	=	55.821 (9.37 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-30: Summary of statistics for environmental flows (E-flows) for the GLET-B81J-LRANC site.

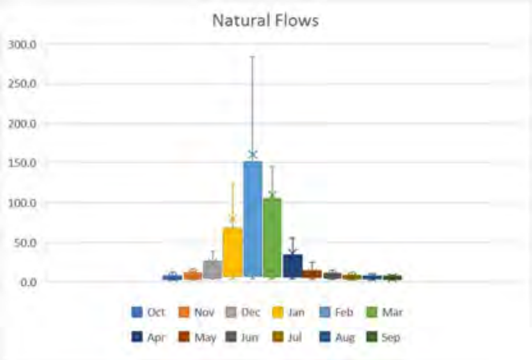
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	6.653	5.12	0.287	3.596	1.7	0	3.596
Nov	14.713	16.419	0.431	4.272	1.8	1.168	5.44
Dec	20.642	16.688	0.302	4.629	1.8	1.13	5.759
Jan	40.63	62.559	0.575	6.126	1.8	8.113	14.239
Feb	58.343	121.584	0.861	7.954	1.8	8.982	16.936
Mar	39.244	66.032	0.628	6.527	1.8	2.355	8.882
Apr	19.62	28.809	0.566	5.471	1.8	0	5.471
May	8.901	8.266	0.347	4.519	1.8	0	4.519
Jun	6.312	2.928	0.179	4.306	1.8	0	4.306
Jul	5.397	2.427	0.168	3.968	1.8	0	3.968
Aug	4.662	1.906	0.153	3.689	1.8	0	3.689
Sep	4.452	2.204	0.191	3.513	1.8	0	3.513

LETABA RIVER: LETA-B83A-LONEB

Table 9-31: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LETA-B83A-LONEB site (The X in the box and whisker chart represents the mean)

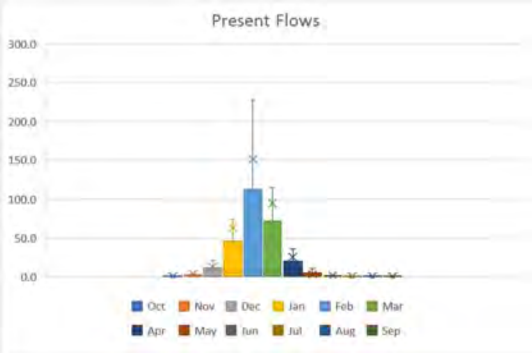
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	12.8	42.7	114.0	637.9	1385.9	849.1	193.9	24.8	14.7	12.9	10.8	9.6
1	9.9	28.8	108.8	300.5	520.7	470.1	180.7	20.7	14.4	11.6	10.3	9.2
5	8.6	17.0	38.9	123.8	283.8	144.4	56.0	17.3	12.0	10.2	8.9	8.8
10	7.8	12.4	28.2	74.6	174.7	128.6	38.1	14.7	10.7	8.7	7.8	7.5
15	7.2	10.9	23.9	61.6	128.3	81.7	30.2	13.3	10.3	8.4	7.6	7.1
20	6.6	8.7	18.7	48.5	87.6	67.7	22.8	12.6	10.1	8.1	7.1	6.6
30	6.1	8.0	14.1	28.8	39.3	34.0	19.0	11.9	9.4	7.5	6.5	6.2
40	5.6	7.6	11.7	18.6	26.4	20.2	14.3	10.7	8.8	7.0	6.0	5.7
50	5.0	6.8	9.8	14.8	17.0	13.6	12.0	9.3	7.9	6.5	5.8	5.3
60	4.5	6.4	8.1	12.2	13.7	11.2	10.2	8.5	7.4	6.1	5.3	4.8
70	4.1	5.2	7.0	9.4	11.2	9.0	8.4	7.7	6.6	5.6	4.9	4.4
80	3.7	4.4	6.2	8.4	8.7	7.7	7.5	6.6	5.8	5.0	4.4	4.1
85	3.6	4.3	5.1	8.0	8.0	6.7	7.0	6.3	5.6	4.6	4.2	3.9
90	3.3	4.0	4.7	6.4	7.3	6.7	6.3	5.5	4.9	4.4	4.1	3.7
95	3.1	3.6	4.0	5.0	6.2	5.6	5.6	5.1	4.6	3.8	3.6	3.3
99	2.7	3.0	3.6	4.1	5.0	4.9	4.6	3.8	3.7	3.3	2.9	2.7
99.9	2.2	2.3	3.0	3.8	4.0	3.9	4.1	3.5	3.2	2.9	2.7	2.5



