water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DWS Report No: P WMA 12/T30/00/5314/17

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE MZIMVUBU WATER PROJECT

RAPID RESERVE DETERMINATION : TSITSA RIVER AT LALINI

FINAL
December 2014

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE MZIMVUBU WATER PROJECT

Report Title:	***Rapid Reserve Determination: Tsitsa River at Lalini***
Authors:	*M Graham and R Stassen*
Project name:	*Environmental Impact Assessment for the Mzimvubu Water Project*
DWS Report Number:	*P WMA 12/T30/00/5314/17*
ILISO Project Reference Number:	*1300113*
Status of Report:	*Final v.1.0*
First Issue:	*September 2014*
Second Issue:	*November 2014*
Final Issue:	*December 2014*

CONSULTANT: ILISO CONSULTING (PTY) LTD IN ASSICIATION WITH GROUNDTRUTH

Approved for GroundTruth by:

Dr Mark Graham
Director

Approved for ILISO Consulting (Pty) Ltd by:

Ms Terry Calmeyer
Study Leader

DEPARTMENT OF WATER AND SANITATION
Directorate: Options Analysis

Approved for DWS:

M Mugumo
Chief Engineer: Options Analysis (South)

L S Mabuda
Chief Director: Integrated Water Resource Planning

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE MZIMVUBU WATER PROJECT

LIST OF REPORTS

REPORT TITLE	DWS REPORT NUMBER
Inception Report	P WMA 12/T30/00/5314/1
Scoping Report	P WMA 12/T30/00/5314/2
Environmental Impact Assessment Report	P WMA 12/T30/00/5314/3
Environmental Management Programme	P WMA 12/T30/00/5314/14
Integrated Water Use License Application for the Mzimvubu Water Project: Technical Report	P WMA 12/T30/00/5314/4
Ntabelanga Dam borrow pits and quarry Environmental Management Plan	P WMA 12/T30/00/5314/5
Lalini Dam borrow pits and quarry Environmental Management Plan	P WMA 12/T30/00/5314/6
SUPPORTING REPORTS	
Social Impact Assessment	P WMA 12/T30/00/5314/7
Economic Impact Assessment	P WMA 12/T30/00/5314/8
Visual Impact Assessment	P WMA 12/T30/00/5314/9
Floral Impact Assessment	P WMA 12/T30/00/5314/10
Faunal Impact Assessment	P WMA 12/T30/00/5314/11
Heritage Impact Assessment	P WMA 12/T30/00/5314/12
Water Quality Study	P WMA 12/T30/00/5314/13
Aquatic Ecology Assessment	P WMA 12/T30/00/5314/15
Wetland Assessment	P WMA 12/T30/00/5314/16
Rapid Reserve Determination: Tsitsa River at Lalini	P WMA 12/T30/00/5314/17

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE MZIMVUBU WATER PROJECT

DEA REF No. 14/12/16/3/3/2/677 (Dam construction application)
14/12/16/3/3/2/678 (Electricity generation application)
14/12/16/3/3/1/1169 (Roads application)

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa (2014). ***Environmental Impact Assessment for the Mzimvubu Water Project: Rapid Reserve Determination: Tsitsa River at Lalini***

DWA Report No: P WMA 12/T30/00/5314/17

Prepared for: Directorate – Options Analysis

Prepared by: GrondTruth Water, Wetlands and Environmental Engineering,
P O Box 2005, Hilton, 3245

Tel: (033) 343 2229, Fax: (086) 599 2300
Contact: Dr Mark Graham
Email: mark@groundtruth.co.za

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE MZIMVUBU WATER PROJECT

RESERVE DETERMINATION: TSITSA RIVER AT LALINI

Executive summary

Background

The National Water Act (NWA) No. 36 of 1998 requires that before water use authorisations can be granted to utilise a particular water resource, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. This requires the implementation of Resource Directed Measures (RDM) to protect the water resources of the country.

The construction of Ntabelanga and Lalini dams has been proposed in the Tsitsa catchment in quaternary catchments T35E and T35L respectively. The proposed Lalini Dam is just upstream of the Tsitsa Falls. These proposed dams will have both direct (i.e. hydraulic) and indirect (i.e. geomorphological, habitat integrity and response variable) impacts on the downstream aquatic ecosystems. These impacts necessitate that the riverine Reserve (ecological and basic human needs) is determined for the catchment to ensure adequate protection of the water resources.

Therefore, an Intermediate level Ecological Water Requirement assessment was undertaken for the Tsitsa River downstream of the proposed Ntabelanga Dam (T35E) and in order to determine the effects of reduced flows on the system. The results of this study are provided in a separate report (Volume 1 of the Feasibility Study for the Mzimvubu Water Project).

This report provides the results of the preliminary determination of the quantity requirements of the Reserve for the Tsitsa River downstream of the proposed Lalini Dam (T35L) at a rapid level of detail. The rapid study also included a geomorphological and riparian vegetation assessment. Activities and tasks for this ecological Reserve determination study were undertaken in accordance with the appropriate approaches and methodologies for rivers as prescribed by the Department of Water and Sanitation (DWS).

Results

The Tsitsa River at the EWR site is currently in a B/C category (largely natural to moderately modified state). This B/C state is mainly due to non-flow related drivers, essentially the impacts of overgrazing on the riparian vegetation and sedimentation, especially settling of fines in pools. However, the instream integrity of the system is still in a B category. The overall confidence in these results is low to medium.

The system has a moderate Ecological Importance and Ecological Sensitivity. This is primarily driven by:

a) *Cycads and other associated specialists cliff dwelling plant species growing on cliffs at the waterfall dependant on flows and micro climate variation associated with waterfall spray.*
b) *Unique* Barbus anoplus*-type minnow likely to be present in the system as high waterfalls upstream create barriers to fish movement, thus enabling the development of an Evolutionary Significant Unit for this species.*
c) *Psephenidae, Perlidae, Prosopistomatidae present which are sensitive to flow and water quality changes.*
d) *A wide variety of aquatic habitats available including cobles, boulders, bedrock, gravel/sand/mud, sand bars, stones in current, stones out of current, gorge, waterfall upstream.*
e) *The most recent DWS PES/EI-ES study classifies the system as a critical migration corridor; also an important link for three eel species to the upper Tsitsa River.*

The Recommended Ecological Category (REC) is a B/C.

The results obtained with the Desktop Reserve Model (SPATSIM, version 2.12) and accepted by the various specialists for the recommended ecological category are summarised in the following table.

Summarised key EWR details for the Tsitsa River in quaternary catchment T35L

Quaternary Catchment	T35L
EWR Site Co-ordinates	S 31.294; E 28.992
River	Tsitsa
Recommended Ecological Category	B/C
VMAR for Quaternary Catchment Area	868.6
Total EWR	287.053 (33.05 %MAR)
Maintenance Low flows	136.868 (15.76 %MAR)
Drought Low flows	52.012 (5.99 %MAR)
Maintenance High flows*	150.186 (17.29 %MAR)
Overall confidence	Low-Medium

** It is important to use the peak floods specified by the specialists as releases from the dam and not the average flood volumes as modelled*

Conclusions and recommendations

The Tsitsa River in quaternary catchment T35L is in a largely natural to moderately modified state: impacted by both catchment scale processes (e.g. erosion and sedimentation) and localised impacts (e.g. overgrazing). It is critical that the ecological water requirements specified in this report are met, as well as special recommendations noted in the conclusions section of this report. This will allow management to maintain the REC of a B/C.

It is recommended that the biomonitoring programme include annual sampling of:

- *Macroinvertebrates (per the SASS5 protocol (Dickens and Graham, 2002) by a Department of Water Affairs Accredited SASS5 practitioner),*
- *Benthic diatoms and*
- *Fish, including specific monitoring for eels on an annual basis. This need to be undertaken at two sites: (i) at the outflow of the proposed Lalini Dam (upstream of waterfall) and (ii) upstream of the proposed Lalini Dam.*

These measures will allow for analysis of ecological trends in the system in response to the proposed dam.

This report is based on scenarios and models run at various workshops. Additional scenarios may need to be run in the future and appropriate modifications made to this report if appropriate. These modifications may include the following:

- *Recommendations on the magnitudes of the high flow (flood) releases from Lalini Dam so that the outlet works can be sized accordingly.*
- *Specific requirements for eel migration to the upper Tsitsa and Inxu Rivers past the proposed Lalini Dam, requiring appropriate eel-way designs being incorporated into the dam wall design.*
- *A specific vegetation survey of the waterfall and adjacent river reach by a botanical specialist familiar with the area and vegetation related to cliffs and waterfall processes, with emphasis on Cycads and other unique vegetation dependant on the falls and related microclimates.*
- *Refining the recommended Scenario 2a (1.18 MAR Ntabelanga Dam with full EWR, hydropower releases. 0.28 MAR Lalini Dam with full EWR, hydro power discharge after EWR site).*
- *Refinement of specific EcoSpecs and monitoring including: 1:3 and 1:10 years flood releases, updated water quality monitoring, and monitoring plans for fish, macroinvertebrates, geomorphology and riparian vegetation.*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

APPENDIX A – Hydraulics Results

APPENDIX B – Invertebrate Assessment

APPENDIX C – Geomorphology Assessment

APPENDIX D – Riparian Vegetation Assessment

APPENDIX E – Fish Assessment

APPENDIX F – Desktop Reserve Model Results

APPENDIX G – Report by Dr Neels Kleynhans, DWS

ACRONYMS

ASPT	Average Score Per Taxon
DRM	Desktop Reserve Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EI	Ecological Importance
ES	Ecological Sensitivity
EIA	Environmental Impact Assessment
EIS	Ecological Importance and Sensitivity
EIS	Ecological Sensitivity
EWR	Ecological Water Requirements
FIFHA	Fish Invertebrate Flow Habitat Assessment
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GAI	Geomorphological Driver Assessment Index
HFSR	Habitat Flow Stressor Response
IHAS	Integrated Habitat Assessment System
IHI	Integrated Habitat Integrity
MAR	Mean Annual Runoff
MIRAI	Macroinvertebrate Response Assessment Index
NWA	National Water Act
PAI	Physico-chemical Assessment Index
PES	Present Ecological State/Ecostatus
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objectives
SADI	South African Diatom Index
SASS5	South African Scoring System (version 5)
VEGRAI	Vegetation Response Assessment Index
WMA	Water Management Area
WRCS	Water Resources Classification System

1. INTRODUCTION

1.1 Background

1.1.1 National Water Act

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) requires the implementation of Resource Directed Measures (RDM) to protect the water resources of the country, based on the guiding principles of sustainability and equity. In terms of the Act, before the required authorization to utilise a particular water resource can be granted, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use.

According to the Act, all Reserve determinations that are currently determined and approved by the Department of Water and Sanitation (DWS) are preliminary Reserve determinations and the associated recommended class is a preliminary class (section 17(1)), until the Classification of the water resources has been undertaken.

The ecological component of the Reserve is defined as the quantity, quality and reliability of water required to "protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource" (National Water Act, 1998).

1.1.2 Resource Directed Measures (RDM)

Classification

The NWA makes provision in section 12 for the development of a national classification system for the classification of all significant water resources. The approaches and methodologies to undertake the classification of water resources have been developed and the management class of a water resource is based on ecological, social and economic considerations.

The regulations for a Water Resources Classification System (WRCS) were promulgated in September 2010 and the Department initiated a process of classifying significant water resources in the country. The water resources of the uMzimvubu catchment have not been classified yet and the recommended ecological category is used for the preliminary class.

Reserve

A suite of methods has been developed for determining the ecological Reserve depending on the level of accuracy and confidence in the results required. These are outlined in Volume 2 of the RDM method manuals (DWAF, 1999) and consist of approaches to undertake a Rapid, Intermediate or a Comprehensive ecological Reserve. The results of Reserve determinations are also linked to a level of confidence (very low to high), based on the availability of information and accuracy of the determination.

The application of the appropriate RDM method to ensure that the necessary level of confidence in the results is obtained for the particular water resource under consideration depends on a number of factors. These include:

- The Ecological Importance (EI) and Ecological Sensitivity (ES) of the catchment;
- The degree to which the catchment is already utilised;

- The potential impact of the proposed water use(s) to be authorised and possible future use; and
- The need to establish a catchment management plan.

The ecological Reserve is not intended to protect the aquatic ecosystem *per se*, but to maintain aquatic ecosystems in such a way that they can continue to provide the goods and services to society. The Reserve (ecological and basic human needs) is the only right to water; all other water uses are subject to authorizations.

A summary of the generic steps which form part of the procedure to determine the ecological Reserve for aquatic ecosystems is provided in Figure 1-1.

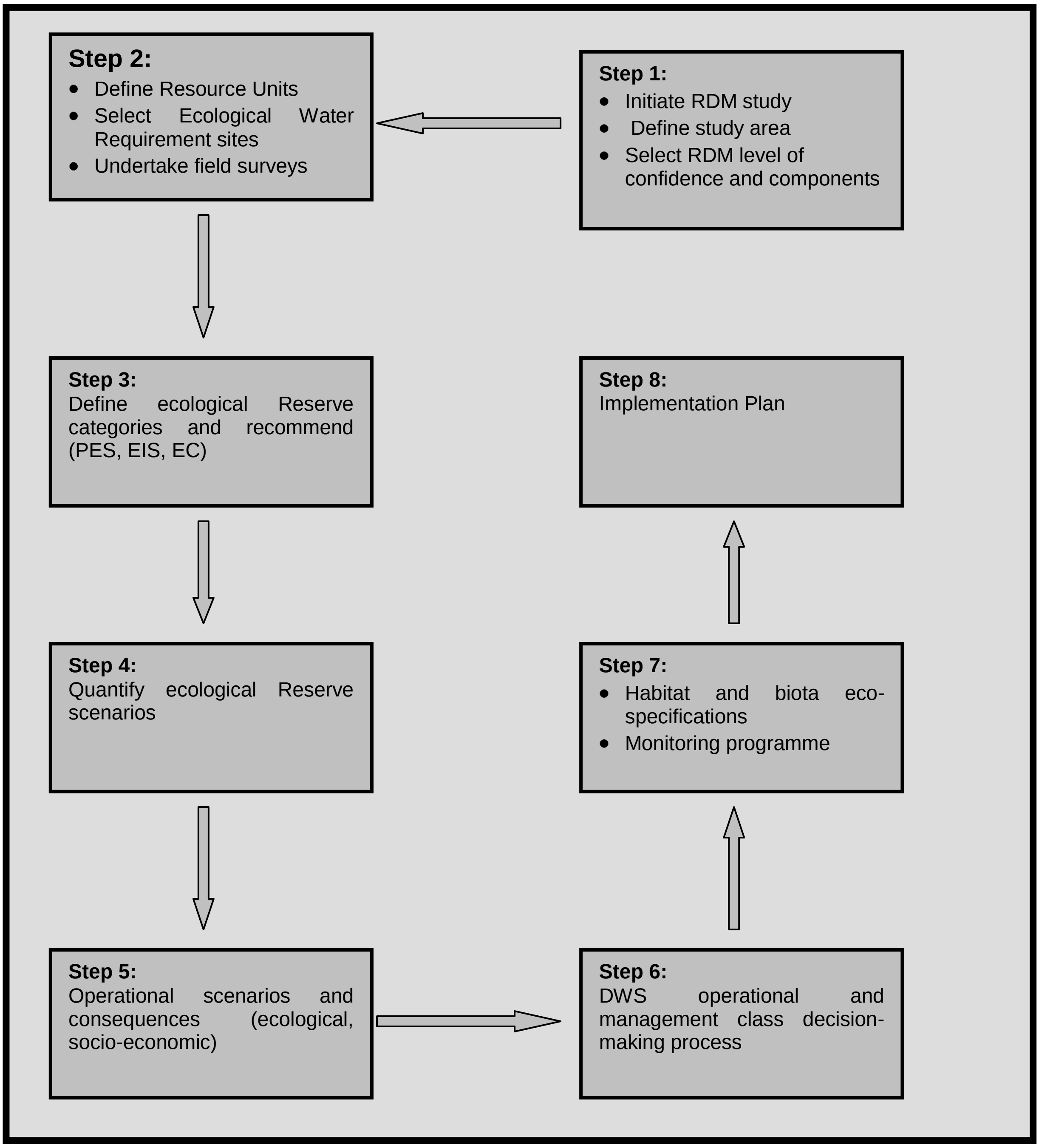

Figure 1-1: Generic procedure for the determination of the ecological Reserve

Resource Quality Objectives

Resource Quality Objectives (RQOs) are defined as clear goals (numerical or descriptive statements) relating to the quality of a water resource and are set in accordance to the management class (preliminary class) specified for the resource to ensure the water resource is protected. The purpose of RQOs is to set clear objectives for the resource against which water use licenses and the related impacts can be evaluated and managed to achieve a balance between the need to protect and utilise the resource.

1.1.3 Reserve determination procedures

The Reserve refers to the quantity and quality of water required to (i) supply basic human needs and (ii) protect aquatic ecosystems. The ecological component of the Reserve (i.e. water to protect aquatic ecosystems), refers to water quantity and water quality within the following four components:

- Groundwater;
- Wetlands;
- Rivers; and
- Estuaries.

The water quantity component for a river will typically refer to the flows and flow patterns (magnitude, timing and duration) needed to maintain a river ecosystem within acceptable limits of change, or the specified Ecological Category.

The DWS requires that a standard procedure be followed in order to determine the appropriate level of Ecological Reserve determination as set out in the RDM method manuals (DWAF, 1999) for each component of the water resource under consideration.

1.1.4 Background to the rapid ecological Reserve determination study

The investigation for the construction of dams in the uMzimvubu system in secondary catchment T3 has been initiated by the Department in 2006. Initially, nineteen potential dam sites (Figure 1-2) have been identified within the system during the Water Resource study in Support of the ASGISA-EC Mzimvubu Development Project finalised in 2010 by the Department.

A follow up study (Mzimvubu Water Resources Development Project) has been undertaken by Jeffares and Green to eliminate those dams that (i) are not economically viable, (ii) won’t provide adequate yield for developments, or (iii) that are situated in ecologically sensitive or important areas. As part of this study, a desktop based ecological assessment was undertaken to reduce the number of the potential dam sites to a more manageable number which could go forward into further feasibility stages of dam site selection and Reserve determination studies.