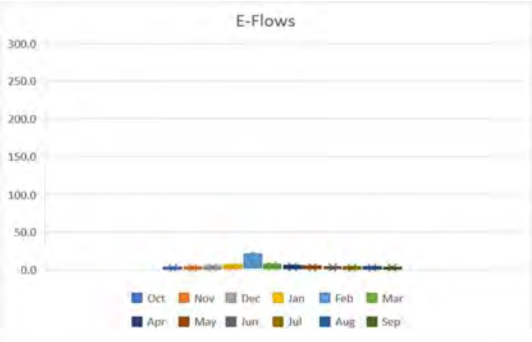
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	3.5	30.2	91.1	588.3	1476.3	875.2	158.9	14.7	8.3	4.0	1.1	1.3
1	1.6	18.7	62.9	255.6	512.9	382.8	156.8	10.6	5.4	3.8	0.8	0.8
5	0.8	7.7	21.1	74.3	227.7	114.9	36.1	8.3	3.5	1.7	0.6	0.6
10	0.6	3.2	13.2	53.3	127.3	88.9	22.0	5.6	1.7	0.9	0.6	0.6
15	0.6	2.1	9.9	38.7	97.9	54.3	17.4	4.1	1.4	0.6	0.6	0.6
20	0.6	1.2	7.8	32.9	65.0	43.3	14.3	3.5	1.0	0.6	0.6	0.6
30	0.6	0.8	4.1	16.2	30.7	26.0	10.0	2.3	0.6	0.6	0.6	0.6
40	0.6	0.6	1.8	7.5	17.4	12.8	7.5	1.0	0.6	0.6	0.6	0.6
50	0.6	0.6	0.8	4.7	7.7	5.6	3.9	0.6	0.6	0.6	0.6	0.6
60	0.6	0.6	0.7	2.7	3.0	2.2	1.1	0.6	0.6	0.6	0.6	0.6
70	0.6	0.6	0.6	0.9	1.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6
80	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
85	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
90	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
95	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
99	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
99.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	3.2	3.8	4.9	6.7	22.5	7.5	5.7	4.6	4.3	4.0	3.7	3.5
1	3.2	3.7	4.9	6.7	22.4	7.5	5.7	4.6	4.3	4.0	3.7	3.5
5	3.2	3.7	4.8	6.7	22.4	7.5	5.7	4.5	4.2	4.0	3.7	3.5
10	3.2	3.7	4.8	6.7	21.6	7.4	5.6	4.5	4.2	3.9	3.6	3.4
15	3.1	3.6	4.6	6.3	20.2	7.3	5.5	4.4	4.1	3.8	3.6	3.3
20	3.0	3.5	4.4	6.1	17.8	7.1	5.2	4.2	4.0	3.7	3.5	3.3
30	2.6	3.2	3.8	5.4	14.7	6.3	4.7	3.7	3.6	3.2	3.0	2.9
40	2.2	2.7	2.8	4.4	9.8	5.3	3.8	3.0	2.8	2.7	2.5	2.4
50	1.7	2.1	2.2	3.1	6.5	4.1	3.0	2.3	2.3	2.0	2.0	1.8
60	1.2	1.5	1.5	2.2	4.3	2.9	2.1	1.6	1.7	1.5	1.4	1.3
70	0.9	1.1	1.1	1.5	3.0	2.0	1.5	1.2	1.3	1.1	1.1	1.0
80	0.8	0.9	1.0	1.3	2.4	1.6	1.3	1.1	1.1	1.0	0.9	0.9
85	0.8	0.8	0.9	1.3	2.4	1.6	1.2	1.0	1.0	0.9	0.9	0.8
90	0.7	0.8	0.9	1.3	2.4	1.5	1.2	1.0	1.0	0.9	0.8	0.8
95	0.7	0.8	0.9	1.3	2.4	1.5	1.2	1.0	0.9	0.9	0.8	0.8
99	0.7	0.8	0.9	1.3	2.4	1.5	1.2	1.0	0.9	0.9	0.8	0.8
99.9	0.7	0.8	0.9	1.3	2.4	1.5	1.2	1.0	0.9	0.9	0.8	0.8



Summary of IFR estimate for: LETA-B83A-LONEB site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	595.859
S.Dev.	=	583.5
CV	=	0.979
Q75	=	12.1
Q75/MMF	=	0.244
BFI Index	=	0.324
CV(JJA+JFM) Index	=	2.21
ERC	=	C/D

Total IFR	=	209.116 (35.09 %MAR)
Maint. Low flow	=	153.295 (25.73%MAR)
Drought Low flow	=	56.497 (9.48 %MAR)
Maint. High flow	=	55.821 (9.37 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-32: Summary of statistics for environmental flows (E-flows) for the LETA-B83A-LONEB site.

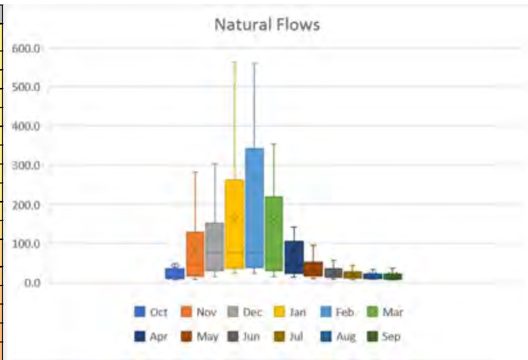
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	6.653	5.12	0.287	3.596	1.7	0	3.596
Nov	14.713	16.419	0.431	4.272	1.8	1.168	5.44
Dec	20.642	16.688	0.302	4.629	1.8	1.13	5.759
Jan	40.63	62.559	0.575	6.126	1.8	8.113	14.239
Feb	58.343	121.584	0.861	7.954	1.8	8.982	16.936
Mar	39.244	66.032	0.628	6.527	1.8	2.355	8.882
Apr	19.62	28.809	0.566	5.471	1.8	0	5.471
May	8.901	8.266	0.347	4.519	1.8	0	4.519
Jun	6.312	2.928	0.179	4.306	1.8	0	4.306
Jul	5.397	2.427	0.168	3.968	1.8	0	3.968
Aug	4.662	1.906	0.153	3.689	1.8	0	3.689
Sep	4.452	2.204	0.191	3.513	1.8	0	3.513

OLIFANTS RIVER: OLIF-B73H-BALUL

Table 9-33: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the OLIF-B73H-BALUL site (The X in the box and whisker chart represents the mean)