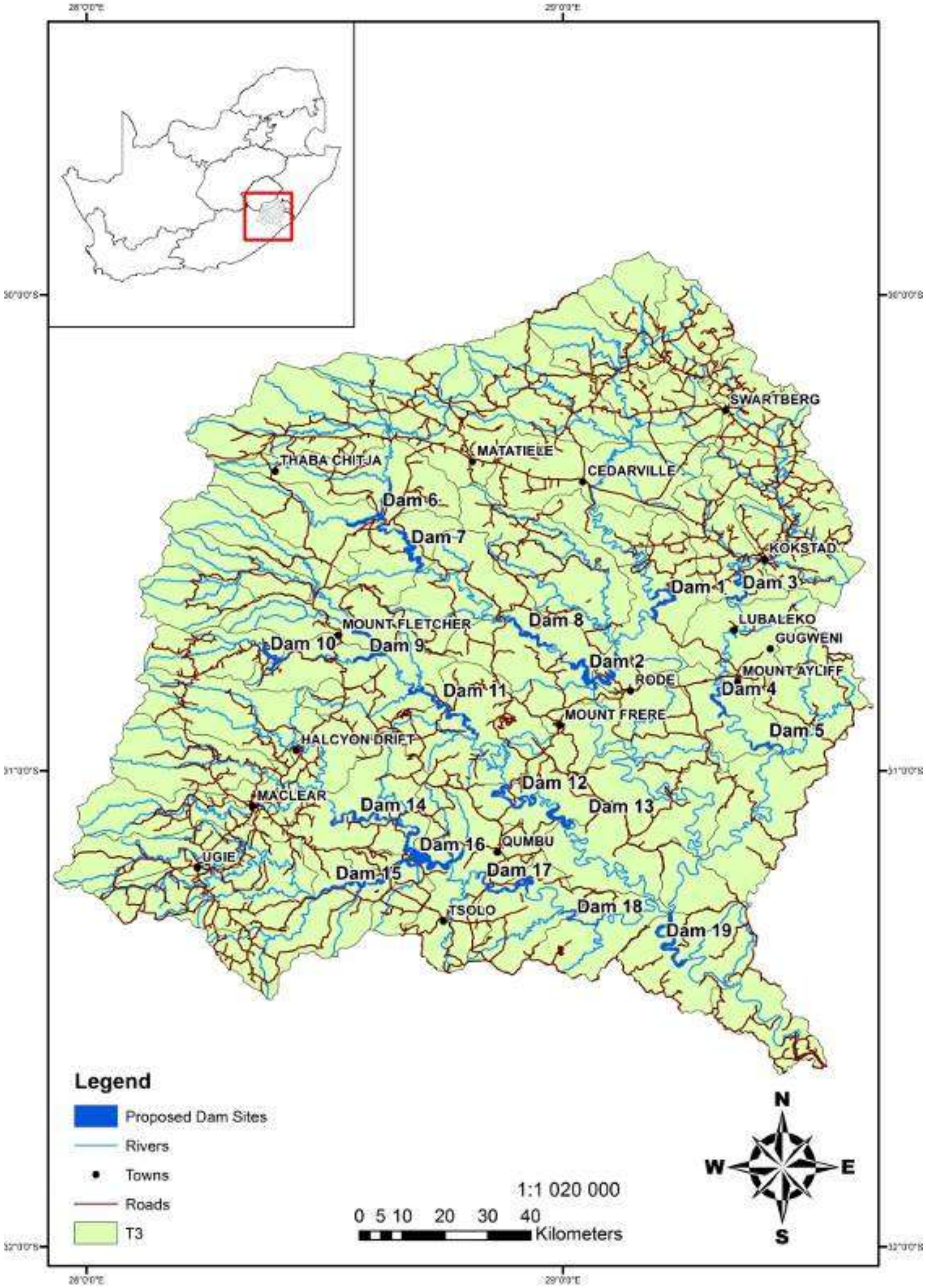

Figure 1-2: Map of the uMzimvubu system indicating the 19 proposed dams

This elimination process resulted in five potential dam sites that were investigated in more detail during phase 1 of the Water Resources Development Project to identify the final dam site to undertake the intermediate Reserve study. The five identified dams were:

i. Somabadi Dam in T33E on the Kinira River (Dam 7)
ii. Thabeng Dam in T33D on the Kinira River (Dam 6)
iii. Mpindweni Dam in T34G/T34H on the Tina River (Dam 11)
iv. Ntabelanga Dam in T35E on the Tsitsa River (Dam 14)
v. Lalini Dam in T35L on the Tsitsa River (Dam 17)

Rapid level III Reserve determinations studies were undertaken during phase 1 on the Kinira (downstream Dam 6 and Dam 7), Tsitsa (downstream Dam 14) and Tina (downstream Dam 11) Rivers to provide the necessary ecological information for the final selection of one dam site.

The final dam site selected from these five dams at the end of phase 1 was the Ntabelenge Dam (Dam 14) on the Tsitsa River in quaternary catchment T35E. An intermediate Reserve determination study was undertaken during phase to of the study downstream of this proposed dam using the existing rapid III EWR site in quaternary catchment T35E.

Towards the end of phase 2, Dam 17 on the Tsitsa River in quaternary catchment T35L was identified as a second possible dam. This dam would be operated for hydro power generation with releases from the upper Ntabelanga Dam. Water released from the Lalini Dam for hydro power generation would be returned to the Tsitsa River approximately 14 km downstream of the waterfall. This could have a serious impact on the Tsitsa River in the gorge area.

Only desktop Reserve results were available and as the dam is situated just upstream of the Tsitsa Fall with an almost inaccessible gorge downstream of the falls, the desktop results didn’t provide adequate information for the protection of the Tsitsa River in the gorge area. During a meeting with officials of DWS in July 2014, it was recommended by Dr Neels Kleynhans that a rapid level III Reserve study be undertaken on the Tsitsa River in the gorge. This study should also include a geomorphological and riparian vegetation assessment.

1.1.5 Purpose of the rapid ecological Reserve study

The purpose of this study is to undertake a rapid level III Reserve study, including the geomorphological and riparian vegetation assessments for the Tsitsa River below the waterfall in quaternary catchment T35L. The results of this study will provide higher confidence ecological information to be used during the final decisions by the DWS for the design and construction of the proposed Lalini Dam.

GroundTruth cc was appointed to conduct all the tasks and activities for the rapid Reserve study. This report summarises the tasks undertaken during the study, provides the results of the preliminary determination of the quantity requirements of the ecological Reserve for the surface water component of the Tsitsa River in quaternary catchment T35L and provides recommendations and monitoring requirements for the river if construction of the dam proceeds.

1.2 Terms of Reference for the proposed study

The purpose of the study was to determine the EWR for the surface water resources of the Tsitsa River in quaternary catchment T35L downstream of the proposed Lalini Dam on a rapid III level of detail. The following main tasks were undertaken as part of the study:

- Undertake a field visit to select an Ecological Water Requirement site in the gorge below the lower Tsitsa waterfall.
- Undertake field surveys to collect data on fish, macroinvertebrates, geomorphology, riparian vegetation and hydraulics (flow measurement and profiling) at the selected EWR site.
- Determine the reference conditions and assess the Present Ecological State (PES), Ecological Importance and Sensitivity (EIS) and the Recommended Ecological Category (REC) for the Tsitsa River.
- Determine the ecological water requirements of the Tsitsa River at the EWR site following the principles of the Habitat Flow Stressor Response (HFSR) approach to determine the minimum stress and the verification of the ecological requirements from the Desktop Reserve Model (DRM) using the cross-sectional profile of the river at the EWR site.
- Determine the ecological consequences for a number of operational scenarios and dam sizes of the proposed Lalini Dam.
- Determine the ecological specifications and provide recommendations and monitoring requirements if construction of the proposed dam proceeds.
- Prepare a report detailing the process followed, approaches, results and recommendations of the study.

1.3 Study approach

The following main activities were undertaken to meet the objectives of the study:

One field survey was undertaken on 26 August 2014 (very low flows) to collect data on fish, macroinvertebrates, geomorphology and riparian vegetation and to undertake the hydraulic measurements.

It should be noted that although a riparian vegetation survey was undertaken during the field visit, the confidence in the results is low as the survey was not undertaken during the growing season (i.e. summer).

Integration of the results from the field survey, to determine the EcoStatus and ecological water requirements (HFSR and SPATSIM) of the river at the EWR site were done during the specialist workshop just after the field surveys.

Modelling to determine the flows at the EWR site for various dam sizes and operation of the dam to assess the ecological consequences was undertaken.

No water quality assessment was undertaken (only *in situ* sampling and diatoms for use during the EWR workshop) as this assessment forms part of the Environmental Impact Assessment (EIA).

Updated hydrology from the Feasibility Study for the Mzimvubu Water Project was used during the assessments and determination of the EWR.

The activities and tasks for this ecological Reserve determination study were undertaken in accordance with the appropriate approaches and methodologies for rivers as prescribed by the Department, namely:

- The methodology as set out in DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 3: River Ecosystems Version 1.0 (Revised water quality methodology, 2002).
- The revised methods as outlined in Louw and Hughes (2002), the Habitat Flow Stressor Response (HFSR) manual of IWR Source-to-Sea (2004) and the EcoClassification manual of Kleynhans *et al* (2005).
- The principles of the Habitat Flow Stressor Response approach and the Desktop Reserve Model within SPATSIM have been used for the integration of data produced from the surveys. It should be noted that the HFSR approach was applied to the low flow months only as only one survey was undertaken during the low flow period (August). No survey was undertaken during high flows (wet season) and subsequently the maximum base flows (no stress) could not be determined.
- The Ecostatus suite of methods has been used for the ecological components.

1.4 Structure of the report

This report is divided into 5 main chapters and applicable appendices, supported by detail specialist reports, where necessary. The main chapters are:

Chapter 1 provides the general background to RDM and the study approach.
Chapter 2 describes the study protocol followed for the assessment of the Tsitsa River.
Chapter 3 provides the results of the field surveys, specialist workshop and the final recommended ecological Reserve for the Tsitsa River.
Chapter 4 presents the ecological consequences of the operational scenarios.
Chapter 5 presents the main conclusions and recommendations.
Chapter 6 cites the references used in this report.

2. STUDY PROTOCOL

This section of the report provides the protocol followed for the ecological Reserve determination of the Tsitsa River in quaternary catchment T35L.

2.1 Study team

The specialists involved in the assessment are listed in Table 2-1.

Table 2-1: Study team for the rapid ecological Reserve determination

Team Member	Affiliation	Specialisation/Task
Stassen R	JMM Stassen	Co-ordination, SPATSIM
Graham, M	GroundTruth cc	Study leader, macroinvertebrates & review
Gray, R	Jeffares & Green	Hydraulics
Tedder, Juan	GroundTruth cc	Macroinvertebrates
Van der Waal, B	Rhodes University	Geomorphology
de Winnaar, G	GroundTruth cc	Fish
de Villiers, A	GroundTruth cc	Riparian Vegetation

2.2 Study area

The study area of the Tsitsa River falls within the Mzimvubu to Keiskamma Water Management Area (WMA) and comprises all the quaternary catchments T35A to part of T35L up to the EWR site. The Inxu River is a major tributary of the Tsitsa River and contributes almost 50% of the flow at the EWR site. The Tsitsa River forms a major tributary of the Mzimvubu River.

The natural Mean Annual Runoff (MAR) at the EWR site in quaternary catchment T35L is 868.6 x $10^6 m^6$ (Jeffares and Green, 2013). The closest gauging weir (T3H006), with a catchment area of 4 268 km^2 is situated just upstream of the Tsitsa waterfall below the N2 road. The record period at the gauging weir is from 1951 to present. However, a large percentage of the data is missing, mainly for the period 1951 to 1985 and only the latter period was used. Flow data from this weir was used during the Reserve determination to provide information on periods of low/zero flows and floods.

The town of Maclear and smaller rural villages are situated in the upper catchment. Forestry plantations and irrigation, mainly in the Mooi River catchment are present. No other large development (irrigation schemes or dams) are currently in the catchment.

The selected EWR site on the Tsitsa River is in quaternary catchment T35L in the gorge below the Tsitsa waterfall. The details of the site are indicated in Table 2-2 and the figure below.

Table 2-2: Tsitsa EWR site information in quaternary catchment T35L

EWR site	River	Quaternary	Latitude	Longitude	MAR ($10^6 m^3$)
LaliniEWR	Tsitsa	T35L	S 31.294°	E 28.992°	868.6

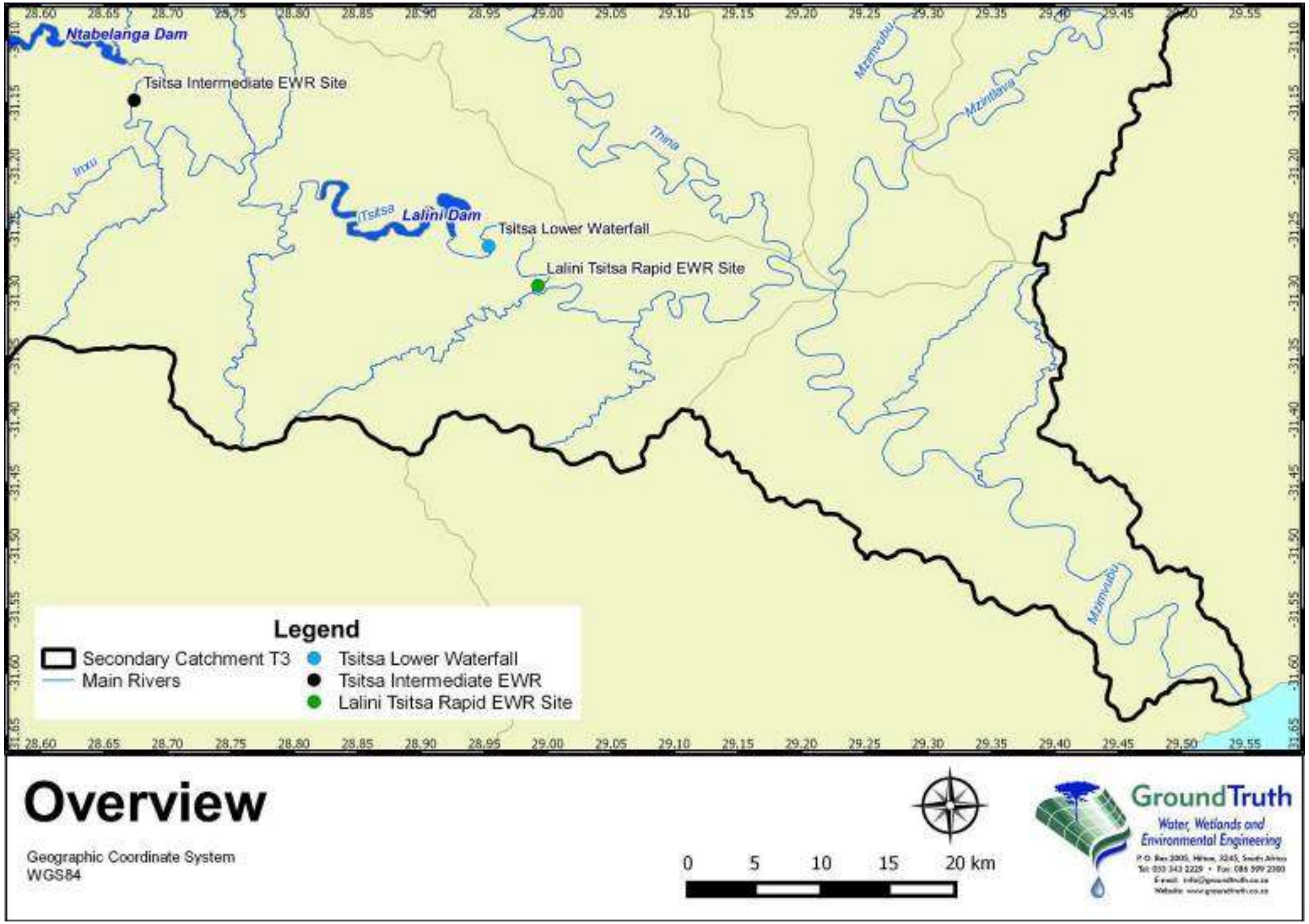

Figure 2-1: Study area of the Tsitsa River in T35L

2.3 Site visit

The tasks undertaken during the site visit on 26 August 2014 included:

- A visual “survey” of the river reach downstream of the waterfall to upstream of the proposed discharge point of the hydro power plant (~14 km downstream of the falls) to select the best EWR site;
- Finding a suitable EWR site. This was governed by the suitability of the river channel for accurate hydraulic modelling and flow measurement, as well as the presence of habitats critical for ecosystem functioning, such as riffles. The site should also be representative of the catchment to allow scaling of the results to other relevant points in the catchment;
- The specialists assessed the present condition of their study component in relation to the considered reference condition, which allowed the allocation of the PES for the specific component;
- A cross-sectional profile of the river channel was surveyed using a Total Station by the hydraulic specialist. Hydraulic data for calibration purposes was collected and the river flow was determined with the aid of a current meter at the EWR site;
- The fish specialist sampled fish in all suitable aquatic habitats in the vicinity of the EWR site using an electro-fish shocker and noted any man-induced habitat modifications impacting on fish fauna;
- The macroinvertebrate specialist surveyed aquatic macroinvertebrates occurring within the range of instream habitats at the site using the SASS5 methodology. A habitat assessment of the site pertaining to SASS was also conducted;
- *In situ* water quality data and diatom samples were collected at the EWR site;
- The fluvial geomorphologist surveyed the stream morphology (riffles, pools and instream islands), habitat quality (substrate embeddedness), boundary conditions (erosion, sedimentation and channel stability), instream disturbance (weirs, bridges, river crossings and dams), historical and current land use activities (agriculture, residential), impacts of current and historical land use (erosion) valley form (confined or unconfined), channel pattern (single thread, anastomosing or meandering), morphometry (channel width and channel depth) and sediment flow pattern (bed load and suspended load). The Geomorphological Driver Index Assessment (Rowntree, 2013) field sheet was used to capture site data as input for the PES classification and scenario rating process (measure of deviation of the current state or scenario from a pre-determined reference condition). Sediment class sizes and elevation of sedimentation features were used to calculate the system flood requirements.
- The riparian vegetation specialist assessed the condition of both woody and non-woody vegetation in the marginal and non-marginal riparian vegetation zones. Assessments included quantifying the intensity and extent of indigenous vegetation removal and modification (i.e. changes in species composition, cover and abundance), and infestation of alien invasive species.

2.4 Specialist workshop (EcoClassification workshop)

The results of the field assessment of the various habitat and biotic components to obtain the EcoStatus and the recommended ecological category were compiled after the completion of the site visit. This assessment took place during the ecoclassification workshop with input from all the specialists. The process included the determination of the following:

- Reference conditions: - it is those conditions that occur under natural conditions before anthropogenic impacts.
- Present ecological state (PES) or EcoStatus: - the determination of the current state of the resource through rule-based models for the driver components (geomorphology – GAI (Rowntree, 2013), hydrology – HAI and water quality – PAI) and for the biological response components (fish – FRAI, macro-invertebrates – MIRAI and vegetation – VEGRAI). A rule-based model is then used to derive the EcoStatus or overall/integrated condition/health of the resource by integrating the driver and response status. In this study all the models except the PAI model (water quality component part of the EIA) were used to determine the present state per component.
- Integrated Habitat Integrity (IHI): - the Integrated Habitat Integrity model (Kleynhans, 1996 model with revised 2009 methodology) was used to evaluate the habitat integrity of both the instream and riparian components in the vicinity of the EWR site. This assessment model is based on the qualitative assessment (allocation of scores) for various impact criteria on both the instream and riparian zones.
- Trends: - this is the reaction of the components to changes in the catchment and can be stable, negative or positive.
- Ecological Importance (EI) and Ecological Sensitivity (ES): - the ecological importance is defined by Kleynhans (1999), and is regarded as an expression of the water resource’s ability to maintain the ecological diversity and functioning on local and wider scales. The ecological sensitivity refers to the river’s ability to recover from disturbance. The Ecological Importance and Ecological Sensitivity scores were derived from the desktop PES EI ES model (DWA, 2014).
- Recommended Ecological Category (REC): - the PES, EI and ES were used in the decision on the REC as well as the feasibility to realistically be able to maintain or improve the current condition of the water resource.

3. RESULTS

The results of the ecological Reserve determination of the Tsitsa River at the EWR site are presented in this section. The Tsitsa River in quaternary catchment T35L falls within an area of moderate to high relief dominated by valley bushveld. The river is situated in the Eastern Coastal Belt ecoregion level I and in eco-region level II (31.01).

3.1 EWR Site selection and evaluation

A number of possible EWR sites in the gorge were assessed by the project team during the field visit in August 2014. The final site selected for this assessment is just upstream of the proposed discharge point of the hydro power plant and is characterised by a combination of a cobble-dominated riffle and runs with very limited marginal vegetation. Above and below the site are cobble dominated runs and sand and cobble based pools. The details of the river at the EWR site can be seen in Figure 3-1.

Figure 3-1: View of the EWR site on the Tsitsa River in T35L

The chosen site was evaluated by the various specialists in terms of advantages and disadvantages as well as given a confidence score to provide cues for undertaking field verification. The scores allocated were from 0-5, with 0 = no confidence and 5 = high confidence that the EWR site provides sufficient indicators. The results of this evaluation are given in Table 3-1.

Table 3-1: Tsitsa River EWR site evaluation

Component	Confidence Score*	Advantages	Disadvantages
Hydraulics	2	Good proximity to critical habitat, best site available given access and site conditions.	Not at Thalweg, some divergent/convergent flows in cross-section, two pools in greater cross-section, one on each bank.
Fish	3	A wide selection of different velocity depth classes available for sampling.	Access to the site is difficult. Under low flow sampling the undercut banks and marginal vegetation habitat types were limited.
Macroinvertebrates	3	Good diversity of habitats i.e. velocities, depths and substrates.	Limited vegetation habitat due to low flows and grazing impacts.
Geomorphology	3.5	Good variety of morphological features such as riffles, pools, boulder bars, etc. Limited vegetation encroachment made various features easy to assess.	The steep channel slope in the gorge results in high energy conditions that minimizes the impacts of catchment processes such as extensive erosion. Lateral bars were mostly lacking due to high energy conditions.
Riparian vegetation	2	Most areas accessible once at the site. Distinct marginal and non-marginal zones visible.	Not surveyed in the growing season (i.e. summer). Limited background information on site.

* Confidence scores: 0 = no confidence; 5 = high confidence

3.2 Data collected

3.2.1 Hydraulics

The GoogleEarth view of the reach where the EWR cross-section was selected for the EWR assessment is shown in Figure 3-2. The GPS co-ordinates for the cross section are S31.294°, E28.992°. During the site visit the following activities were undertaken:

- A survey of the cross-sectional profile of the site;
- Longitudinal water slope was surveyed;
- Discharge was measured at a DWS gauge site; and
- EWR site photographs were taken.

Figure 3-2: Aerial View of the Tsitsa Cross Section (LaliniEWR)

There was limited riffle habitat available during the site selection trip and, this, coupled with access constraints made the selection of a site difficult. Due to these constraints the selected site has limitations from a hydraulic perspective (situated downstream of the thalweg between two bends approaching the entrance to a bend in the river). However, the site, and thus hydraulic results for the site, was considered sufficient for use in this study.

As a result of the two pools in the cross-section, two cross-sections and two rating curves have been developed. The first set of results is to account for the low flow conditions existing in the active channel measures on site (i.e. the actively flowing channel situated between the two pools). The second cross-section exists for the entire site and should be used to account for high flows as the two pools are considered.

Velocity data was measured by means of a flow metre taking measurements at 60 % of depth, which was assumed to be the average velocity for that specific column of water. The topographical measurements were collected using a Total Station and downloaded for conversion into an appropriate co-ordinate system for further analyses. The hydraulic data collected during the site visits are listed in Table 3-2.

Table 3-2: Hydraulics data measured at the EWR site

Date	Discharge Q (m^3/s)	Maximum flow depth (m)
26 August 2014	1.61	0.95

3.2.2 Derivation of the rating curve

Modelling was carried out using the one measured stage-discharge pair, as well as two modelled points (zero flow and a hypothetical flood flow condition) to develop a stage discharge curve. The following data was required in the use of the modelling:

- y – maximum flow depth;
- n – resistance coefficient;
- S – slope;
- Q – discharge;
- A – area; and
- WP – wetted perimeter.

The accuracy of the rating curve is dependent on the number of measured points used in its creation and the hydraulic stability of the selected cross-section under high flow conditions (it is rarely possible to measure these during high flow conditions). The measured and modelled data are shown in Table 3-3 below.

Table 3-3: Hydraulic data used to extend observed rating data at the EWR site

EWR site	Discharge, *Q* (m^3/s)	Maximum flow depth (m)	Manning's resistance, *n*	Surface Slope, *S* m/m)	Ave. Velocity, V (m/s)
LaliniEWR	1.61	0.95	1.082	0.015	0.058
	259.26	3.80	0.150	0.006	0.972

The depth-discharge relationship (Hirschowitz PM, Birkhead AL, James CS) was determined using the following equation as it is most widely accepted for use in Southern Africa:

$$y = aQ^{b} + c \qquad (1)$$

where:

- y is the maximum depth;
- Q is the discharge (m^3/s); and
- *a*, *b* and *c* are coefficients.

The coefficients used in equation (1) are shown in Table 3-4 below.

Table 3-4: Regression coefficients in equation (1)

EWR site	Regression coefficients		
	a	*b*	*c*
LaliniEWR – Low Flows	0.4528	0.5460	0.0000
LaliniEWR – High Flows	0.3956	0.4855	0.0000

The cross-section of the EWR site in the Tsitsa River and the stage discharge relationships developed (low and high flow profiles) from the modelling are shown in Figure 3-3 , Figure 3-4, Figure 3-5 and Figure 3-6, respectively.

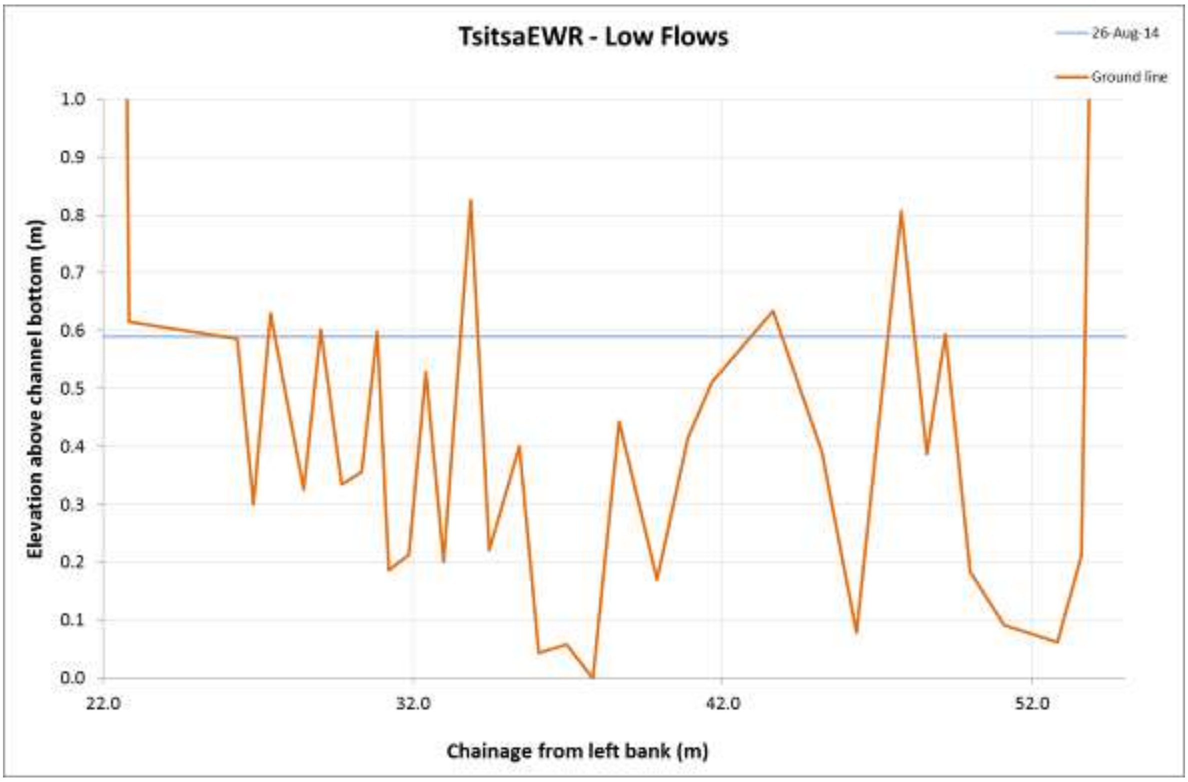

Figure 3-3: Cross-sectional view of the EWR site on the Tsitsa River in T35L – LOW FLOWS

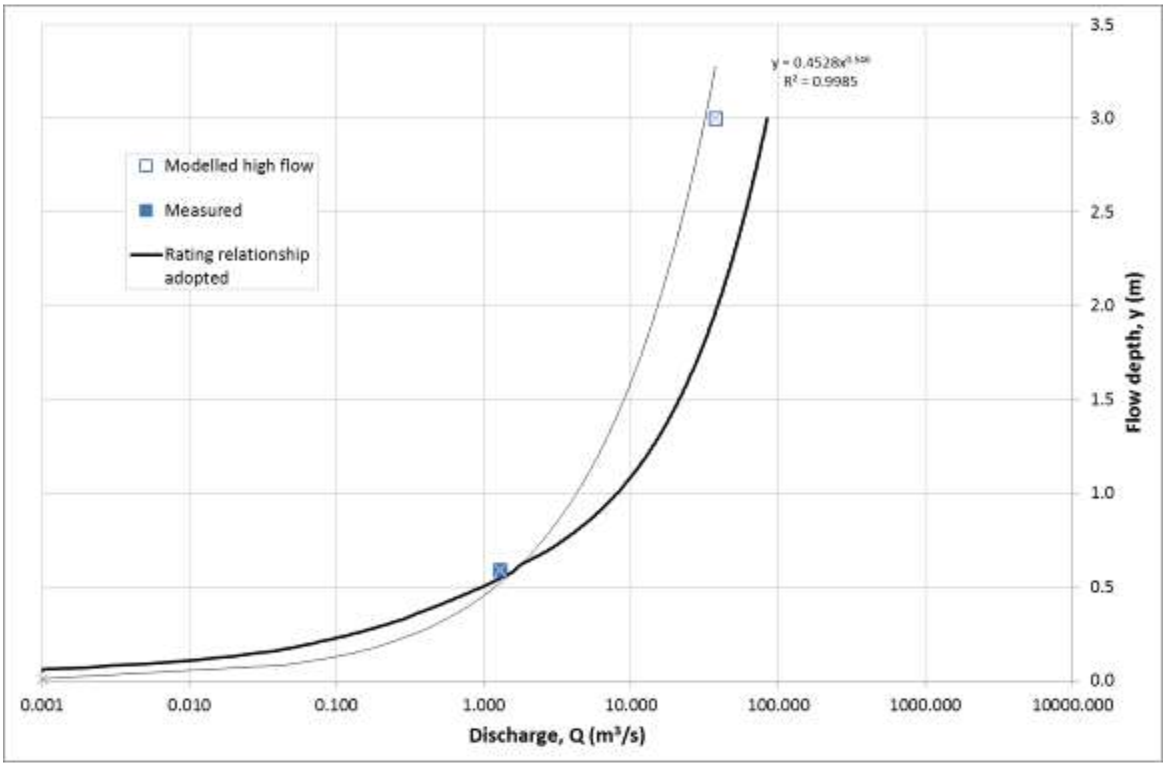

Figure 3-4: Calibrated cross sectional profile for the Tsitsa EWR site in T35L – LOW FLOWS

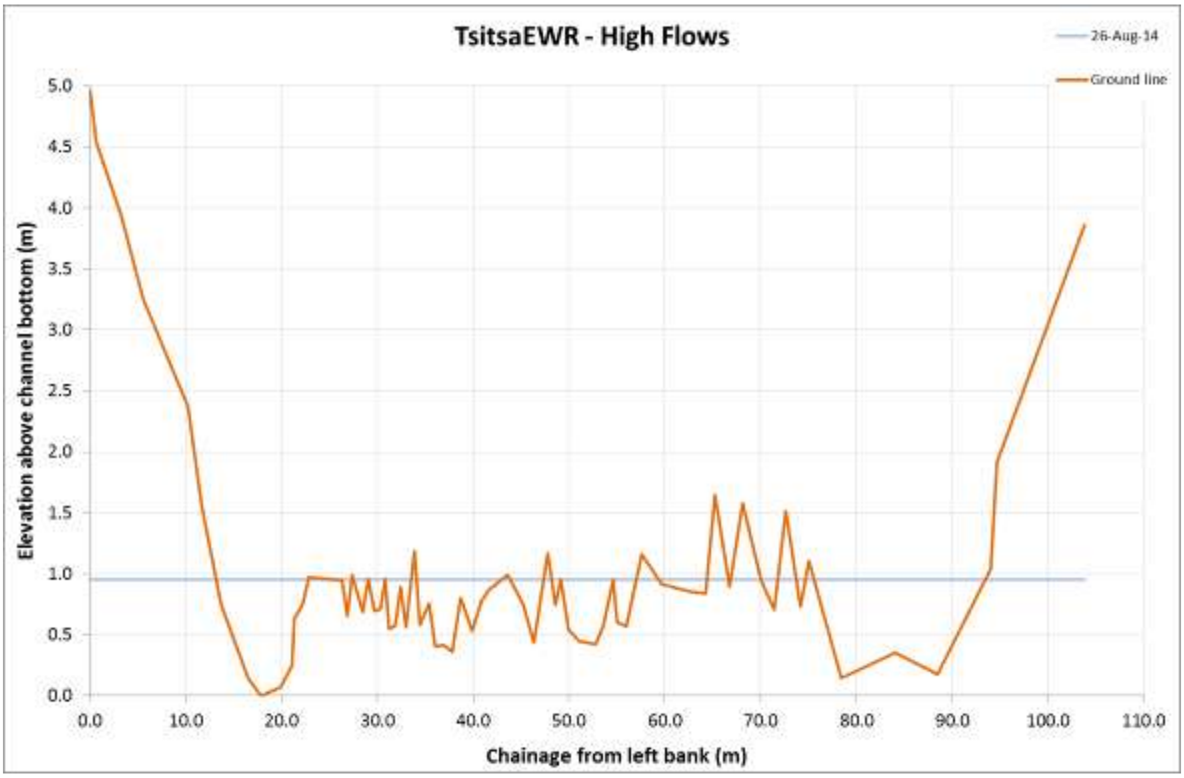

Figure 3-5: Cross-sectional view of the EWR site on the Tsitsa River in T35L – HIGH FLOWS

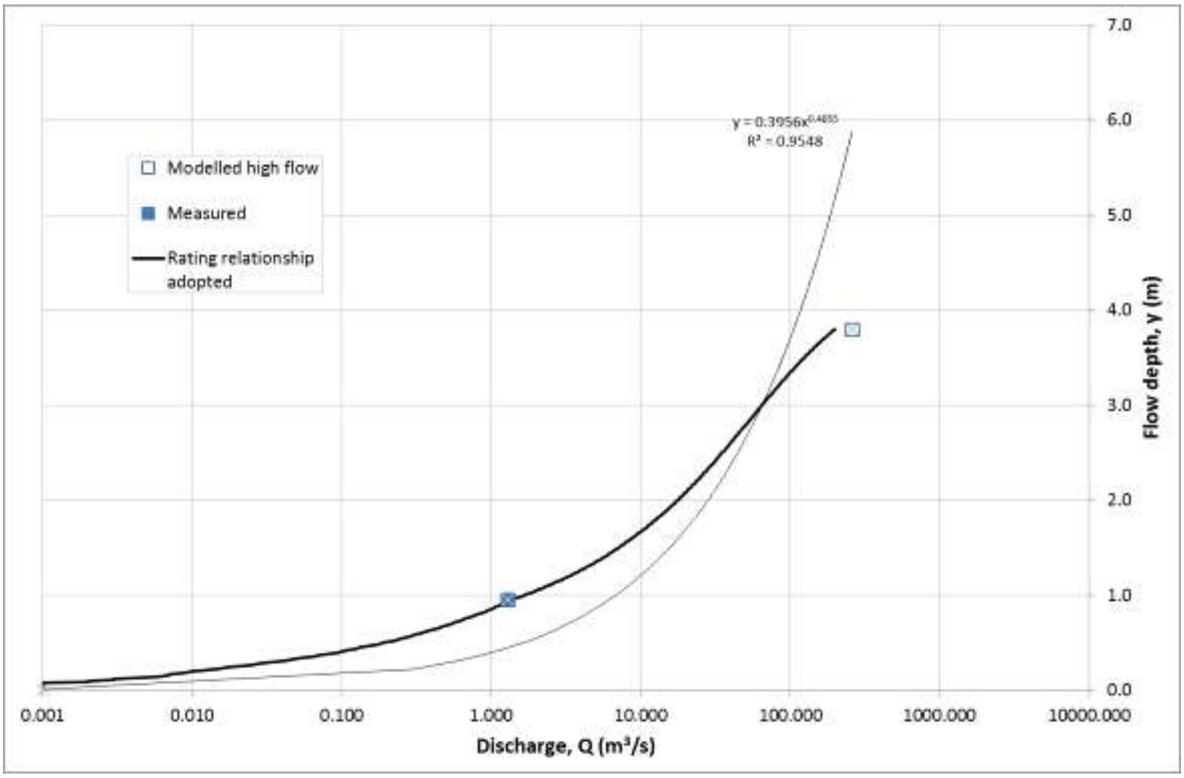

Figure 3-6: Calibrated cross sectional profile for the Tsitsa EWR site in T35L – HIGH FLOWS

In addition to the above, the hydraulics was further modelled using the HABFLO (HABitat FLOw) program (Hirschowitz *et al*, 2007). The program is used to predict statistical distributions of hydraulic habitat for fish and invertebrates based on inputs such as cross-section survey, observed velocities, observed depths, rating curve and specific hydraulic parameters relating to the substrate and vegetation in the river reach.