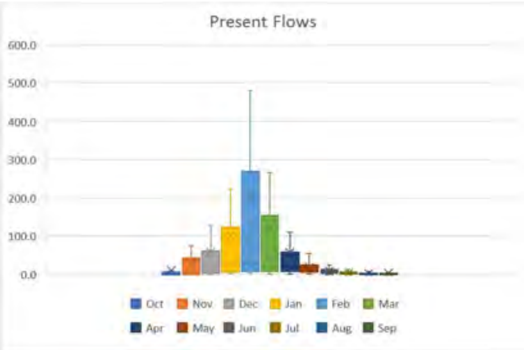
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	164.0	280.7	449.8	563.7	1166.5	683.0	388.6	115.6	56.0	42.5	33.1	39.1
1	144.1	254.3	302.1	492.8	1142.4	608.8	247.6	94.5	55.2	38.4	32.6	36.7
5	48.3	167.3	220.1	352.9	558.6	353.1	142.1	68.3	42.4	31.3	25.8	25.4
10	39.7	138.2	162.3	299.3	385.1	236.4	112.3	54.8	36.8	29.0	21.2	22.9
15	30.9	118.0	140.3	223.1	299.3	200.5	96.9	47.3	33.0	24.6	19.6	18.0
20	26.1	96.2	127.4	181.2	250.1	174.0	82.2	43.8	29.0	22.9	18.4	17.0
30	21.4	68.5	108.0	121.7	118.2	120.4	62.9	36.5	26.2	19.7	15.7	14.7
40	18.0	52.4	93.8	93.1	88.9	84.8	52.2	31.1	22.1	18.1	14.7	12.7
50	16.1	44.5	77.3	76.1	76.7	56.4	44.1	27.2	20.5	15.5	13.1	12.0
60	13.0	35.6	57.7	66.1	61.4	49.5	38.2	24.8	18.8	14.6	12.1	10.8
70	10.8	28.4	46.7	53.3	49.8	39.4	32.9	21.3	16.1	14.0	11.5	10.0
80	10.2	21.7	33.2	44.7	44.4	34.5	24.5	17.8	14.6	12.1	10.9	9.0
85	9.9	18.6	30.9	39.9	40.1	31.9	22.8	17.2	13.7	11.3	9.5	8.4
90	8.6	15.1	26.5	33.8	36.7	27.8	21.7	15.9	12.7	10.5	9.0	7.6
95	7.7	12.0	21.6	29.3	30.8	24.5	19.7	14.8	11.9	9.8	8.4	7.2
99	6.9	9.1	14.3	24.1	25.6	18.0	14.6	10.2	9.0	7.7	7.3	6.7
99.9	6.5	7.2	13.9	23.9	22.1	14.5	12.0	9.4	8.1	6.5	7.3	6.7



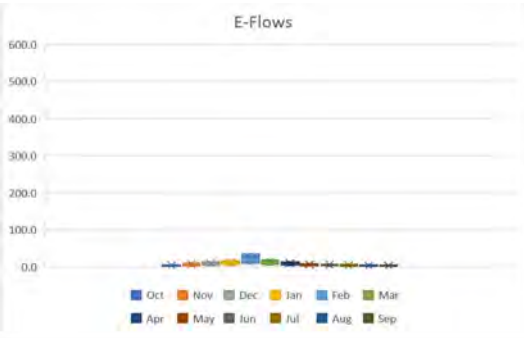
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	113.0	140.3	400.9	496.8	987.5	641.9	357.3	72.4	27.9	14.3	10.3	36.1
1	40.1	130.2	198.5	464.1	976.1	566.2	209.0	54.7	25.4	13.2	9.2	17.7
5	10.1	76.2	127.6	225.0	480.1	265.8	109.9	36.3	16.9	10.4	5.7	5.6
10	7.7	48.6	68.3	140.0	297.8	173.4	61.1	29.0	13.4	7.5	4.4	4.0
15	5.2	37.4	56.2	109.8	240.7	134.2	55.8	22.8	12.2	6.6	3.8	3.5
20	4.7	22.0	43.0	90.8	188.8	101.8	47.4	21.4	11.3	6.2	3.0	2.9
30	3.6	15.2	38.4	51.7	70.8	66.0	31.7	17.0	9.1	4.4	2.6	1.6
40	2.6	11.5	28.2	34.3	43.2	38.6	25.3	14.6	7.9	3.5	2.0	1.3
50	2.0	7.4	24.2	25.3	27.6	22.1	20.2	12.8	7.0	3.1	1.7	1.1
60	1.2	4.8	15.7	18.4	22.9	20.3	15.8	10.8	6.3	2.8	1.4	0.8
70	0.7	2.8	10.7	14.4	16.1	16.8	14.4	8.9	4.9	2.4	1.2	0.4
80	0.3	1.7	7.0	10.5	11.3	11.9	11.2	7.2	4.0	1.5	0.6	0.2
85	0.2	1.3	5.9	8.7	10.0	10.0	9.9	6.7	3.4	1.2	0.4	0.1
90	0.2	0.6	2.5	5.8	7.8	8.1	8.2	6.1	2.9	1.0	0.2	0.1
95	0.1	0.3	1.7	4.9	4.8	5.5	7.0	5.2	2.1	0.8	0.1	0.1
99	0.1	0.1	0.6	3.1	3.0	2.8	3.3	1.8	1.3	0.3	0.1	0.1
99.9	0.1	0.1	0.4	1.1	2.9	1.7	1.7	1.2	0.7	0.1	0.1	0.1



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	5.7	10.4	14.4	16.8	36.2	19.5	13.7	9.4	7.6	6.2	5.2	4.7
1	5.7	10.4	14.4	16.8	36.2	19.5	13.7	9.4	7.6	6.2	5.2	4.7
5	5.7	10.4	14.4	16.8	36.2	19.5	13.7	9.4	7.6	6.2	5.2	4.7
10	5.7	10.4	14.4	16.8	35.9	19.5	13.7	9.4	7.6	6.2	5.2	4.7
15	5.7	10.4	14.4	16.3	34.5	19.0	13.7	9.4	7.6	6.1	5.2	4.7
20	5.6	10.3	14.3	15.9	33.1	18.7	13.6	9.3	7.5	6.1	5.2	4.7
30	5.6	10.2	14.2	15.2	30.8	17.9	13.4	9.2	7.4	6.0	5.1	4.6
40	5.4	10.0	13.8	14.4	27.8	17.1	12.9	8.9	7.2	5.8	5.0	4.5
50	5.1	9.6	13.2	13.6	26.0	16.1	12.2	8.4	6.8	5.5	4.7	4.2
60	4.5	8.8	12.0	11.9	21.8	14.3	10.7	7.4	6.1	4.9	4.2	3.8
70	3.8	7.6	10.4	10.4	18.7	12.5	9.1	6.3	5.1	4.2	3.5	3.3
80	2.9	5.8	7.9	8.1	14.0	9.6	6.8	4.9	4.0	3.2	2.8	2.5
85	2.5	4.8	6.4	6.8	11.4	8.1	5.8	4.2	3.4	2.8	2.4	2.2
90	2.2	4.0	5.2	5.6	9.8	6.7	5.1	3.7	3.1	2.5	2.1	2.0
95	1.9	3.2	4.1	4.5	7.2	5.5	4.5	3.3	2.7	2.2	1.9	1.7
99	1.8	2.7	3.4	4.0	6.1	4.8	4.2	3.1	2.6	2.1	1.8	1.7
99.9	1.8	2.7	3.4	4.0	6.1	4.8	4.2	3.1	2.6	2.1	1.8	1.7



Summary of IFR estimate for: OLIF-B73H-BALUL site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	595.859
S.Dev.	=	583.5
CV	=	0.979
Q75	=	12.1
Q75/MMF	=	0.244
BFI Index	=	0.324
CV(JJA+JFM) Index	=	2.21
ERC	=	C/D

Total IFR	=	209.116 (35.09 %MAR)
Maint. Low flow	=	153.295 (25.73%MAR)
Drought Low flow	=	56.497 (9.48 %MAR)
Maint. High flow	=	55.821 (9.37 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-34: Summary of statistics for environmental flows (E-flows) for the OLIF-B73H-BALUL site.

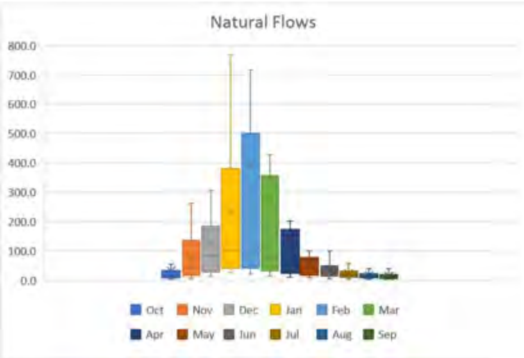
Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	6.653	5.12	0.287	3.596	1.7	0	3.596
Nov	14.713	16.419	0.431	4.272	1.8	1.168	5.44
Dec	20.642	16.688	0.302	4.629	1.8	1.13	5.759
Jan	40.63	62.559	0.575	6.126	1.8	8.113	14.239
Feb	58.343	121.584	0.861	7.954	1.8	8.982	16.936
Mar	39.244	66.032	0.628	6.527	1.8	2.355	8.882
Apr	19.62	28.809	0.566	5.471	1.8	0	5.471
May	8.901	8.266	0.347	4.519	1.8	0	4.519
Jun	6.312	2.928	0.179	4.306	1.8	0	4.306
Jul	5.397	2.427	0.168	3.968	1.8	0	3.968
Aug	4.662	1.906	0.153	3.689	1.8	0	3.689
Sep	4.452	2.204	0.191	3.513	1.8	0	3.513

ELEFANTES RIVER: ELEP-Y30C-SINGU

Table 9-35: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the ELEP-Y30C-SINGU site (The X in the box and whisker chart represents the mean)

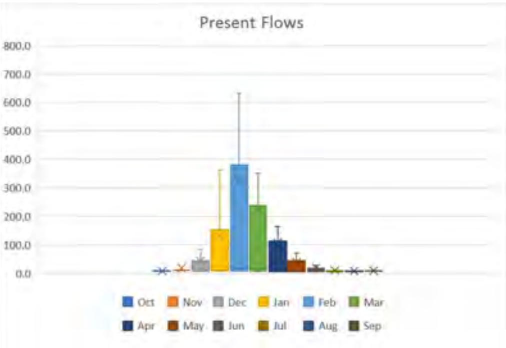
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	149.3	262.9	490.0	1028.6	2289.1	1548.0	658.5	198.0	107.5	62.5	39.5	38.9
1	122.0	248.1	308.7	767.3	1465.5	1098.2	578.2	179.2	100.4	56.9	37.9	33.3
5	55.6	204.4	238.2	443.9	716.9	426.1	201.9	99.4	57.0	40.2	29.2	29.4
10	37.3	146.0	210.3	422.7	556.4	363.6	180.3	83.8	52.0	31.2	22.3	21.7
15	30.2	123.8	157.7	335.6	444.5	344.3	167.3	73.0	46.5	29.6	21.0	18.6
20	26.2	109.0	146.3	237.8	365.7	227.6	146.9	68.1	41.1	28.1	20.5	16.6
30	19.7	76.1	115.4	169.9	220.1	195.6	100.1	56.3	35.9	24.0	18.4	15.1
40	16.6	48.5	107.5	115.4	130.3	125.0	79.5	47.0	31.9	21.5	16.3	13.4
50	14.5	40.9	84.2	101.7	91.9	76.6	64.4	39.5	27.9	19.8	14.7	12.4
60	11.4	33.6	70.6	75.2	77.1	57.4	50.5	35.2	24.3	18.2	13.6	11.0
70	9.4	28.5	49.0	66.4	64.4	49.2	39.2	26.4	19.0	15.9	12.3	9.4
80	8.5	21.7	33.5	50.7	52.0	41.2	30.5	20.8	15.9	12.2	10.5	7.6
85	7.9	19.0	30.9	44.9	46.1	36.1	25.2	19.0	14.6	11.2	8.9	7.0
90	6.7	13.9	26.4	37.8	36.6	27.7	23.4	17.0	12.9	10.0	8.1	6.2
95	5.9	9.6	20.4	34.0	34.6	24.8	21.1	15.4	11.6	8.8	6.7	5.4
99	4.6	8.1	13.5	25.7	28.2	19.6	16.7	11.3	9.0	7.1	5.8	4.5
99.9	4.0	4.9	12.3	25.4	22.4	14.7	11.4	7.6	5.8	4.5	4.7	4.2