The hydraulic habitat predictions for fish were used in this study and were based on accepted combinations of depth and velocity in Southern Africa (James and King, 2010). Six classes were modelled in this study namely:

- SVS – Slow-Very Shallow
- SS – Slow-Shallow.
- SD – Slow-Deep.
- FVS – Fast-Very Shallow.
- FS – Fast- Shallow.
- FI – Fast-Intermediate
- FD – Fast-Deep.

The invertebrate habitat distributions used as input into the model were obtained from the geomorphology results (for sedimentation habitat). The vegetation inputs (proportion of vegetation in the habitat, stem diameters, spacings and lengths) were assumed based on visual assessments during the site visit. The following four classes were used:

- VSCS – Very Slow-Course Sediment.
- SCS – Slow-Course Sediment.
- FCS – Fast-Course Sediment.
- VSFS – Very Slow-Fine Sediment.
- SFS – Slow-Fine Sediment.
- FFS – Fast-Fine Sediment.
- VFFS – Very Fast-Fine Sediment.

3.2.3 Hydraulic results

The modelled predictions appear to provide a reasonable correlation between the results obtained from the measured sample, thus indicating that the model should be able to predict habitat distributions to a reasonable level of accuracy, at least for depth. Tabulated output from HABFLO is provided in **Appendix A**.

The confidence rating in the hydraulic modelling results for the EWR site ranges from 0=none to 5=high and is indicated in Table 3-5.

Table 3-5: Confidence in the hydraulic modelled results

EWR site	Limits of measured discharge range (m^3/s)	Confidence rating for discharge range		Comments
	Q measured	Q< Q measured	Q> Q measured	
LaliniEWR	1.61	3	2	Pools on both banks reduce confidence above the measured flow. Some divergent and convergent flow paths within the measured cross-section limit the confidence to a 3 for below the measured Q.

3.2.4 Fish

A fish survey was undertaken during the site visit at the selected EWR site on the Tsitsa River in T35L. Electro-narcosis (conducting an electric current into the water, which immobilises the fish momentarily) was applied at all available biotopes. A minnow seine net was also used in suitable pools and backwaters.

The Ecological Category was determined using historical fish data and from the sampling that took place during the surveys of the Tsitsa River. The data were given moderate confidence and weighting scores in determining the overall category for the site.

Expected and Observed Frequency of Occurrence (FROC) of fish species were compiled using data obtained from the PES/EI/ES 2014 dataset, which is developed on available records and expert opinion (DWA, 2014). These FROC values were used to interrogate the Fish Response Assessment Index (FRAI) to evaluate changes from reference conditions. FRAI is a rule-based model developed by DWS and is an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers (Kleynhans, 2008). These intolerance and preference attributes are categorised into metric groups with constituent metrics that relates to the environmental requirements and preferences of individual species.

Assessment of the response of the species metrics to changing environmental conditions occur either through direct measurement (surveys) or are inferred from changing environmental conditions (habitat). Evaluation of the derived response of species metrics to habitat changes are based on knowledge of species ecological requirements. Usually the FRAI is based on a combination of fish sample data and available habitat for fish.

Changes in environmental conditions are related to fish stress and form the basis of ecological response interpretation and to determine the Present Ecological State category of the fish assemblage.

3.2.5 Macroinvertebrates

Macroinvertebrate diversity and abundances were measured during the site visit using the South African Scoring System Version 5 (SASS5; Dickens and Graham, 2002). Historic sampled data (including upstream sites sampled as part of the broader study) and specialist knowledge were used to determine reference conditions. The following assessment methods were used to collect and/or analyse the data:

- The South African Scoring System Version 5 (SASS5). This index measures aquatic macroinvertebrate presence data at a family taxon level. Each taxon is allocated a value between 1 and 15 according to its perceived sensitivity to water quality changes (with 1 being the least sensitive and 15 the most sensitive). Results are expressed as index scores: the SASS Score and the Average Score per Taxon (ASPT).
- The Invertebrate Habitat Assessment System (IHAS) was used in assessing the instream and riparian habitat (McMillan, 1998). Sections of the site characterisation

manual (Dallas, 2005) were used to assist in characterising the site and interpreting data.

- The Macroinvertebrate Response Assessment Index (MIRAI; Thirion, 2008) uses SASS and pre-determined reference condition data to determine the Present Ecological State (PES) of a site. The model considers the three main drivers of a river, namely: i) flow conditions, ii) geomorphology and iii) water quality. These drivers create the instream habitats that affect instream biotic communities. Therefore, the ecological category generated by the MIRAI reflects the influence of the various drivers on the site and the macroinvertebrate community response.

Appendix B shows the SASS data sheet for the Tsitsa EWR site.

3.2.6 Geomorphology

The geomorphologic assessment was conducted during the field visit on 26 August 2014. The reach from the waterfall to downstream of the discharge point of the hydro power plant was surveyed from a helicopter. This provided an opportunity to assess the larger reach in more detail than usual. The dominant land use activities and the non-flow related impacts of land use activities within the catchment were assessed using Google Earth.

The GAI assessment (version 2; Rowntree, 2013) is a rule based assessment that was used to classify the channel, construct a reference condition and assess the PES. GAI considers two metric groups: the catchment geomorphic drivers (sediment budget, landscape connectivity and channel stability) and channel morphology (habitat).

Catchment geomorphic drivers were assessed based on the helicopter survey and aerial images. Frequency and extent of erosion features were assessed. Changes in slope – channel, upstream - downstream and channel – floodplain connectivity were noted. Furthermore, the frequency and extent of upstream channel disturbance and erosion was evaluated.

The instream and riparian morphology were assessed at the LaliniEWR site. Likely changes to the various features were assessed in terms of size and composition based on the reference condition.

Findings indicate that extensive livestock grazing and localised cultivation on slopes throughout the majority of the catchment area have resulted in widespread erosion. Silt and fine sand form the bulk of the sediment and is transported in suspension. Very few sediment sinks, such as wetlands, dams and extensive flood floodplains, exist along the drainage lines and main channel, resulting in high slope-channel and down channel connectivity and limited sediment storage within the catchment. The upstream channel was relatively stable as it is bedrock controlled with localised bank erosion due to river crossings, grazing and invasive alien vegetation. Sediment loads are thus increased for the present day condition.

The steep gradient (high energy) and confined setting (limited accommodation space) of the LaliniEWR channel reach resulted in limited depositional features to have formed (as would be expected for increased sediment loads). Sediment deposition in the active channel has resulted in the anchoring of cobbles and boulders to the active channel floor; the embedding of larger particles (e.g. cobble and gravel) and silt drapes lining bedrock, cobble and gravel bars in areas of lower flow velocities.

Appendix C provides the results of the field survey.

3.2.7 Riparian Vegetation

Riparian vegetation was assessed using the Vegetation Response Assessment Index (level 3; Kleynhans *et al.*, 2007). As a result, assessments included: distinguishing between marginal and non-marginal zones; determining the condition of each vegetation zone; describing the indigenous woody and non-woody vegetation; describing riparian vegetation degradation; and assessing the extent of alien vegetation infestation at the site.

Riparian vegetation at the site was subdivided into marginal and non-marginal zones in order to: i) assess vegetation changes from the reference state within each zone and ii) determine each zone's contribution to the instream habitat integrity of the system. The marginal zone was considered to be the active zone at the water's edge; and the non-marginal zone the area that would be inundated at least once every three years. Each zone was assessed separately and weighted in terms of its contribution (in the reference state) to the instream habitat integrity of the river. Furthermore, each zone was assessed in terms of intensity and extent of vegetation removal, alien vegetation infestation, and changes in water quantity and quality from the reference.

VEGRAI level 3 required the assessment of changes in cover, abundance and species composition of both the woody and non-woody vegetation from the reference state within each zone. The contributions of woody and non-woody vegetation to the instream habitat integrity were assessed individually and scored in relation to each other.

Appendix D describes the detail results of the riparian vegetation assessment.

3.2.8 Hydrology

The Tsitsa River is a major tributary of the Mzimvubu River. The selected EWR site is in quaternary catchment T35L with a natural MAR of 868.6 x $10^6 m^3$. The EWR site is situated in the lower reaches of quaternary catchment T35L just upstream of the proposed discharge point of the hydro power plant. The main tributary of the Tsitsa River upstream of the EWR site is the Inxu River that contributes almost 50% of the natural flow at the EWR site.

Updated hydrology (Jeffares & Green, 2013) was used for the hydrological analysis and the preparation of the various statistics for use by the other component specialists. The detailed hydrological modelling for the EWR site is described in a separate report (Jeffares and Green, 2013).

The only gauging weir in the Tsitsa River is T3H006 that is situated approximately 35 km upstream of the EWR site. Flow contribution from the catchment between the weir and the

EWR site is minimal and the observed data from 1985 to present was used during the assessments for low/zero flows and the specification of flood requirements.

3.3 Information Availability

The available information for the EWR site is summarized in

Table 3-6 using a score from 0 (no information) to 4 (large amount of data available).

Table 3-6: Information availability for the EWR site in T35L

COMPONENT	INFORMATION AVAILABILITY					DESCRIPTION OF INFORMATION
	0	1	2	3	4	
Hydraulics						One set of measured data was used in the modelling.
Hydrology						Updated hydrology from Jeffares and Green, 2013 was used during the assessment. Daily data from gauge T3H006 on the Tsitsa River (upstream of EWR site) was used for low/zero flows and flood specification.
Fish						Data available from the 2014 PES/EI/ES, FROC and EKZNW databases
Macroinvertebrates						Once off macroinvertebrate survey at the site, augmented with historical data from RHP site upstream of the Tsitsa falls.
Geomorphology						Recent high resolution colour aerial images were available. The helicopter flight gave a good overview of the reach. No historical geomorphological data was available.
Riparian vegetation						Information from imagery, past surveys in the area and Mucina and Rutherford (2006) were used.

3.4 Specialist workshop (Ecoclassification)

The results of the specialist workshop are summarized per sub-section for the following:

- Reference conditions
- Present Ecological State (EcoStatus) per component
- Ecological Importance and Ecological Sensitivity
- Integrated PES (EcoStatus)
- Trends and
- Recommended Ecological Category

3.4.1 Reference conditions

Reference conditions usually reflect the natural, un-impacted/pre-development conditions and are used as a baseline against which surveyed data can be compared to reflect the degree of change from the natural/un-impacted state of a resource.

Reference conditions for EWR sites are usually derived from un-impacted rivers in the same catchment area, aerial photographs, knowledge of the catchment and historical information, where available. The reference conditions for the EWR site in the Tsitsa River per specialist component are summarized in Table 3-7.

Table 3-7: Description of reference conditions for the Tsitsa EWR site

COMPONENT	DESCRIPTION OF REFERENCE CONDITIONS
Fish	Three indigenous fish species are expected, namely Giant Mottled Eel (*Anguilla marmorata*), Longfin Eel (*Anguilla mossambica*), and Chubbyhead Barb (Barbus anoplus).
Macroinvertebrates	SASS5 scores: The total SASS5 score should be >201 and the Average Score Per Taxon (ASPT) should be >7.3. Reference taxa include: *Heptageniidae*, *Prosopistomatidae* and *Perlidae*.
Geomorphology	The EWR site is located along a section of rejuvenated foothills (Rowntree and Wadeson, 1999) where the reference state would have been characterised by a similar pool riffle sequence with limited suspended sediment within the water column, even during higher flows. The riffle sections would have been comprised of large boulders, cobbles and very course gravel with limited fine sand in the riffles. In the pools habitat would range from gravel to sand to bedrock with localised silt and clay deposits. The banks would be lined with well sorted inset benches of sand or gravel that are stabilised by marginal vegetation. The bank composition would be more cohesive, as a result of less silt and fine sand input.
Riparian vegetation	The marginal zone would have been dominated by a sedge-grassland vegetation type. This vegetation type would have had a greater basal cover and fewer sand banks in between than found in the present state. Boulder bars would have been scattered along the banks that would limit vegetation cover in these areas. The non-marginal zone would have been a mixture of Eastern Valley Bushveld and common riparian vegetation species. The left- and right-hand banks would be different because of their different slopes. The grass basal layer would have been denser. Relatively infrequent fires in the steep gorge would result in dense woody vegetation cover, comprised of *Acacia karroo, Cussonia paniculata, Euphorbia spp., Ficus sur, Gymnosporia sp., Hippobromus pauciflorus* and *Ziziphus mucronata.* The non-marginal zone played the primary role in driving the overall ecological condition of the system. Both zones would have been relatively similar in terms of their basal cover; however, the non-marginal zone would have had a greater surface area and higher abundance of woody species whose roots would help with bank stabilisation.
Hydrology	Natural flows at the EWR site were available for the period 1920 to 2009 as provided by R Gray of Jeffares and Green

3.4.2 Present Ecological State

The PES is determined making use of the recognised models for each component as published in a series of volumes under the lead volume Kleynhans and Louw, (2008). The PES for the fish, macroinvertebrates, riparian vegetation, geomorphology, hydrology and physico-chemical are provided below:

i) Fish

Two of the three expected fish species were collected during the surveys. Fish data from the 2014 PES/EI/ES dataset was used to determine FROC ratings based on conditions of the site as well as the available habitats for species expected under reference conditions. These FROC results were used to inform the Fish Response Assessment Index (FRAI) to determine the PES.

The FRAI results indicate that the fish assemblage is currently in a B category (86.3%) Ecological Category indicating that the fish community is in a good state. Impacts to the fish assemblage, although minimal, include drivers associated fish cover and physico-chemical conditions (notably turbidity). This appears to be mostly associated with land use impacts in the upstream catchment. The paucity of marginal vegetation compared to the reference state has a significant negative impact as this is the required spawning habitat of *Barbus. anoplus* and to provide cover from predation.

The detailed FRAI tables are presented in **Appendix E**.

ii) Macroinvertebrates

The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to macroinvertebrate community changes from the reference condition. This information was then modelled to derive the Present Ecological Category of the site. Results below are for the low flow (and therefore critical period) sampling occasion on the 26th of August 2014.

The macroinvertebrate Ecological Category is a B (83.9%). This means the river is in a good ecological condition. The B category could be attributed to increased sediment loading as a result of both catchment related processed (e.g. overgrazing) and localised impacts (e.g. bank erosion as a result of alien invasive plant infestation).

The most impacted driver metric was water quality (25.8%), followed by habitat integrity (14.1%) and flow modification (7.2%). Table 3-8 provides the summary of the data interpretation and the PES for the macroinvertebrates. Taxa characterising this site included *Libellulidae*, *Heptageniidae, Leptophlebiidae*, *Prosopistomatidae* and *Baetidae* >2spp .

Table 3-8: Macroinvertebrate Ecological Category, MIRAI

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	**FM**	92.8	*0.333*	30.9375	2	90
HABITAT	**H**	85.9	*0.296*	25.4655	3	80
WATER QUALITY	**WQ**	74.2	*0.370*	27.4897	1	100
CONNECTIVITY & SEASONALITY	**CS**	60.0	*0.000*	0		
INVERTEBRATE EC				83.8927		270
INVERTEBRATE EC CATEGORY				B		

According to flow modification assessments, taxa with a preference for very fast flowing water were the most important group; and taxa with a preference for standing water ranked the least important group in the system. Taxa with a preference for fast flowing water were the least impacted group (0), all other flow requirements were equally impacted (0.5).

According to habitat modification assessments, taxa with a preference for loose cobbles were the most important group; and taxa with a preference for bedrock and boulders were the least important group in the system. Taxa with a preference for vegetation were the most impacted group (3). This could be attributed to the removal of marginal vegetation as a result of bank erosion and overgrazing. Taxa with a preference for bedrock/boulders, and gravels, sand and mud, and for the water column or surface water were the least impacted groups (0).

According to water quality assessments, the ASPT was the most important parameter; and taxa with a very low requirement for unmodified physico-chemical condition the least important group in the system. The ASPT and taxa with a moderate requirement for unmodified physico-chemical conditions were the most impacted parameters (3 and 2 respectively); whereas taxa with a high requirement and very low requirement for unmodified physicochemical conditions were the least impacted (0).

Appendix B provides the detail tables for the flow, habitat and water quality modification metrics.

iii) Riparian Vegetation

The riparian vegetation ecological category is a C. This means the river from a vegetation perspective is in a moderately modified ecological condition. The C category is largely attributed to overgrazing and bank erosion. Therefore, the impacts are primarily non-flow related.

The marginal zone: The marginal zone was characterised by sand banks and boulders with non-woody vegetation scattered in between. *Cynodon dactylon* and a variety of *Cyprus spp*. and *Juncus spp*. dominated the marginal zone. Indigenous woody and non-woody cover and abundances were affected by overgrazing and concomitant erosion.

The non-marginal zone: Vegetation communities differed on the left and right hand banks. The left hand bank was less dense, had a more gradual slope (to the cliff) and less diverse than the right hand bank. Both banks had vegetation typical of Eastern Valley Bushveld. Species were largely terrestrial (i.e. riparian zone opportunists). Non-woody vegetation was heavily overgrazed.

Table 3-9: Riparian vegetation ecological category, VEGRAI 3

LEVEL 3 ASSESSMENT					
METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	% WEIGHT
MARGINAL	65.0	18.6	1.7	2.0	40.0
NON MARGINAL	65.8	47.0	1.7	1.0	100.0
LEVEL 3 VEGRAI (%)				65.6	
VEGRAI EC				C	
AVERAGE CONFIDENCE				1.7	

Appendix D provides the detail tables for marginal and non-marginal vegetation zone scoring sheet.

iv) Geomorphology

The geomorphological integrity or PES of the LaliniEWR site falls within a C category due to the increased sediment input and resultant loss of habitat integrity. The flow regime has become more flashy (higher energy) due to increased landscape connectivity, which reduced the prevalence of inset benches.

Table 3-10: Fluvial geomorphology ecological category, GAI

PES	Flow related	Confidence
C (69.13)	36.39%	3.63

Appendix C provides the detailed tables of the GAI assessment.

v) Hydrology

Forestry, small dams and irrigation abstractions are the main impacts in the upper catchment, especially in the Mooi and Pot Rivers. The rest of the catchment is rural, with Maclear the only large town in the upper reaches of the Mooi River (tributary of the Inxu River). The details of the flow and the Hydrological Assessment Index are presented in Table 3-11 below.