A



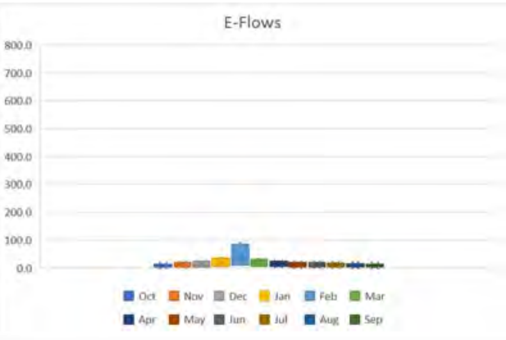
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	9.5	87.1	285.2	805.1	2361.7	1626.7	622.8	190.6	88.2	35.6	14.9	11.8
1	9.3	58.2	188.4	604.2	1354.2	1016.5	595.1	174.2	75.2	29.0	13.3	11.3
5	8.6	15.2	85.1	362.0	631.3	350.5	164.9	70.6	27.6	10.7	8.1	9.2
10	8.4	11.2	53.1	209.4	438.4	297.5	130.0	48.1	21.1	9.5	7.6	8.8
15	8.3	10.9	34.5	95.5	319.2	181.4	95.8	41.3	15.3	8.6	7.3	8.7
20	8.3	10.8	11.0	58.9	223.2	154.4	77.5	31.7	13.6	8.4	7.2	8.6
30	8.2	10.4	9.5	27.4	83.3	82.9	48.7	23.6	11.3	7.7	6.9	8.5
40	8.2	10.3	9.0	12.1	34.6	36.2	28.3	12.9	8.7	7.4	6.7	8.5
50	8.2	10.2	8.7	9.5	18.1	18.2	16.4	8.1	7.3	6.8	6.6	8.5
60	8.2	10.2	8.5	8.8	10.6	8.9	7.2	6.7	6.9	6.6	6.6	8.5
70	8.2	10.1	8.2	8.4	9.6	8.3	6.9	6.6	6.8	6.6	6.6	8.5
80	8.2	10.1	8.2	8.3	9.1	8.2	6.8	6.6	6.8	6.6	6.6	8.5
85	8.2	10.1	8.1	8.2	9.1	8.2	6.7	6.6	6.8	6.6	6.6	8.5
90	8.2	10.1	8.1	8.2	9.0	8.2	6.7	6.6	6.8	6.6	6.6	8.5
95	8.2	10.1	8.1	8.1	9.0	8.2	6.7	6.6	6.8	6.6	6.6	8.5
99	8.2	10.1	8.1	8.1	8.9	8.0	6.7	6.6	6.8	6.6	6.6	8.5
99.9	8.2	10.1	8.0	8.1	8.9	6.9	6.7	6.6	6.8	6.6	6.6	8.5

B



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	12.501	20.373	23.896	36.211	91.228	32.094	23.908	20.153	19.377	17.136	14.566	12.447
1	12.490	20.322	23.819	36.144	91.059	32.023	23.874	20.120	19.352	17.116	14.551	12.416
5	12.462	20.213	23.751	36.063	90.804	31.940	23.768	19.996	19.232	17.070	14.488	12.393
10	12.428	20.017	23.573	35.783	88.596	31.364	23.428	19.801	18.997	16.887	14.333	12.287
15	12.371	19.755	22.546	34.123	81.590	31.124	23.045	19.362	18.626	16.796	14.238	12.155
20	12.279	19.066	21.558	31.607	73.665	29.637	22.475	18.542	18.004	16.573	14.070	11.885
30	11.923	17.023	18.265	27.485	57.596	27.508	20.208	16.499	15.941	15.613	13.133	11.170
40	11.408	13.154	15.139	22.603	43.875	21.795	16.442	13.003	13.523	14.250	12.045	9.926
50	10.599	11.068	10.716	15.812	27.162	17.531	12.588	10.104	10.324	12.406	10.261	8.423
60	9.170	7.746	7.476	10.756	17.998	12.332	9.053	7.322	7.546	9.911	8.056	6.458
70	7.157	5.505	5.537	7.543	12.514	8.825	6.802	5.628	5.706	7.414	5.940	4.694
80	4.819	4.440	4.757	6.278	10.309	7.157	5.741	4.835	4.753	5.436	4.369	3.512
85	3.732	4.200	4.657	6.278	10.026	6.792	5.468	4.647	4.507	4.732	3.817	3.166
90	2.914	4.152	4.657	6.278	10.026	6.707	5.371	4.541	4.358	4.250	3.513	2.960
95	2.914	4.152	4.657	6.278	10.026	6.707	5.371	4.505	4.271	3.920	3.289	2.878
99	2.914	4.152	4.657	6.278	10.026	6.707	5.371	4.505	4.252	3.771	3.247	2.878
99.9	2.914	4.152	4.657	6.278	10.026	6.707	5.371	4.505	4.252	3.747	3.247	2.878

C



Summary of IFR estimate for: ELEP-Y30C-SINGU site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	2552.026
S.Dev.	=	2129.008
CV	=	0.834
Q75	=	45.86
Q75/MMF	=	0.216
BFI Index	=	0.272
CV(JJA+JFM) Index	=	1.777
ERC	=	C
Total IFR	=	490.143 (19.21 %MAR)
Maint. Low flow	=	399.376 (15.65 %MAR)
Drought Low flow	=	140.787 (5.52 %MAR)
Maint. High flow	=	90.767 (3.56 %MAR)

Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

Table 9-36: Summary of statistics for environmental flows (E-flows) for the ELEP-Y30C-SINGU site.

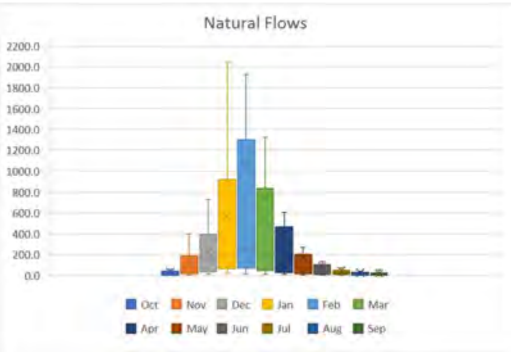
Month	Natural flows			Modified flows (IFR)			
				Low flows		High flows	Total flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	20.806	22.902	0.411	7.852	2.854	0	7.852
Nov	65.679	60.32	0.354	10.514	3.75	3	13.514
Dec	100.029	78.415	0.293	12.356	4.357	1.978	14.334
Jan	165.434	173.435	0.391	16.198	5.64	4.923	21.121
Feb	237.729	345.291	0.6	21.635	7.479	23.45	45.085
Mar	169.745	228.36	0.502	18.05	6.257	2.903	20.953
Apr	94.101	99.11	0.406	15.019	5.254	0	15.019
May	47.847	33.324	0.26	12.504	4.406	0	12.504
Jun	30.716	17.37	0.218	11.733	4.157	0	11.733
Jul	21.046	10.086	0.179	10.252	3.655	0	10.252
Aug	15.892	7.007	0.165	8.819	3.176	0	8.819
Sep	13.376	6.919	0.2	7.723	2.818	0	7.723

LIMPOPO RIVER: LIMP-Y30F-CHOKW

Table 9-37: Exceedance tables and box and whisker charts for A) natural, B) present C) e-flow scenarios for the LIMP-Y30F-CHOKW site (The X in the box and whisker chart represents the mean)

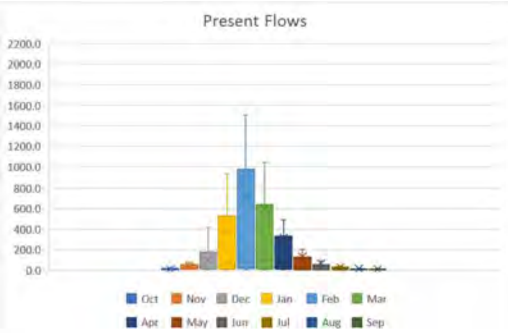
A

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	189.4	504.3	727.4	2535.0	7762.4	5062.8	2282.8	994.4	509.6	245.7	120.6	63.6
1	120.1	398.4	599.8	2044.4	3203.9	2656.8	1785.6	692.0	352.3	164.7	78.9	52.7
5	59.7	260.3	501.3	1332.8	1928.6	1325.7	604.3	268.6	134.1	72.6	42.1	31.2
10	41.9	195.6	417.0	1143.5	1383.6	872.8	512.5	211.8	117.9	55.0	31.5	27.6
15	34.3	175.9	368.1	693.4	1223.9	798.8	420.6	195.2	88.9	45.0	24.5	19.5
20	27.5	155.7	288.4	599.1	837.4	652.6	333.5	158.3	76.1	41.4	22.2	16.2
30	21.6	121.3	219.9	378.2	600.0	423.0	267.3	121.0	64.7	31.4	18.5	12.6
40	17.7	71.9	176.5	285.7	337.8	302.9	189.9	91.4	50.4	26.5	16.3	11.1
50	13.4	58.3	146.8	194.3	241.1	187.8	125.5	63.9	38.0	19.9	13.4	9.3
60	8.6	46.3	117.3	139.2	156.8	127.0	89.2	46.6	25.8	16.2	10.5	7.4
70	6.2	36.1	82.1	126.5	97.2	84.4	62.7	37.4	21.6	13.0	8.3	5.6
80	5.3	24.8	46.0	95.2	80.6	65.2	43.6	20.5	14.3	8.9	6.5	4.0
85	4.8	20.0	38.6	76.6	75.3	60.4	36.3	18.2	10.6	7.9	5.1	3.6
90	3.6	15.0	30.8	59.6	68.7	34.6	26.7	15.1	9.4	6.1	4.6	2.8
95	2.8	9.3	20.0	38.0	52.5	29.7	21.3	13.6	8.1	4.9	3.1	2.1
99	1.5	4.8	12.0	29.6	24.9	21.5	12.9	8.4	6.2	3.8	2.5	1.3
99.9	0.9	1.7	9.1	22.4	17.5	11.1	7.5	4.3	2.5	1.3	1.6	1.0



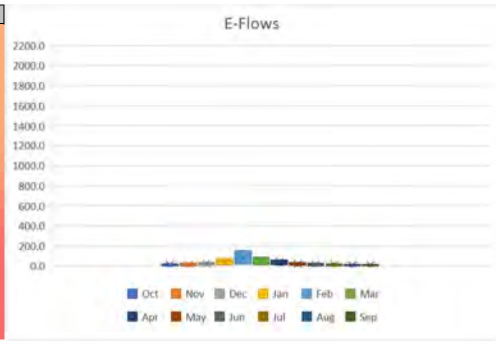
B

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	24.2	216.3	415.7	2087.3	4608.8	4414.3	1953.1	821.1	404.1	176.3	74.5	33.8
1	22.7	165.8	385.4	1467.2	2492.6	2393.3	1627.1	626.9	288.5	118.0	47.2	26.0
5	17.5	76.9	252.6	932.6	1505.0	1045.5	491.8	203.5	87.6	41.5	17.7	14.3
10	14.3	66.5	197.8	628.6	1074.0	697.8	367.8	136.3	58.6	28.4	11.8	10.7
15	12.9	37.8	158.0	426.2	879.0	580.6	292.7	117.2	50.3	22.7	11.3	9.6
20	11.8	29.5	113.3	311.7	649.8	465.6	217.4	97.6	41.2	18.4	10.1	9.1
30	10.7	23.9	76.0	176.6	385.2	267.4	166.9	60.3	31.3	15.4	8.8	8.5
40	10.1	18.8	49.7	89.2	161.4	143.4	90.2	44.2	18.3	11.3	7.8	7.7
50	9.2	13.4	32.1	60.2	78.4	102.8	52.8	19.4	11.0	9.8	7.1	6.9
60	8.5	11.4	19.5	40.8	57.9	58.7	28.5	12.2	9.5	8.7	6.6	6.8
70	8.0	9.8	14.9	26.6	27.7	23.2	16.2	9.4	8.6	8.3	6.4	6.7
80	7.0	8.7	9.8	14.9	19.7	11.8	9.4	6.6	6.6	7.6	6.4	6.7
85	6.7	7.2	8.4	10.4	16.5	9.4	7.4	6.5	6.6	6.3	6.4	6.7
90	6.6	7.2	7.3	6.8	12.1	7.0	6.8	6.1	6.5	6.3	6.3	6.6
95	6.6	7.1	6.9	6.5	7.9	6.7	6.4	5.8	6.1	6.2	6.2	6.3
99	6.6	7.0	6.7	5.8	6.7	5.7	5.2	5.4	5.9	6.1	5.9	6.0
99.9	6.6	7.0	6.7	5.7	6.0	5.5	5.0	5.1	5.7	6.1	5.8	5.9