Table 3-11: HAI scores for the Tsitsa EWR site in T35L

HYDROLOGY DRIVER ASSESSMENT INDEX				
HYDROLOGY METRICS	**Rank**	**%wt**	**RATING**	**CONFIDENCE**
LOW FLOWS	3.00	70.00	0.50	4.00
ZERO FLOW DURATION	1.00	100.00	1.00	2.00
SEASONALITY	3.00	70.00	0.00	4.00
MODERATE EVENTS	2.00	80.00	0.50	4.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	50.00	0.00	4.00
HYDROLOGY SCORE	**90.5**			
HYDROLOGY ECOLOGICAL CATEGORY	**A/B**			

Note: Moderate events include freshets, 1:1 and 1:2 year flood events

vi) Integrated Habitat Integrity

The habitat integrity assessment for the Tsitsa River from the waterfall to the EWR site was conducted using the procedure described by Kleynhans (Kleynhans, 1996) and the latest IHI DWA model. The habitat integrity was evaluated taking flow related impacts of the upstream catchment into account.

The results of the assessment of the habitat integrity of both the riparian and instream zones are presented in Table 3-12 and Table 3-13 respectively. The instream integrity is in a B category (i.e. largely natural) and the riparian integrity is in a B/C category (i.e. moderately modified). The main impacts are bed modification (settling out of fines in pools) and vegetation removal (loss of basal cover due to overgrazing).

Table 3-12: Habitat Integrity assessment scores for the riparian zone

RIPARIAN ZONE HABITAT INTEGRITY	August 2014 (Tsitsa@ Lalini EWR site)	COMMENT
VEGETATION REMOVAL (IMPACT 1-25)	13	Basal cover lost due to over-grazing. Large trees and shrubs still intact, but with limited recruitment
EXOTIC VEGETATION (IMPACT 1-25)	2	Very small (sesbania, wattle, seringa)
BANK EROSION (IMPACT 1-25)	4	Localised at the site
CHANNEL MODIFICATION (IMPACT 1-25)	2	Lost some of the margins where one expect sedges
WATER ABSTRACTION (IMPACT 1-25)	0	-
INUNDATION (IMPACT 1-25)	0	-
FLOW MODIFICATION (IMPACT 1-25)	1	-
PHYSICO-CHEMICAL (IMPACT 1-25)	1	-
RIPARIAN VEGETATION INTEGRITY SCORE *	79.0	
RIPARIAN INTEGRITY CATEGORY	**B/C**	

* Weighted riparian integrity score

Table 3-13: Habitat Integrity assessment scores for the instream zone

IN STREAM HABITAT INTEGRITY	August 2014 (Tsitsa@Lalini EWR site)	COMMENT
WATER ABSTRACTION (IMPACT 1-25)	4	Irrigation in upper reaches of Inxu River catchment
FLOW MODIFICATION (IMPACT 1-25)	2	Forestry and small dams in upper reaches of Inxu River catchment
BED MODIFICATION (IMPACT 1-25)	10	Steep system with flushing of sediments in the riffles but fines settle out in pools
CHANNEL MODIFICATION (IMPACT 1-25)	4	Increased connectivity and over-crazing – scouring due to increased discharge from catchment
PHYSICO-CHEMICAL (IMPACT 1-25)	4	Small increase in nutrients
INUNDATION (IMPACT 1-25)	0	-
SECONDARY		
ALIEN MACROPHYTES (IMPACT 1-25)	0	-
INTRODUCED AQUATIC FAUNA (IMPACT 1-25)	2	Expect carp in the system
RUBBISH DUMPING (IMPACT 1-25)	1	-
INSTREAM INTEGRITY SCORE *	86.0	
INSTREAM INTEGRITY CATEGORY	**B**	

* Weighted instream integrity score

vii) ECOSTATUS

The PES per component as derived from the various models, the rationale and an indication if it is flow or non-flow related impacts are provided in Table 3-14.

Table 3-14: The PES, with reasons for this classification, of the various components

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Hydrology	A/B (90.5)	F	Impacts on the low flows and moderate events due to forestry, small dams and irrigation in upper catchment. Possible zero flows as observed at gauging weir.
Fish	B (86.3)	NF	Fish community is minimally affected by the loss of natural cover features (e.g. marginal vegetation) and water quality impacts caused by increased sedimentation.
Macroinvertebrates	B (83.9)	F/NF	Water quality (e.g. nutrient enrichment and turbidity) having an impact at the site and the low flows, resulting in limited vegetation habitat.
Geomorphology	C (69.13)	NF	Increased fine sediment input reduce cobble and gravel mobility, increase embeddedness of gravel and cobble and form a silt drape in areas with lower flow velocities. Increased landscape connectivity result in high energy flashy flows that reduce the formation of inset benches.
Riparian vegetation	C (65.6)	NF	Overgrazing and concomitant bank erosion in both the marginal and non-marginal zones.
IHI: Instream	B (86.0)	F	Bed modification - settling out of fines in pools
IHI: Riparian	79.0 (B/C)	NF	Vegetation removal - loss of basal cover due to over-grazing

(F-flow, NF-Non-flow)

The assessments of the various biophysical components impacting on the present ecological status of the river can be integrated, with the overall classification given as an EcoStatus score.

To determine the EcoStatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Vegetation Response Assessment Index (VEGRAI) category and confidence is then included in the assessment index and the integrated EcoStatus is calculated.

The integrated PES or EcoStatus of the Tsitsa River at the EWR site is a B/C category (largely natural to moderately modified) and is presented in

Table 3-15 below. The main negative impacts on the Tsitsa River at the EWR site are increased sedimentation and the loss of basal cover on the river banks.

Table 3-15: EcoStatus for the Tsitsa River at EWR site in T35L

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	2	50		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	50		
FISH ECOLOGICAL CATEGORY	11	280	**86.3**	**B**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	4	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	4	100		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**12**	300	**83.9**	**B**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		580	**84.8**	**B**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	4	0.50	43.15
Confidence rating for **macro-invertebrate** information	4	0.50	41.95
	8.0	1.00	85.10
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**65.6**	**C**

ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	4	0.62	52.37
Confidence rating for riparian vegetation zone information	2.5	0.38	25.23
	6.5	1.00	77.60
ECOSTATUS	**EC**		**B/C**

3.4.3 Ecological Importance and Ecological Sensitivity

Both the EI and ES for the Tsitsa River were determined as moderate during the PES/EI/ES study (DWS 2014). The EI was mainly driven by macroinvertebrate rarity and representivity, habitat diversity and instream and riparian-wetland zone migration linkage and integrity. This reach is seen as a critical migration corridor for the movement of the three eel species to the upper Tsitsa River. The ES was largely driven by macroinvertebrate physico-chemical and velocity sensitivities. Additional to the above and based on the survey data collected at the EWR site, the following should be noted:

i. Two waterfalls are present in the system, namely the large Tsitsa Falls approximately 20 km upstream (below N2 road) of the EWR site and the smaller falls further upstream (below R56 road). These falls act as barriers that could result in the creation of an evolutionary significant unit with the potential presence of the unique *Barbus cf. anoplus.* DNA analyses of fish from this river reach and comparison with chubbyhead barb populations upstream of the Upper Tsitsa falls and in adjacent rivers will be required to resolve this issue. Until this information is available, the use of the precautionary principle is considered prudent.

ii. Furthermore, *Psephenidae* (that are dependent on high velocities) were sampled during the low flow survey in August 2014. *Perlidae* and *Prosopistomatidae* (that are sensitive to water quality changes) were also present at the EWR site.

iii. At a provincial scale cycads are a highly threatened plant group. A significant colony of these plants is present on the cliffs associated with the waterfall.

iv. A variety of aquatic habitats were available at the EWR site, including cobles, boulders, bedrock, gravel/sand/mud, sand bars, stones in current, stones out of current, gorge below the waterfall.

v. The waterfall and gorge forms part of the Provincial CBA.

3.4.4 Trends

The trend in ecological status gives an idea whether the present state is realistic and would **stay the same if the management of the catchment were to continue in the same way** that gave rise to the present state.

Thus the definition of the trend is *"…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux",* Kleynhans and Louw (2008).

The ecological trends are presented in
Table 3-16 below.

Table 3-16: Ecological trends for the Tsitsa River at the EWR site

Component	Trend	Reason	Confidence (0-5)*
Fish	Stable	No recent major changes to the upstream catchment.	3
Macro-invertebrates	Stable	No recent major changes to the upstream catchment. Some nutrient enrichment from the upper catchment increasing productivity of the system. A system already largely modified/adapted to high sediment loads from the catchment	3
Riparian Vegetation	Stable	Riparian zone already heavily overgrazed with no other impacts.	3
Fluvial geomorphology	Negative	Increased invasion of alien vegetation along riparian corridors will destabilize the channel margins, leading to increased instability and loss of geomorphological integrity.	3
Hydrology	Stable	No recent changes to forestry areas, increases in small dams or irrigation use.	3

* 0 – no confidence to 5 – high confidence

3.4.5 Integration of results (EcoStatus) and Recommended Ecological Category

The EcoStatus of the Tsitsa River EWR site is in a B/C category. This EcoStatus score can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC.

During the final allocation of the REC, if the resource is degraded (i.e. has a low PES) but has a high ecological importance and sensitivity (EIS), the REC can be upgraded if it is potentially feasible to do so. Both the EI and ES for the Tsitsa River is moderate and the present state of a B/C is mostly due to the riparian vegetation that is a non-flow related impact. After discussions between the various specialists, it was decided to maintain the B/C category as the Recommended Ecological Category.

3.4.6 Ecological Water Requirements (quantity)

The above information together with the hydraulic cross-section were utilised to determine the stress indices for low flows and the flood requirements for the fish, macroinvertebrates, geomorphology and riparian vegetation.

Stress indices are set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependent biota. It therefore describes the habitat conditions for fish and macroinvertebrate indicator species or guild for various low flows. These habitat conditions for different flows are rated from 10 (zero flows, high stress) to 0 (no stress), which is optimum habitat for the indicator species.

The Desktop Reserve Model (DRM) in SPATSIM, version 2.12 was used to calculate the final Ecological Water Requirements for the REC of a B/C. The reference flow used was the natural simulated flows with the mean annual runoff of 868.6 x $10^6 m^3$.

Some stress was present during the field visit (discharge of 1.61 m^3/s) and the departure point with no stress was taken as 2.0 m^3/s based on no stress for the macroinvertebrates during the dry season. As only a low flow survey was undertaken, the stress was based on the maximum base flow for the lowest flow month (August). The maximum base flow for August (no stress) was determined as 2.0 m^3/s, derived from the daily observed flows at gauging weir T3H006. The stress-flow relationships were determined for flows lower than these using the hydraulic cross-section, available habitats and velocities.

As no high flow survey was undertaken (rapid study), the maximum base flows or 'no stress' for the wet season was not determined. The approach adopted for the wet season maximum base flows was to check if the DRM requirements for February provided adequate habitats and velocities for fish and macroinvertebrates.

The selected stress values and associated flows based on the dry season maximum base flow are provided in Table 3-17 and the final integrated stress curve is shown in Figure 3-7.

Table 3-17: Selected stress values, flows and rationale for the Tsitsa River EWR site

Stress	Fish Flow (m^3/s)	Macro-invertebrates Flow (m^3/s)	Rationale for Fish and Macroinvertebrates
0	1.6	2.0	Habitat of very high quality and well represented at the site. Correspondingly biota abundant and are healthy at all life stages.
1		1.6	High quality habitat amply available. Biota abundant and healthy at all life stages.
2	0.22		
3			
4		0.69	Loss of riffle habitat below this volume. Limited critical habitat available and of moderate quality. All life stages still viable but with sensitive rheophilic species at risk. e.g Plecoptera
5			
6	0.01		
7		0.22	No critical habitats available, other habitats of only moderate quality. Most rheophilic species rare. All life stages of sensitive rheophilic species either at risk or nonviable. Both presence and abundance of Perlidae, Psephenidae and Turbellaria likely to decline and it is anticipated that the abundance of Hydropsychidae spp will decrease
8			
9		0.01	Only standing water habitats of low quality anticipated. Mostly pool dwelling species present. Rheophilic life stages nonviable. Tabanidae, Gomphidae, Oligochaeta and Caenidae may persist.
10	0.001	0.001	No surface water only hyporheic refugia. Only specialists will persist.

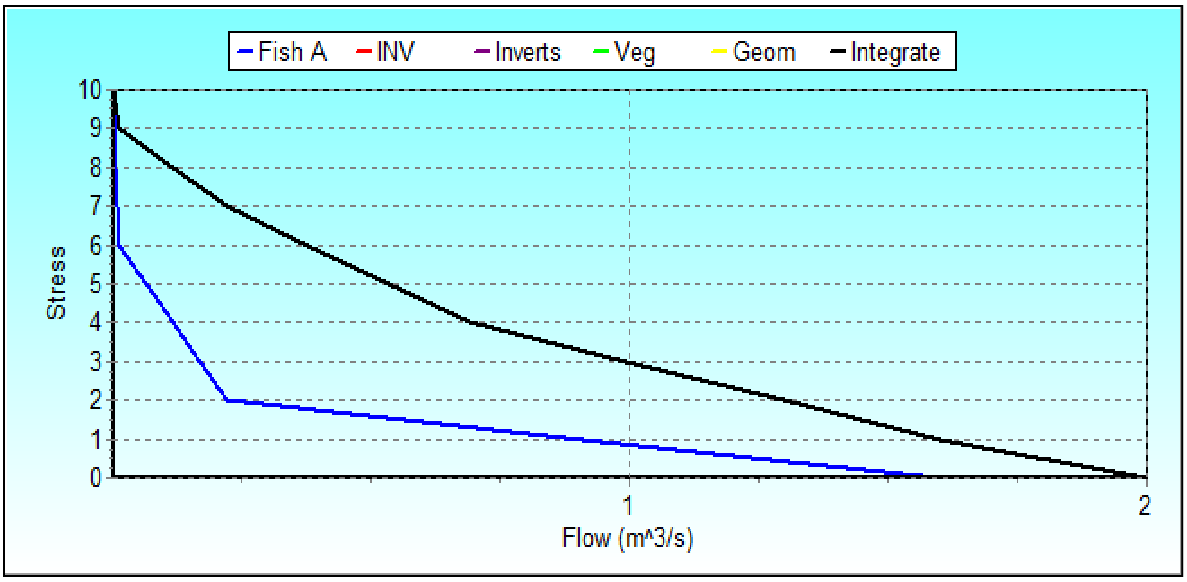

Figure 3-7: Final stress curve for the Tsitsa River EWR site

The Desktop Reserve Model (DRM) (SPATSIM, version 2.12) was used to calculate the Ecological Water Requirements (EWR) for the recommended ecological category of B/C for the Tsitsa River at the EWR site in quaternary catchment T35L.

Maintenance low flows were examined for August and February/March. August is the month with the lowest maintenance flow (i.e. base-flow) and February/March have the highest maintenance flow conditions according to the DRM model. The water level in the Tsitsa River during the site visit on 26 August 2014 (1.61 m^3/s) was used as a reference (refer to Figure 3-8).

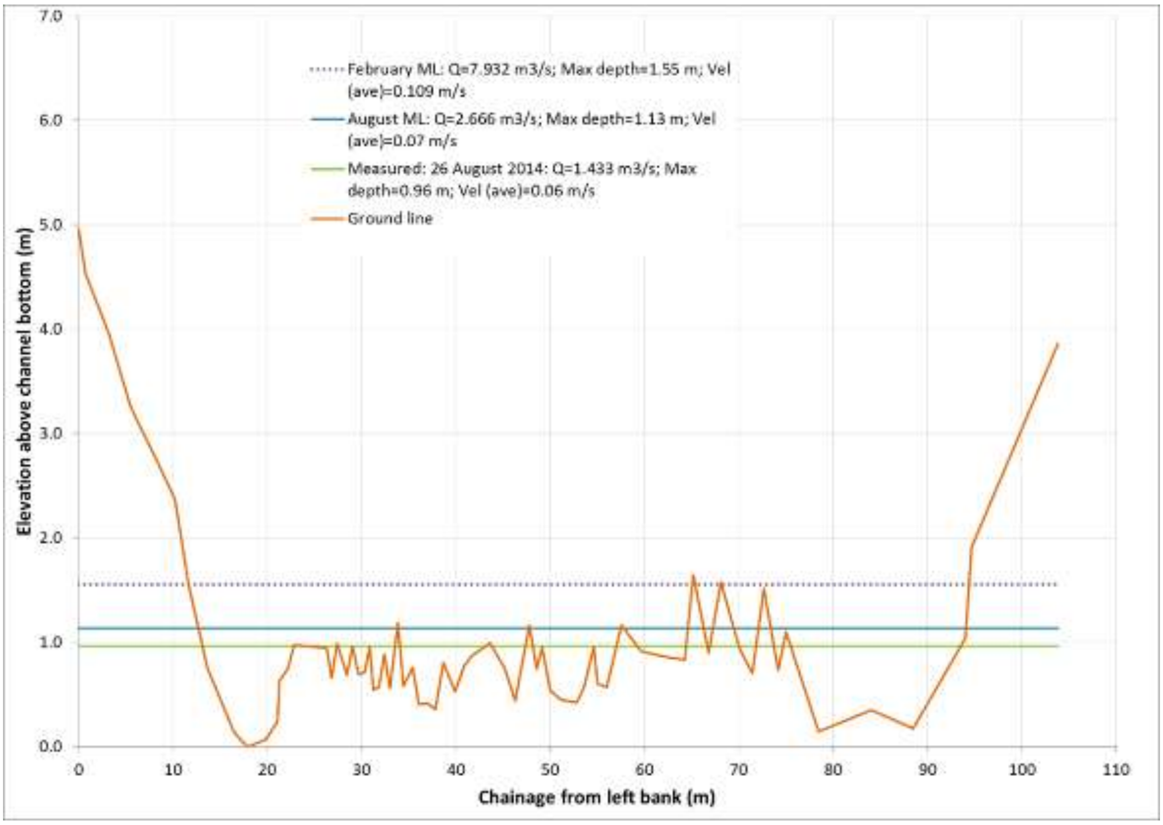

Figure 3-8: Modelled and measured water levels at the cross-section of the EWR site

Together with the site photographs and the rating relationships (flow depth versus discharge) from the hydraulic model, the water levels proposed by the DRM for maintenance low flows were assessed in terms of the habitat and biotic requirements. The flow in the river was very low during the site visit.

The site-specific flow requirements were based mainly on the velocity and habitat requirements of flow-sensitive aquatic macroinvertebrates that resulted in no or low stress. The consensus reached by the ecologists was that the velocities and depths at the critical habitat, recommended by the DRM model during August (2.667 m^3/s) was more than adequate to provide the necessary velocities for the flow sensitive macroinvertebrates. As 'no stress' for macroinvertebrates was determined at ~2.0 m^3/s, the requirements for the low flow months (June to September) were reduced. This resulted in an overall reduction of the maintenance low flows from 16.78% to 15.76% of the natural flow of 868.6 x $10^6 m^3$.

Table 3-18 gives the various results for the maintenance low flows at the EWR site in quaternary catchment T35L.

Table 3-18: EWR results for specific months for the Tsitsa River in T35L (REC = B/C)

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s)
			Maximum	Average	Average
Maintenance low flows					
Low flows	August	2.667	1.134	0.494	0.070
High flows	February	7.531	1.553	0.854	0.109
Measured discharge at site (26th August 2014)		1.610	0.950	0.380	0.060

The flood requirements for the Tsitsa River were specified by the macroinvertebrates, fish, geomorphology and riparian vegetation specialists and include small freshets to provide specific cues as well as larger floods for clearing of the river channel. The individual requirements were integrated for inclusion in the final EWR results and are summarised in Table 3-19.

Table 3-19: Flood requirements for the Tsitsa River at the EWR site in T35L

Floods	Flood size (range)	Fish	Inverts	Vegetation	Geomorp	Actual Flood Value in SPATSIM
Class 1	0-10				10 cumec Average 10 days Sep, Oct, Nov, 2xDec, 3xJan, 2xFeb	***10 cumec Average 10 days Sep, Oct, Nov, 2xDec, 3xJan, 2xFeb***
Class 2	11-25	25 cumec Average 4 days Oct, Nov, Dec, Jan	20 cumec Average 4 days Sep, Oct, Dec, Jan	20 cumec Average 4 days Sep, Nov, Jan, Mar	20 cumec Average 6 days Oct, Nov, Dec, 2xJan, Feb	***25 cumec Average 6 days Sep, Oct, Nov, Dec, 2xJan, Feb, Mar***
Class 3	100-170	100 cumec Peak 6 days Feb/Mar	170 cumec Peak 5 days Feb	150 cumec Peak 6 days Any Dec-Mar	200 cumec Peak 4 days Any Nov-Mar	***170 cumec Peak 5 days Feb***
Class 4	200-350			200 cumec Peak 6 days Mar	350 cumec Peak 4 days Feb/Mar 1:2 year	***200 cumec Peak 4 days Mar***
Class 5	500				500 cumec Peak 5 days 1:5 year	
Class 6	1000				1000 cumec Peak 6 days ~1:10 year	

* The freshets as defined in the DRM for April have been included.

The final EWR for the Tsitsa River in T35L is summarised in Table 3-20**.** These EWR results are used to produce the final Ecological Reserve quantity results in the format of an assurance table or EWR rule curves. These curves specify the frequency of occurrence relationships of the defined maintenance and drought flow requirements for each month of the year. The tables thus specify the percentage of time that defined flows should equal or exceed the flow regime required to satisfy the ecological Reserve. The detail EWR and assurance tables are provided in **Appendix F**.

Table 3-20: Summary of the EWR results (flows in million m3 per annum)

Quaternary Catchment	T35L
EWR Site Co-ordinates	S 31.294; E 28.992
Recommended Ecological Category	B/C
VMAR for Quaternary Catchment Area	868.6
Total EWR	287.053 (33.05 %MAR)
Maintenance Low flows	136.868 (15.76 %MAR)
Drought Low flows	52.012 (5.99 %MAR)
Maintenance High flows	150.186 (17.29 %MAR)
Overall confidence	Low-Medium

4. ECOLOGICAL CONSEQUENCES OF SCENARIOS

A number of scenarios were identified to assess the likely impact of the proposed Ntabelanga and Lalini Dams and releases for hydro power generation on the Tsitsa River downstream of the waterfall, before the discharge point. The scenarios assessed are listed in Table 4-1 below.

Table 4-1: Operational scenarios for the Tsitsa River at EWR site in T35L

Scenario	Description	Full Supply Capacity ($10^6 m^3$)	
		Ntabelanga	Lalini
Nat	Natural	0.0	0.0
Prs	Present day flows without EWR (present day is almost natural flows)	0.0	0.0
Sc1	1.18 MAR Ntabelanga Dam with full EWR, hydropower releases 0.15 MAR Lalini Dam with full EWR, hydro power.	490.0	123.8
Sc2a	1.18 MAR Ntabelanga Dam with full EWR, hydropower releases 0.28 MAR Lalini Dam with full EWR, hydro power discharge after EWR site.	490.0	231.0
Sc2b	1.18 MAR Ntabelanga Dam with full EWR, hydropower releases 0.28 MAR Lalini Dam with maintenance flows (no floods), hydro power discharge after EWR site.	490.0	231.0
Sc3	1.18 MAR Ntabelanga Dam with full EWR, hydropower releases 0.6 MAR Lalini Dam with full EWR, hydro power discharge <u>after</u> EWR site.	490.0	495.0
Sc4	1.18 MAR Ntabelanga Dam with full EWR, hydropower releases 0.28 MAR Lalini Dam with full EWR, hydro power discharge <u>before</u> EWR site.	490.0	231.0

The hydrological changes associated with each of the identified scenarios were modelled and used as the primary driver of change. The EWR of the Tsitsa River was assessed in terms of how these changes in flow will impact on the level of stress being experienced in the system and the state of the various response variables.

The flows as provided for the operational scenarios were converted into m^3/s and seasonal distribution and flow duration plots were prepared for the scenarios. The seasonal distribution plot is shown in Figure 4-1 and the flow duration plots for August and February in Figure 4-2 and Figure 4-3.

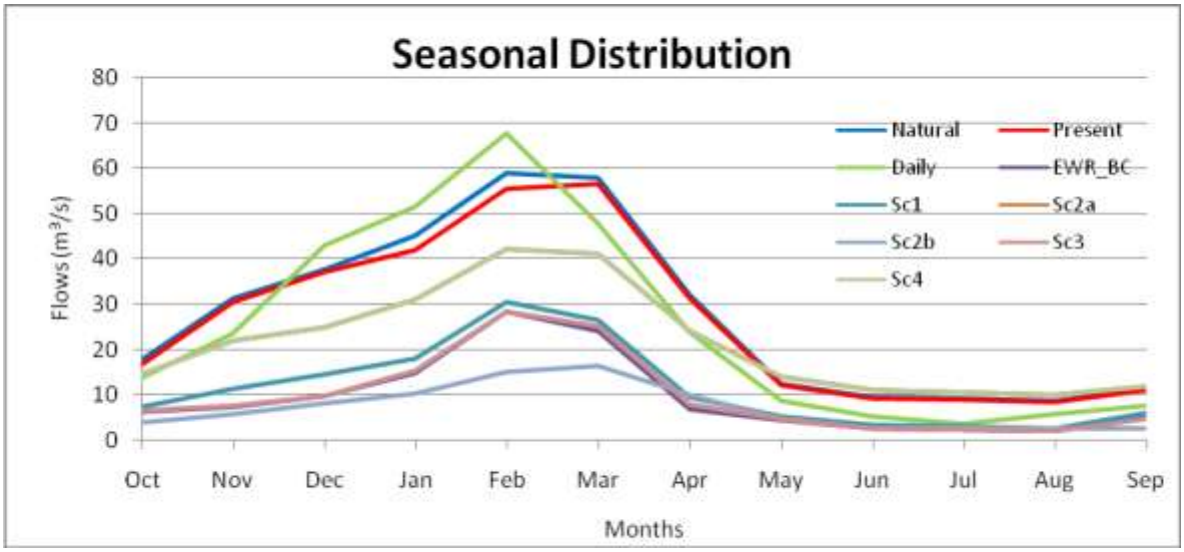

Figure 4-1: Seasonal distribution plots of scenarios at LaliniEWR in the Tsitsa River

From the above figure it is clear that the EWR could not be met on average for ‘scenario 2b’, and also not be supplied for the low flow months of June to September for ‘scenario 3’.

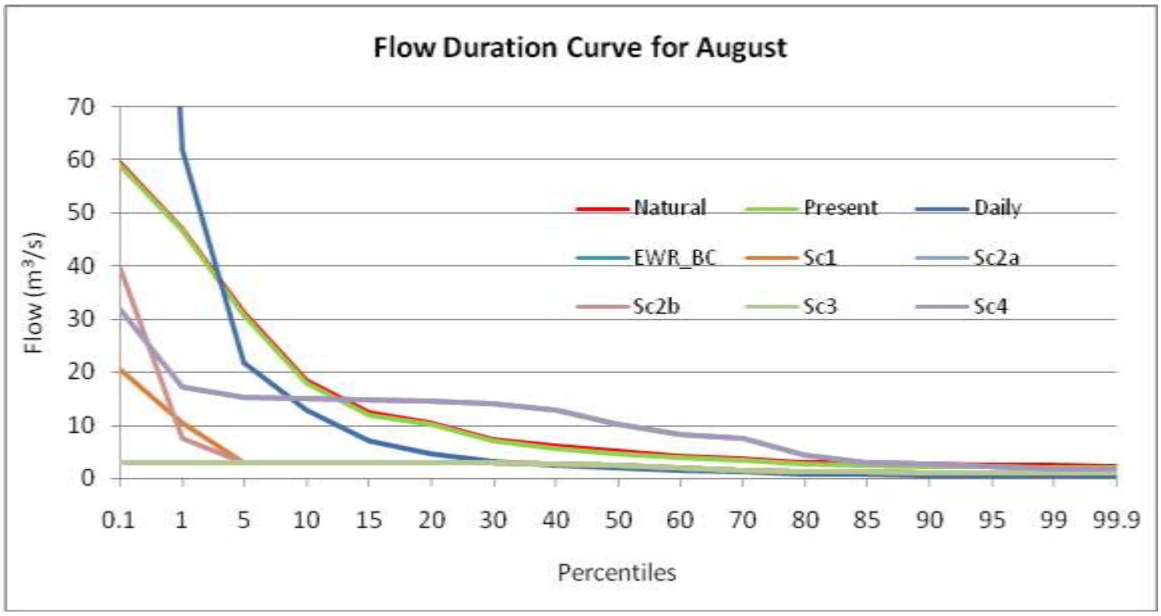

Figure 4-2: Flow duration curves for August for the scenarios

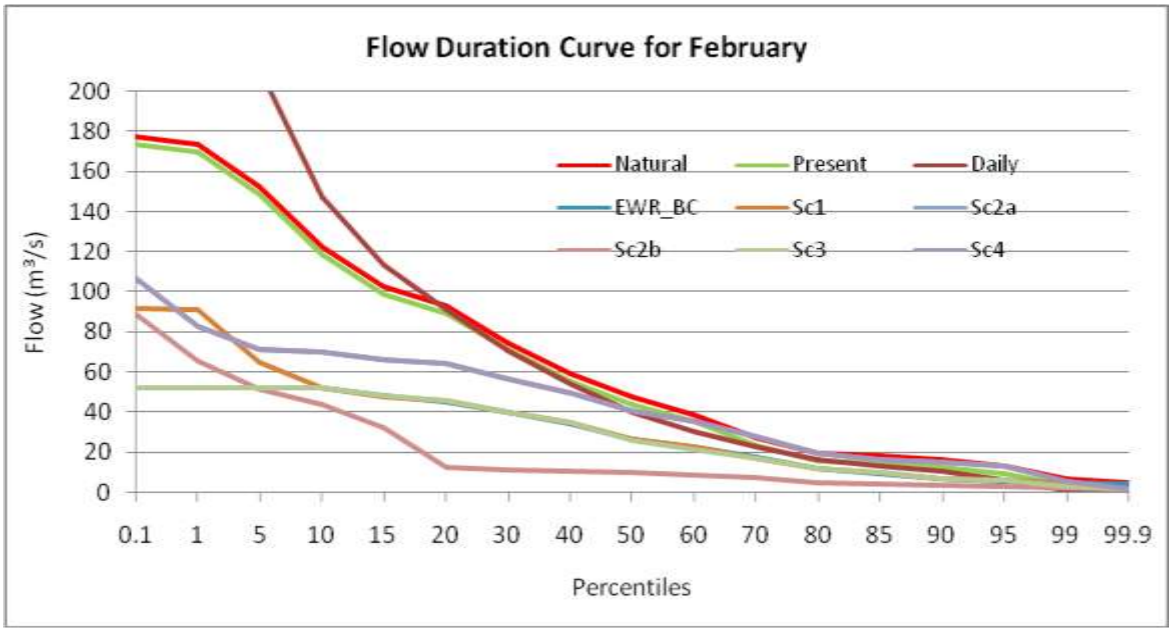

Figure 4-3: Flow duration curves for February for the scenarios

The flow duration curves of the scenarios for both months show that the EWR could be supplied for most of the time. Table 4-2 and

Table 4-3 show the percentiles for August and February for the various scenarios and indicate where the EWR could not be met - in red. It is expected that the flood requirements for February are not met in 'scenario 2b' as no floods were specified. However, the base flows should still be met.

Table 4-2: Percentiles for August per scenario at EWR site

Percentiles	Natural	Present	EWR_BC	Sc1	Sc2a	Sc2b	Sc3	Sc4
0.1	59.440	59.041	2.96	20.61	31.82	39.93	2.95	31.82
1	46.984	46.663	2.96	10.53	17.25	7.41	2.95	17.25
5	31.131	30.789	2.96	2.95	15.16	2.95	2.95	15.16
10	18.311	18.004	2.94	2.95	15.01	2.95	2.95	15.01
15	12.297	11.905	2.93	2.92	14.78	2.92	2.92	14.78
20	10.448	10.102	2.90	2.91	14.58	2.91	2.91	14.58
30	7.338	6.975	2.81	2.81	14.10	2.81	2.81	14.10
40	6.055	5.689	2.61	2.63	12.94	2.63	2.63	12.94
50	5.093	4.725	2.33	2.34	10.07	2.34	2.34	10.07
60	4.194	3.807	1.96	1.96	8.16	1.96	1.96	8.16
70	3.733	3.347	1.57	1.58	7.54	1.58	1.58	7.54
80	3.046	2.658	1.26	1.26	4.37	1.26	1.26	4.37
85	2.873	2.485	1.18	1.19	3.04	1.19	1.19	3.04
90	2.651	2.263	1.09	1.09	2.69	1.09	1.09	2.69
95	2.526	2.139	1.05	1.06	2.14	1.06	1.06	2.14
99	2.422	2.041	1.03	1.03	1.78	1.03	1.03	1.78
99.9	2.221	1.841	1.03	0.94	1.63	0.94	0.94	1.63

Table 4-3: Percentiles for February per scenario at EWR site

Percentiles	Natural	Present	EWR_BC	Sc1	Sc2a	Sc2b	Sc3	Sc4
0.1	177.336	173.608	51.89	91.597	106.99	89.147	51.87	106.99
1	173.506	169.778	51.89	91.24	82.48	65.70	51.87	82.48
5	152.195	148.466	51.89	64.65	70.97	51.62	51.87	70.97
10	122.405	118.676	51.81	51.87	70.22	43.97	51.86	70.22
15	102.357	98.621	48.48	47.53	66.37	32.46	48.46	66.37
20	93.174	89.402	45.08	45.74	64.05	12.34	45.79	64.05
30	74.726	70.996	39.72	39.92	56.49	11.14	39.92	56.49
40	59.338	55.578	34.39	34.86	49.23	10.74	34.86	49.23
50	47.632	43.869	26.19	26.35	40.35	9.95	26.11	40.35
60	38.945	35.175	22.60	22.39	35.52	8.73	21.31	35.52
70	27.156	23.395	17.51	17.02	27.51	7.01	17.02	27.51
80	19.300	15.523	11.77	11.83	19.29	5.06	11.83	19.29
85	18.032	14.193	9.42	9.84	16.37	4.38	9.84	16.37
90	16.220	12.450	6.94	6.99	15.18	3.42	6.98	15.18
95	12.936	9.135	5.44	6.16	12.99	3.14	6.16	12.99
99	6.793	3.233	4.62	4.36	5.60	2.50	3.01	5.60
99.9	4.466	1.444	4.25	1.53	1.65	1.34	1.39	1.65

The following table provides a description of the ecological consequences per component.

Table 4-4: Ecological consequences per scenario at the Tsitsa River EWR site

EC and score						**Ecological Consequences**	
GEOMORPHOLOGY							
Prs	**Sc1**	**Sc2a**	**Sc2b**	**Sc3**	**Sc4**	**Dry season**	**Wet season**
C (69.13)	B/C (79.21)	C (77.16)	D (57.23)	C (75.00)	C (70.00)	Sc 1, 2a and 3: Reduced habitat area Sc2b: Reduced habitat area and integrity Sc4: Increased habitat area, with less habitat diversity	Sc 1, 2a and 3: Reduced habitat area Sc2b: Reduced habitat area and integrity Sc4: Increased habitat area, with less habitat diversity
General: Ntabalenga and Lalini Dams will trap all bed loads and a large proportion of the suspended sediment, reducing sediment loads to more natural/reference state levels. The larger the volume of the Lalini Dam the more effective it will be in reducing suspended sediment loads and reducing flood flows. As a result of reduced sediment loads, less fine sediment will be available to settle out in low energy hydraulic habitats. The bed will become more mobile due to reduced cementing and embeddedness of cobble and gravel, potentially becoming armoured in the longer term due to removal of gravel and small cobble and reduced input of gravel and small cobble from upstream. High and low flows will be reduced, leading to less frequent bench inundation and overbank connectivity. The confined bedrock controlled channel is resistant to incision or major changes in bed and bank composition, thus resistant to significant change due to reductions in sediment load and flow volumes. Sc1: Ntabalenga will trap sediment from the upper catchment, Lalini will trap the least amount of suspended sediment and will let more of the natural flow regime from the lower catchment through. Fine sediment drapes and embeddedness will be reduced, with a reduction in gravel and small cobble over time. EWR flows will maintain the critical instream habitat. Sc2a: Ntabalenga will trap sediment from the upper catchment. A moderate amount of suspended sediment							

and flood flows from the lower catchment will be trapped by the Lalini Dam. Fine sediment drapes and embeddedness will be reduced. EWR flows will maintain the critical instream habitat.

Sc2b: Ntabalenga will trap sediment from the upper catchment. A moderate amount of sediment and flood flows will be trapped by the Lalini Dam. Not releasing EWR flood flows will lead to a substantial reduction of critical habitat integrity. Cobbles and gravels will not be turned on a frequent basis and fine material will not be removed from gravel and cobble bars. Fine sediment will not be flushed from low velocity habitats on a regular basis. Bench and flood plain inundation will be substantially reduced, preventing sediment exchange and maintenance of these features. Natural floods that spill from the Lalini Dam will not be sufficient and frequent enough to maintain the critical habitat (e.g. cobble, gravel, benches, etc.).