C

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	17.968	24.454	35.042	70.585	155.024	85.938	54.390	31.089	27.740	22.414	15.661	11.070
1	17.905	24.387	34.996	70.528	154.716	85.796	54.351	31.045	27.657	22.334	15.606	11.053
5	17.849	24.315	34.964	70.450	154.611	85.710	54.271	30.968	27.498	22.243	15.548	11.010
10	17.573	23.944	34.474	70.260	148.886	85.054	54.112	30.820	27.148	21.844	15.361	10.952
15	17.245	23.554	33.768	68.324	142.491	84.746	53.921	30.627	26.380	21.372	15.042	10.856
20	16.305	22.813	32.712	66.718	129.814	83.712	53.576	30.310	25.047	20.397	14.402	10.610
30	14.514	20.353	30.970	62.608	115.684	80.916	52.753	29.250	22.533	17.680	12.338	10.083
40	11.515	15.748	27.985	57.946	94.449	77.552	51.092	27.040	17.727	13.505	10.169	9.166
50	7.885	11.596	24.943	52.493	64.658	69.910	48.498	24.173	12.459	9.072	7.258	7.696
60	4.736	7.005	19.195	41.322	44.826	57.775	43.698	19.571	7.768	5.388	4.678	5.750
70	2.730	3.909	13.024	28.241	27.961	41.051	35.746	13.931	4.660	3.051	2.969	3.716
80	1.785	2.436	7.122	10.586	18.686	22.853	23.651	8.436	3.051	1.861	2.084	2.095
85	1.569	2.106	5.787	10.586	17.291	15.406	15.544	5.825	2.628	1.524	1.839	1.547
90	1.455	2.039	5.787	10.586	17.291	12.992	8.247	4.702	2.385	1.356	1.718	1.208
95	1.455	2.039	5.787	10.586	17.291	12.992	8.247	4.017	2.234	1.230	1.631	1.066
99	1.392	1.970	5.787	10.586	17.230	12.686	8.112	3.999	2.190	1.172	1.611	1.060
99.9	0.878	1.412	5.787	10.586	16.730	10.207	7.027	3.861	2.059	1.058	1.539	1.009



Summary of IFR estimate for: LIMP-Y30F-CHOKW site

Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	5572.163
S.Dev.	=	6482.975
CV	=	1.163
Q75	=	44.5
Q75/MMF	=	0.096
BFI Index	=	0.196
CV(JJA+JFM) Index	=	2.632
ERC	=	C
Total IFR	=	878.658 (15.77 %MAR)
Maint. Low flow	=	595.803 (10.69 %MAR)
Drought Low flow	=	143.062 (2.57 %MAR)
Maint. High flow	=	282.855 (5.08 %MAR)

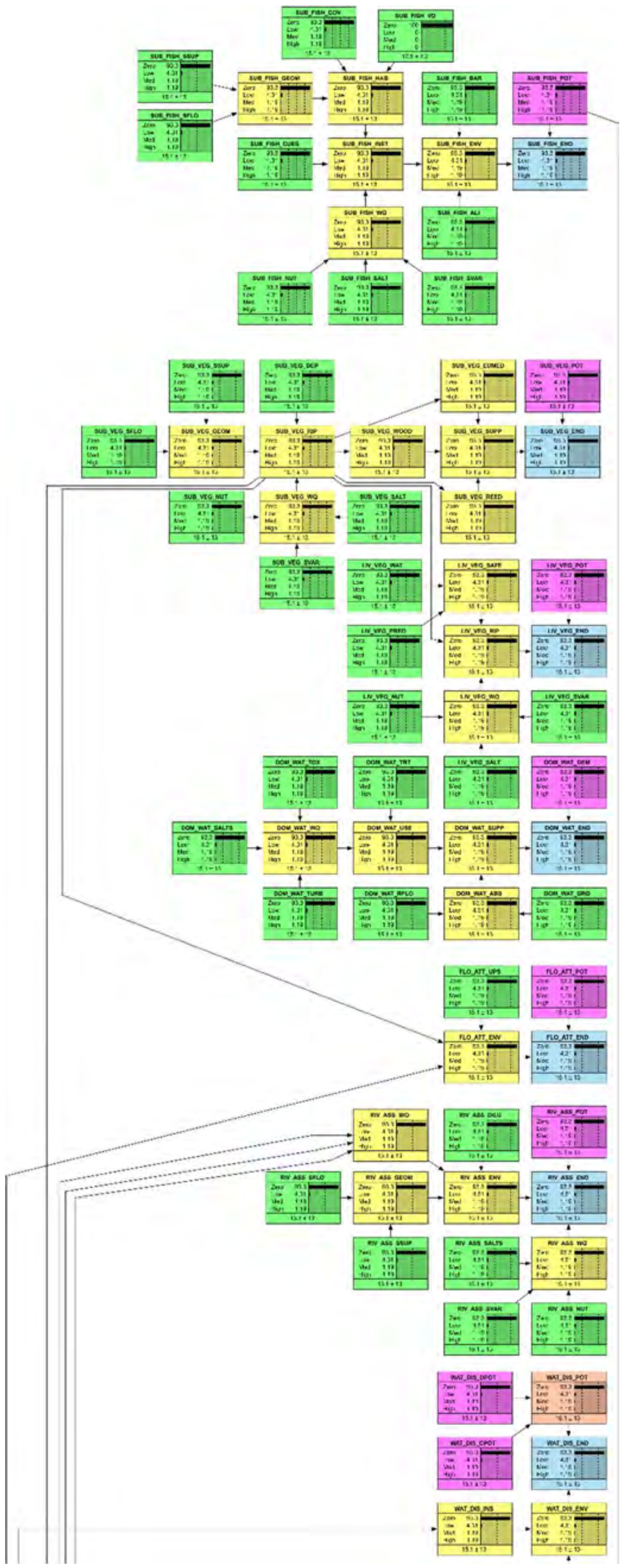
Monthly Distributions (cu.m./s)

Distribution Type : Lowveld

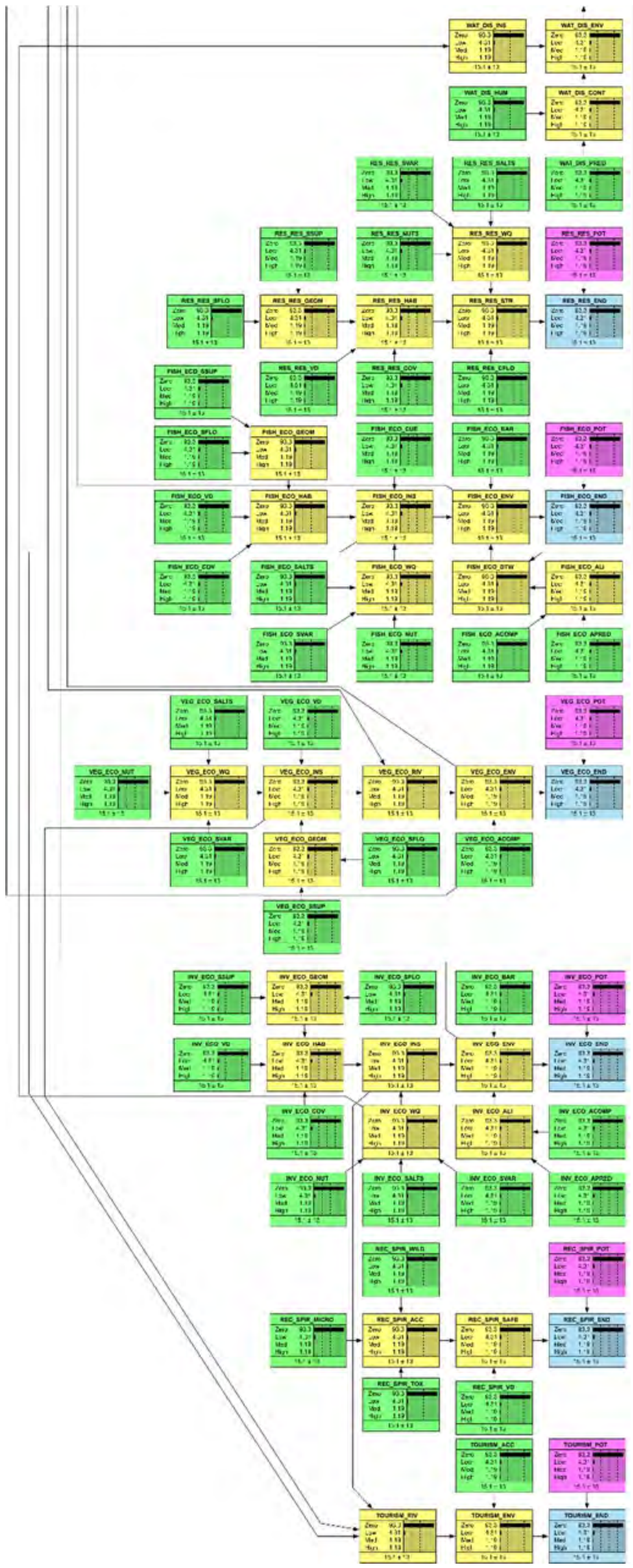
Table 9-38: Summary of statistics for environmental flows (E-flows) for the LIMP-Y30F-CHOKW site.

Month	Natural flows			Modified flows (IFR)			
	Mean	SD	CV	Low flows		High flows	Total flows
				Maint.	Drought	Maint.	Maint.
Oct	20.665	26.903	0.486	6.994	0.821	5.3	12.294
Nov	93.675	93.09	0.383	11.101	1.35	5.477	16.578
Dec	185.945	157.558	0.316	16.154	5.104	5.3	21.454
Jan	392.657	471.96	0.449	27.961	8.696	15.906	43.867
Feb	590.217	1021.282	0.715	41.157	12.732	41.657	82.814
Mar	419.018	666.224	0.594	33.456	9.931	26.013	59.469
Apr	230.281	326.762	0.547	25.648	6.906	10.5	36.148
May	104.719	137.083	0.489	19.3	3.846	0	19.3
Jun	54.906	69.146	0.486	16.815	2.045	0	16.815
Jul	29.163	33.089	0.424	13.428	1.045	0	13.428
Aug	17	16.649	0.366	9.492	1.531	0	9.492
Sep	11.882	10.669	0.346	6.874	1.003	0	6.874

10 APPENDIX E – Bayesian Network Model



Annexure D Bayesian network developed using Netica software for the Limpopo e-flow study (prior to population with data). Green nodes represent input environmental variable information related to the exposure of the system by multiple stressors. Yellow nodes integrate input information to represent the exposure of the large system. The pink node represents the potential for subsistence fishermen to occur in a Risk Region that represents the effects part of the risk model. The blue node represents the endpoint.



Annexure D continued: Bayesian network developed using Netica software for the Limpopo e-flow study (prior to population with data). Green nodes represent input environmental variable information related to the exposure of the system by multiple stressors. Yellow nodes integrate input information to represent the exposure of the large system. The pink node represents the potential for subsistence fishermen to occur in a Risk Region that represents the effects part of the risk model. The blue node represents the endpoint.

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