Sc3: Ntabalenga will trap sediment from the upper catchment. Lalini will trap the greatest proportion of the sediment and floods coming from the lower catchment. Fine sediment drapes and embeddedness will be reduced. Smallest chance of having natural floods spill from Lalini. EWR flows will maintain the critical instream habitat.

Sc4: Ntabalenga will trap sediment from the upper catchment. Lalini will trap a moderate amount of suspended sediment and flood flows from the lower catchment. EWR flows will maintain the critical instream habitat. Constant high flows from the hydro power outlet will increase the wetted habitat/perimeter and increase flow velocities. Less fine sediment will settle out in pools due to higher flow velocities. Finer sediment will be removed from the gravel and cobble bars, leading to an armoured layer. The area of fine gravel and sand bars will be reduced, but where they do form, particles will be better sorted creating habitat with more interstitial spaces.

RIPARIAN VEGETATION							
C (65.6)	C (62.2)	C (62.2)	C/D (58.0)	C (62.2)	C (64.8)	Current impacts are non-flow related. Reduced water in the system will have minimal impact on the general riparian vegetation community at the EWR site. However, marginal vegetation community structures may be altered as a result of geomorphic changes in the system.	Current impacts are non-flow related. Reduction in flood magnitude and frequency may cause an increase in woody species (including alien species) in the marginal and lower dynamic zones. A corresponding decrease in basal cover of non-woody vegetation is anticipated.

General:
Current impacts are non-flow related. Species in the non-marginal zone at the EWR site are largely terrestrial. Reduced flows will therefore not have a notable negative effect on them. However, riparian species in the marginal zone are likely to be affected by changes in geomorphic conditions as a result of altered flows. Furthermore, reduction in high flows and floods are likely to result in an increase in woody species (both indigenous and alien) in the marginal and non-marginal zones with a corresponding decrease in basal cover of non-woody vegetation. This may result in a decrease in Ecological Category from a C to a C/D in scenario 2b.

Sc1:
Species in the non-marginal zone at the EWR site are largely terrestrial. Reduced flows will therefore not have a notable negative effect on them. However, riparian species in the marginal zone are likely to be affected by changes in geomorphic conditions as a result of altered flows. These potential changes in the marginal zone are not enough to decrease the ecological condition of the riparian zone to a lower category.

Sc2a:
Similar to scenario 1.

Sc2b:
A reduction in high flows and floods are likely to result in an increase in woody species (both indigenous and alien) in the marginal and non-marginal zones with a corresponding decrease in basal cover of non-woody vegetation. This may result in a decrease in Ecological Category from a C to a C/D.

<table>
<tr><td colspan="8">Sc3:
Similar to scenario 1.

Sc4:
Constant flows from the hydro power outlet will increase the wetted habitat associated with the marginal zone in the dry season, relative to the other scenarios. This will increase non-woody vegetation cover and abundances in the marginal zone. Furthermore, more stable flows could result in ingress of woody vegetation into the marginal zone, relative to the other scenarios.</td></tr>
<tr><th colspan="8">FISH</th></tr>
<tr><td>B
(86.3)</td><td>B/C
(78.0)</td><td>B/C
(79.4)</td><td>C
(74.0)</td><td>B/C
(77.5)</td><td>B/C
(81.2)</td><td>Catchment-scale migrations of anguillid eels will be compromised should the impoundments be constructed without the appropriate fish ladders.
Reduced low flows may result in loss of some fish cover habitat.</td><td>Reduced high flows during the wet season (e.g. freshets, floods, etc.) will affect fish lifecycle stages – breeding opportunities of Barbus anoplus, needing inundation of aquatic vegetation, will be more limited, and migration cues for anguillid eels will be less frequent.</td></tr>
<tr><td colspan="8">General: Present impacts are largely non-flow related and primarily linked to land use activities in the upstream catchment. The fish assemblage is predominantly of limnophillics (fish with preference for slow flowing habitat) and therefore less likely to be affected by reduced low flows. Constructing impoundments along the Tsitsa River will result in a loss of connectivity for fish migrations, notably anguillid eels (e.g. Anguilla mossambica) that are capable of scaling the Tsitsa Falls (applicable to all scenarios). Small improvements in fish ecological condition can be expected with reduced sedimentation of substrate cover features.

Sc1: Low (>70%) and high (<20%) flows are affected as demonstrated by FIFHA assessment (Kleynhans, 2014). The fish ecological condition is more likely to be affected during the high flow season due to corresponding effects to fish life-cycles relating to specific flow conditions.

Sc2a: EWR flows are maintained during low flow season. High flows (<15%) will be influenced, but not likely to affect the present ecological condition as demonstrated by FIFHA assessment (Kleynhans, 2014).

Sc2b: Flows in the low flow season are generally maintained except for extreme low flows (>99%) and is unlikely to affect the fish assemblage as demonstrated by FIFHA assessment (Kleynhans, 2014). The reduction of high flows and loss of EWR floods will have a negative impact on the breeding of Barbus anoplus, requiring high flow periods for marginal vegetation to become inundated and movement patterns of anguillid eels will be compromised. Substrate cover features will reduce over time with build-up of sediments and fines resulting in a decrease in fish habitat availability. Impacts to the high flow season will therefore affect the flow and habitat requires of the fish assemblage.

Sc3: Similar response to the fish assemblage as for Scenario 1 except that flows during the high flow season will be more affected (<30%) with further consequences in terms of fish flow/habitat requirements.

Sc4: High and low flow EWR are maintained for the entire river reach downstream of the Lalini Dam and are not expected to affect fish flow and habitat requirements as demonstrated by FIFHA assessment (Kleynhans, 2014).</td></tr>
<tr><th colspan="8">MACROINVERTEBRATES</th></tr>
<tr><td>B
(83.9)</td><td>B/C
(80.5)</td><td>B
(82.9)</td><td>B/C
(79.4)</td><td>B/C
(81.9)</td><td>B
(82.9)</td><td>Velocities and flows will be reduced in the dry season, limiting habitat availability with</td><td>Change in allochthonous organic inputs, nutrients and sediments resulting from deposition within the dam. May have a negative impact</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>concomitant changes in the macroinvertebrate communities.</td><td>on productivity of the system.</td></tr>
<tr><td colspan="8">General: Flows generally exceed the EWR requirement. Scenarios where lower flow percentiles (>70%) no longer exceed EWR requirements may result in a lower ecological category. A loss of allochthanous organic inputs and nutrients may negatively impact the EWR site.

Sc1: Generally velocity substrate classes are maintained with lower flow (>70% percentile) likely to result in a lower category as demonstrated by Kleynhans FIFHA method (2014) assessment.

Sc2a: Generally velocity substrate classes are maintained with lower flow (>95% percentile) likely to result in a minor change to EC as demonstrated by Kleynhans FIFHA method (2014) assessment.

Sc2b: Generally velocity substrate classes are maintained with lower flow (>70% percentile) likely to result in a lower category as demonstrated by Kleynhans FIFHA method (2014) assessment. Loss of floods would result in less tumbling of cobble biotope and scouring of boulders which is likely to result in an algal build-up which will negatively impact the habitat of the taxa reliant on these biotopes

Sc3: Generally velocity substrate classes are maintained with lower flow (>70% percentile) likely to result in a lower category as demonstrated by Kleynhans FIFHA method (2014) assessment.

Sc4: Generally velocity substrate classes are maintained with lower flow (>95% percentile) likely to result in a minor change to EC as demonstrated by Kleynhans FIFHA method (2014) assessment. Continuous discharge from the hydropower my result in scouring and loss of sediment habitat, although the remaining and reduced sediment habitat will be better sorted with reduced interstitial infilling and embeddedness.</td></tr>
<tr><th colspan="8">ECOSTATUS</th></tr>
<tr><td>B/C
(77.7)</td><td>C
(72.9)</td><td>C
(74.0)</td><td>C
(69.5)</td><td>C
(73.0)</td><td>C
(74.4)</td><td colspan="2"></td></tr>
<tr><td colspan="8">General: In terms of flow related versus non-flow related impacts there is a general inability to meet a B/C. This is primarily due to catchment (sediment and livestock pressures) and essentially non-flow related processes</td></tr>
<tr><th colspan="8">FIFHA</th></tr>
<tr><td>B</td><td>B</td><td>A</td><td>B</td><td>B</td><td>A</td><td colspan="2">August</td></tr>
<tr><td>B/C</td><td>B</td><td>B</td><td>B/C</td><td>B/C</td><td>B</td><td colspan="2">February</td></tr>
</table>

Additional modelling work based on the hydrological outputs from the EWR determination was undertaken by Dr. Neels Kleynhans of the DWS: RQIS (**Appendix G**). This involved flow requirements determined using the Fish Invertebrate Flow Habitat Assessment (FIFHA) method. The FIFHA is a modification of the Fish Flow Habitat Assessment (FFHA) that was previously used in several instream flow requirement determinations that used the Habitat Flow Stressor Response (HFSR) method for Ecological Water Requirements.

A summary report of the approach and modelling using the scenarios assessed in this study (see Table 4-1) and the results are attached as **Appendix G**. A summary of the results per scenario is provided for August (low flows) and February (wet):

August:

- Scenario 1: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with lower flows (>50% percentiles) being more influenced.
- Scenario 2a: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of A. There is very little variation of categories per percentile.

- Scenario 2b: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with lower flows (>50% percentiles) being more influenced.
- Scenario 3: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with lower flows (>50% percentile) being more influenced.
- Scenario 4: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of A. Flow Percentiles >95%, relates to a category of B.

February:

- Scenario 1: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with higher flows (<50% percentiles) being more influenced.
- Scenario 2a: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with higher flows (<50% percentiles) being more influenced.
- Scenario 2b: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B/C. Variation of categories are similar with higher flows (<50% percentiles) being more influenced.
- Scenario 3: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B/C. Generally, variation of categories are similar with higher flows (<40% percentiles) being more influenced.
- Scenario 4: Both Fish and Macroinvertebrate VD & VS classes indicate an overall category of B. Generally, variation of categories are similar with higher flows (<40% percentiles) being more influenced.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 General

The overall conclusion of this EWR study is that the state of the Tsitsa River at the EWR site is in a moderately modified condition, mainly due to non-flow related impacts on the riparian vegetation. The instream condition of the river is still in a largely natural state (B category). Drivers in the system were both at a catchment scale (e.g. overgrazing and concomitant erosion and sedimentation) and localised (e.g. overgrazing).

All the operational scenarios for the proposed Lalini Dam resulted in a C category with scores ranging from 69.5% (scenario 2b – worst scenario) to 74.4% (scenario 4 – best scenario) compared to the present state of a B/C (score=77.6%). This is mainly due to the following:

- Loss of instream habitat,
- Disruption in continuity,
- Changes in flow regimes, and
- Water quality modifications

5.1.2 Water quantity

The hydrology of the Tsitsa River has been re-calibrated using the WRSM2000 model and the flows from gauging weir T3H006 at the N2 Road Bridge. The flows at the gauging weir also include the flow contribution of the Inxu River, a major tributary of the Tsitsa River. Sedimentation is a major problem at T3H006 and this can influence the accuracy of the measured flows that were used for calibration. Thus, the confidence in the hydrology is low.

5.1.3 Water quality

The catchment above the EWR site, and thus above the dam site is a predominantly rural landscape with few land uses which are likely to cause water quality problems. Diatoms samples collected during the field surveys and analysed using the South African Diatom Index (SADI) confirmed a natural state. Water quality concerns that do exist in the catchment are dominated by suspended solids. Human accelerated erosion in the catchment is significant due to the erodible duplex soils present and the heavy utilisation of the grassland areas by livestock and subsistence agriculture.

There are potential negative impacts of a dam on water quality, though these can be mitigated through the implementation of an appropriate release management plan that ensures environmental flows are released to mirror the natural water temperature and dissolved oxygen regime upstream of the dam. This can be achieved through the incorporation of a variable depth off-take facility in the design of the dam.

5.1.4 Fish

The current negative impacts on fish species at the EWR site are not flow related, but due to habitat modification associated with elevated sediment input, especially fines settling out in the pools due to catchment degradation and reduction in marginal vegetation and associated cover features.

The limited changes in water quality due to the dam are expected to have little impact, as the fish species present are moderately tolerant of changes in water quality. These fish are also moderately tolerant of low or even no-flow conditions.

High river flows in summer are required to provide *Barbus cf anoplus* with flooded marginal vegetation for spawning purposes. The Tsitsa Falls, in association with the construction of the proposed Lalini Dam, may provide significant barriers to the migration of eels through this reach of the river. The construction of the dam must cater for appropriate eel-way designs and to maintain flow releases as per the specified EWR.

5.1.5 Macroinvertebrates

The macroinvertebrate community at the EWR site was impacted by water quality largely associated with some nutrient enrichment (from upper catchment inputs) and changes in the instream habitat (i.e. sedimentation). Sedimentation was the result of catchment processes (e.g. overgrazing) and localised impacts (e.g. bank erosion). Therefore, these impacts were non-flow related. However, reduced volumes and velocities may result in a decrease of habitats such as marginal vegetation and runs from a macroinvertebrate perspective.

5.1.6 Geomorphology

The geomorphological degradation of the LaliniEWR site and reach is mainly due to non-flow related increases in fine sediment input. Sediment is derived from overgrazed slopes and gullies throughout the catchment. Gullies have increased the slope-channel connectivity, increasing the effectiveness of water and sediment delivery to the channel. Few sediment sinks are actively storing sediment, thus sediment loads are high throughout the catchment. Flood events have become flashier, as a result of the increased slope-channel connectivity, increasing channel energy and associated removal of overgrazed inset benches.

Gravel and cobble features are embedded with fine sediment and where flow velocities are low, such as in pools, silt and fine sand settles out and smothers bedrock, sand, gravel and cobble habitat. The channel will resist major change due to its stable bedrock nature. The critical habitat, such as riffles, consists mainly of boulders and cobbles that are not likely to change due to decreased flows. The integrity of these habitats should be maintained with the recommended EWR flows, especially the floods. Over time the bed load might coarsen as smaller particles are entrained during flood events and not being replaced due to the barrier caused by the Lalini Dam. Local inputs from tributaries below the dam might not be sufficient to maintain the current particle size composition of the riffle features.

5.1.7 Riparian Vegetation

The riparian vegetation at the EWR site was impacted by overgrazing. Impacts were greatest on the non-woody vegetation in the non-marginal zone, with concomitant bank erosion occurring due to a low basal cover and trampling. Therefore, impacts were non-flow related. Floods in the system are important to maintain the marginal and low dynamic zones, as well as maintain nutrient and hydrological processes in the non-marginal zones.

5.2 Recommendations

Scenario 2a (1.18 MAR Ntabelanga Dam with full EWR, hydropower releases, 0.28 MAR Lalini Dam with full EWR, hydro power discharge after EWR site) is recommended with the following specific recommendations:

5.2.1 Water quantity

It is strongly recommended that EWR quantities, as specified in this report, be maintained.

The EWR releases should be aligned with the flow pattern as reflected at the upstream gauging weir (T3H006). This will simplify the EWR operational procedures and reduce the risk of compliance failures.

5.2.2 Water quality

Water quality is currently not a major concern in this catchment; however recommendations can be made to ensure that issues do not arise subsequent to the construction of the dam:

i. It is vital that a variable depth off-take facility is incorporated into the design of the dam. This will enable the dam controller to release water to fulfil the environmental flows that are of optimal quality and will reduce the probability of negative impacts on the downstream environment.
ii. It is important to monitor downstream temperature and oxygen impacts of the dam and apply an adaptive management strategy to the release process to minimise impacts on the downstream ecology.

5.2.3 Fish

The most important flow requirements for fish are the summer high flows that inundate marginal vegetation, providing a suitable substrate for *Barbus cf anoplus* to spawn successfully, as well as forming flooded backwaters for larval feeding. These freshets and floods will also facilitate fish (including eel) migration upstream over critical riffle areas and prevent habitat fragmentation. However, the flow requirement for the fish will easily be met if those flows recommended for the macroinvertebrates (and riparian vegetation) as specified in this study are provided.

A specific requirement of the eels in the system will be their ability to migrate past the proposed Lalini Dam wall into the upper Tsitsa and Inxu Rivers for maintenance of biodiversity and ecological processes. Appropriate eel-way designs need to be incorporated into the dam wall design.

5.2.4 Macroinvertebrates

It is recommended that the system receive sufficient volumes of water to maintain key fast flowing habitats in the system. These habitat types are important for a number of sensitive and important macroinvertebrate (e.g. *Perlidae* and *Prosopistomatidae*). Furthermore, the natural flooding regime should be emulated in order to tumble the cobbles and scour any algal growth, and to flush out sediments that may accumulate in the low flow months and alter the instream habitat.

5.2.5 Geomorphology

It is strongly recommended that the proposed EWR flows are adhered to as it will maintain the required instream and riparian habitat.

It is recommended that catchment rehabilitation addresses surface soil erosion through changes to grazing and fire regimes. Furthermore, slope-channel connectivity should be decreased through restoring wetlands, constructing gabions in gullies and planting buffer strips near water ways to trap sediment. This will reduce sediment input into the dams and benefit the river health in general.

Monitoring of quality and quantity of habitat should be undertaken on a 2 year basis.

5.2.6 Riparian Vegetation

It is recommended that releases from the proposed Lalini Dam emulate the natural flooding regime (frequency and intensity of floods) per this report. Freshets and larger floods are important in maintaining a healthy riparian vegetation community by retarding ingress of woody vegetation and controlling recruitment and successional processes in the non-marginal zone.

Furthermore, it is highly recommended that a specialist vegetation survey take place on and directly downstream of the waterfall. Such a survey was outside the scope of this study, but is important to ascertain whether specialist cremnophytes (cliff dwelling plants) or other unique vegetation types are dependent on the falls and its associated splash zone/microclimate which may be influenced by the construction of the Lalini Dam and associated hydropower plant operation. This survey should take place in the growing season (i.e. summer) by a botanical specialist who is familiar with the vegetation in the area and waterfall processes. If appropriate, minor channel modifications downstream of the dam may be required to maintain base flows across the width of the channel to sustain dependent plant species.

5.3 EcoSpecs and Monitoring requirements

5.3.1 Water quantity

The hydrological EcoSpecs are included in the water quantity aspects of the Ecological Reserve as provided in **Appendix F**. These EcoSpecs are in the format of a summary table with the requirements specified for the various flow components and an assurance table or EWR rule curve. The curves specify the frequency of occurrence relationships of the defined maintenance and drought flow requirements for each month of the year. The tables thus specify the % of time that defined flows should equal or exceed the flow regime required to satisfy the ecological Reserve. The following descriptors of the hydrological characteristics should be used:

- Total Mean Annual Maintenance Low flow volume
- Total Mean Annual Drought flow volume
- Monthly mean Maintenance Low and Drought flows
- Monthly excedens curves for the low flows (excluding floods) and for the complete flow regime
- Duration, magnitude (in daily average peak), volume and timing of larger floods (see Table 3-19).

The flood requirements, as specified by the various specialists for the Tsitsa River below the proposed Lalini Dam, are important. These floods, including the larger 1:3 and 1:10 year floods, need to be released to ensure that the system is managed in the recommended state of a B/C category.

The releases of the larger floods could coincide with natural flood events when the dam is spilling. However, due to the constant releases for hydro power generation, Lalini Dam spills infrequently, especially for the recommended ‘scenario 2a’ (see graphs below indicating the simulated drawdown and spilling of the dam, per scenario). This reinforces the necessity for ensuring floods are “released” from the dam.

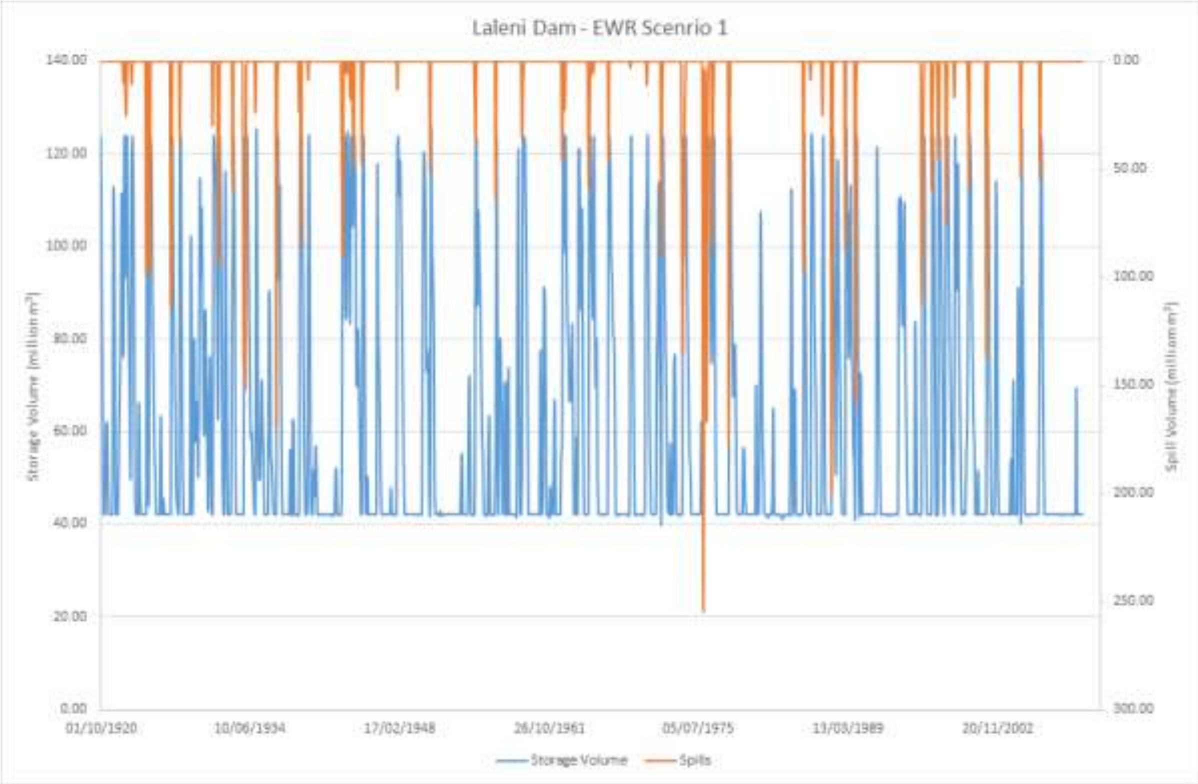

Figure 5-1: Scenario 1 – 1.18 MAR Ntabelanga and 0.15 MAR Lalini, full EWR

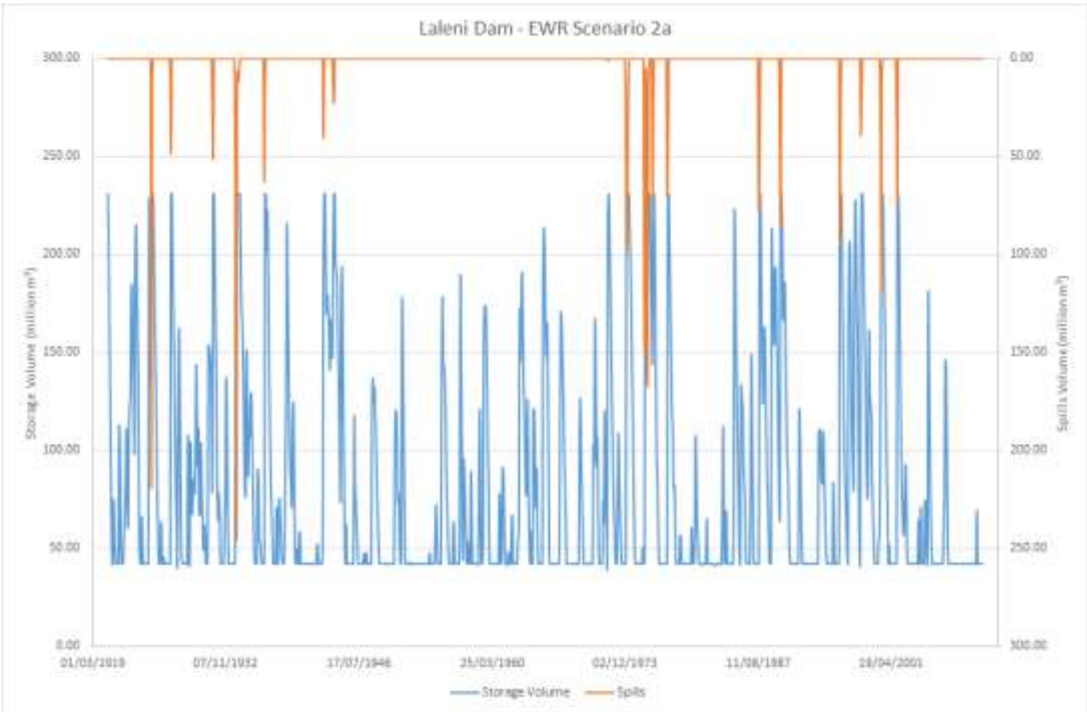

Figure 5-2: Scenario 2a - 1.18 MAR Ntabelanga and 0.28 MAR Lalini, full EWR

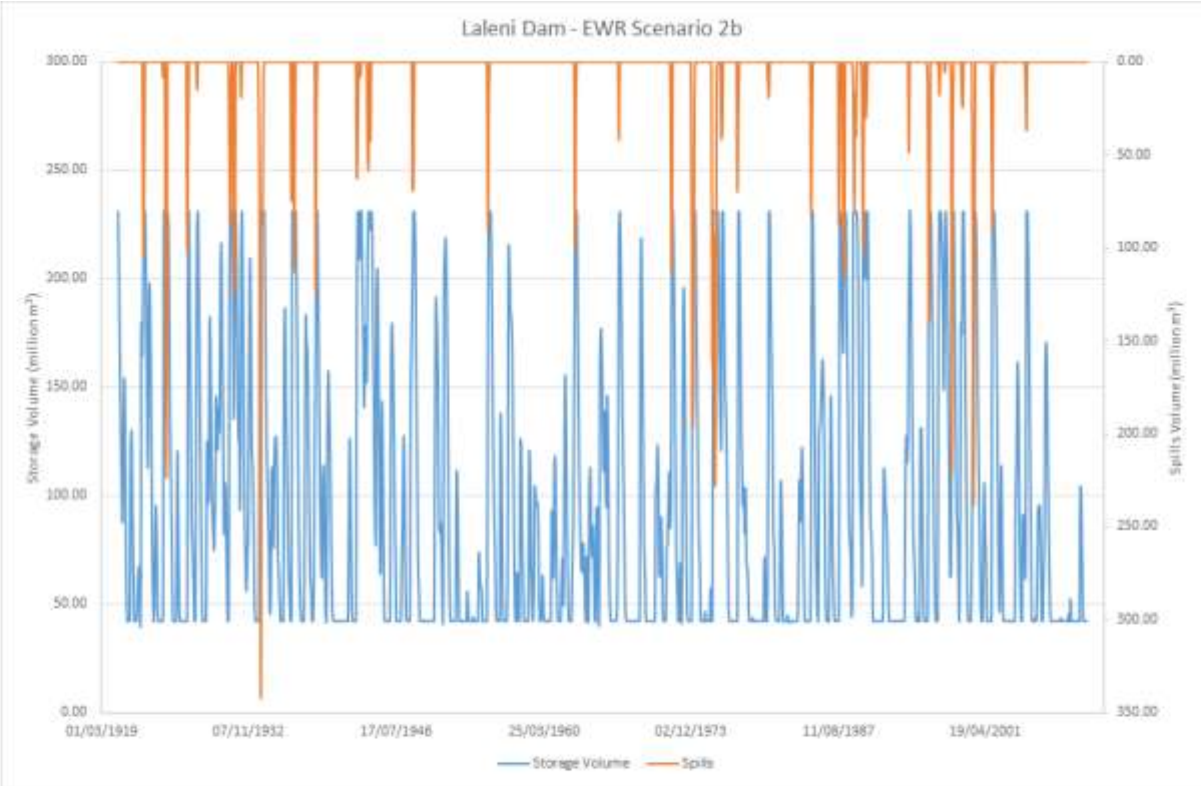

Figure 5-3: Scenario 2b - 1.18 MAR Ntabelanga and 0.28 MAR Lalini, maintenance low EWR

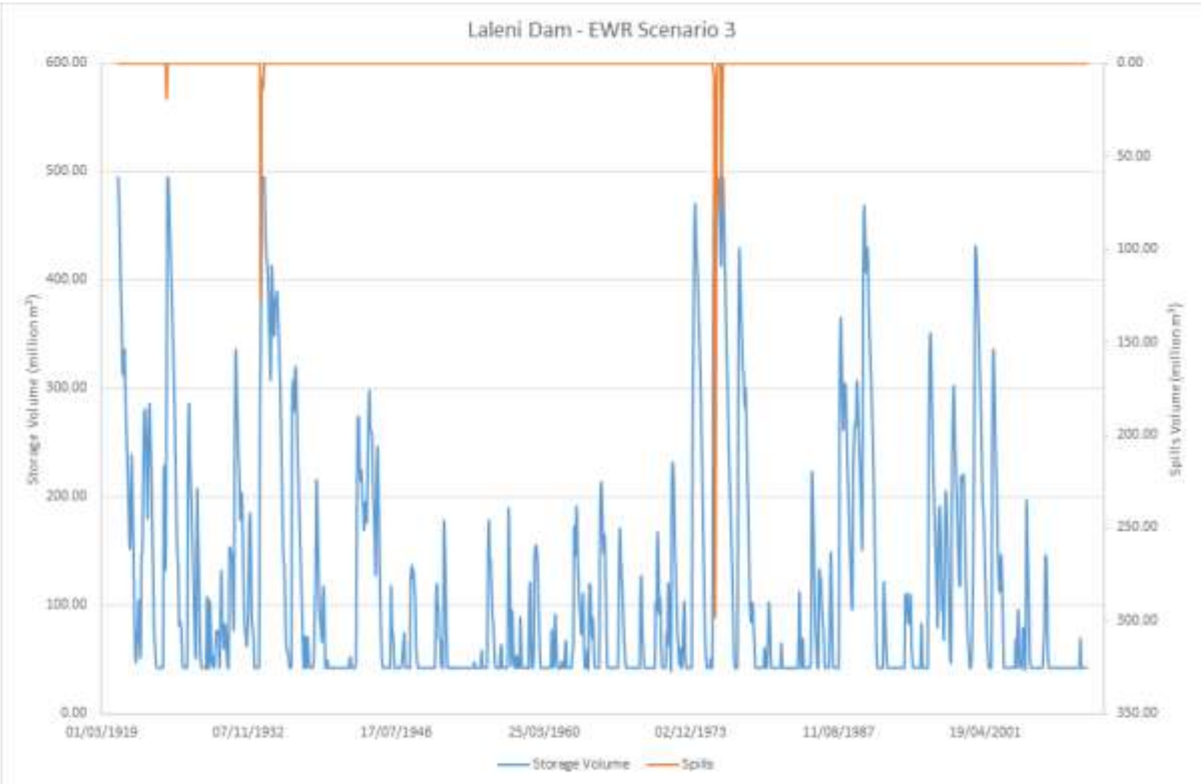

Figure 5-4: Scenario 3 - 1.18 MAR Ntabelanga and 0.60 MAR Lalini, full EWR

5.3.2 Water quality

The current DWS water quality monitoring at T3H006 should be maintained and replicated at a suitable site downstream of the proposed Lalini Dam. The monitoring should consider the following:

a) Nutrients

b) Physical variables

i. pH is important as it has a strong influence on the interactions of other constituents and high or low pH values can increase the toxicity of other constituents (particularly Ammonia). pH must thus be routinely monitored.

ii. Due to the acknowledged difficulty associated with determining aggregated inorganic salt concentrations, Electrical Conductivity (EC), which is easily measurable, has been included as a convenient substitute measure of inorganic salts in the EcoSpecs for this site.

iii. From a catchment perspective, the most significant threat to water quality is the potential for large quantities of sediment to be introduced into the river system due to significant erosion problems, and the large areas observed with poor vegetative cover known to exist in the catchment. Turbidity has not been monitored by DWS in the past, and thus no records of past levels are available. It is recommended that the clarity tube, a cost effective and simple instrument which allows quick and repeatable measurements of water clarity be used.

iv. Dissolved Oxygen (DO) levels play a critical role within the aquatic ecosystem and can be significantly impacted by the release of dam water. DO levels must thus be monitored routinely.

v. Temperature is an important constituent in that it can affect the toxicity of other constituents (such as Ammonia), and can also impact on biodiversity through the loss of temperature sensitive species and interfering with natural biologically attuned cues for critical biological behaviours. Temperature is also one of the most likely determinants to be impacted by the release of dam water. Temperature must thus be monitored monthly.

c) Toxics

It is known that the release of anoxic dam water increases the concentration of ammonia (NH3) downstream of the dam. Free ammonia is toxic to many forms of life in aquatic ecosystems and concentrations should be monitored monthly. Free ammonia can be estimated from Total Ammonia (N) based on the DWA water quality guidelines matrix using temperature and pH readings taken at the site and time of sampling.

Manganese is also toxic to certain forms of aquatic life and concentrations downstream of a dam can also be elevated by anoxic water releases. This should thus also be monitored monthly.

A bi-annual (2X per year) sample should be analysed for the full spectrum of toxics as listed in the DWS Water Quality guideline (DWAF 2008). Should individual toxics be noted as being of concern, monthly monitoring of these should be initiated.

Detailed water quality EcoSpecs should be determined as part of the EIA for the proposed Lalini Dam.

5.3.3 Fish

Fish surveys should be undertaken at least once annually during low flow conditions, preferably at the beginning of summer, when water temperatures are rising but water turbidity is relatively low.

Specific monitoring for eels on an annual basis needs to be undertaken at two sites: (i) at the outflow of the proposed Lalini Dam (upstream of waterfall) and (ii) upstream of the proposed Lalini Dam to check that migration is taking place.

5.3.4 Macroinvertebrates

Macroinvertebrates community health must be monitored on an annual basis during low flow conditions using the SASS5 protocol (Dickens and Graham, 2002). Sampling must be done by an accredited SASS5 practitioner to ensure that results are reliable, defensible and comparable. Furthermore, it is recommended that benthic diatoms be sampled annually to provide ancillary information on water quality in the river.

5.3.5 Geomorphology

- Suitable monitoring sites that are representative of the river reach as well as the land use impacts on the channel should be identified and monitored through fixed point photography and habitat monitoring.
- The bed load material should be surveyed every 2 years post implementation of the proposed dam to ensure that the habitat composition and integrity within the active channel does not change completely as these changes will have a detrimental impacts on the instream biota.

5.3.6 Riparian Vegetation

- Riparian vegetation should be monitored bi-annually using the VEGRAI method to determine the impacts of the dam on the downstream vegetation.
- All alien vegetation must be removed from the dam property.

6. REFERENCES

DWAF (1999). Resource Directed Measures for Protection of Water Resources; Volume 3: River Ecosystems Version 1.0 (Revised Water Quality Methodology).

Department of Water & Sanitation. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Secondary: T3. Compiled by RQIS-RDM. http://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx.

GAIGHER, I.G. AND POTT, R. 1973. Distribution of fishes in Southern Africa. S. Afr. J. Sci. 69: 25-27.

HUGHES, D.A. & MUNSTER, F (1999). A decision support system for an initial “low confidence” estimate of the quantity component of the Reserve for rivers. Unpublished Report, Institute for Water Research, Rhodes University. pp. 32.

IWR Source-to-Sea (eds). (2004). A Comprehensive Ecoclassification and Habitat Flow Stressor Response Manual. Prepared for IWQS: DWAF, Project no: 2002-148.

JUBB, R. A. 1967 Freshwater fishes of southern Africa. Balkema, Cape Town. 248 pp.

KLEYNHANS, C.J. (1996). A Qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo River system, South Africa). Journal of Aquatic Ecosystem Health 5: 41-54.

KOTZE, P. J. and NIEHAUS, B.H. (2003). Rapid Ecological Reserve (Quantity) for the Mzimvubu River (T31G), Mzintlava River (T32C), Tina River (T34J). Tsitsa River (T35K) and Inxu River (T35G). Report No – RDM/F/2003 for Department of Water Affairs and Forestry: Resource Directed Measures.

KLEYNHANS, C.J. (1999). A procedure for the determination of the ecological Reserve for the purpose of the national water balance model for South African rivers. Internal Report, IWQS, DWAF, Pretoria. pp. 19. (Updated Ecological Importance and Sensitivity, 2002).

KLEYNHANS, C.J. and THIRION, C. 2003: Development of an integrated system to derive the EcoStatus of rivers. Report No. 2003-046. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa (Final Draft).

KLEYNHANS, C. J. 2006 River Ecoclassification. Manual for Ecostatus Determination (Version 2). Module D: Fish Response Assessment Index (FRAI).

KLEYNHANS, C.J., MACKENZIE, J., AND LOUW, M.D. 2007. Module F: Riparian Vegetation Response Index in River EcoClassification: Manual for EcoStatus determination (version 2). WRC Report No. TT 332/08, Joint Water Research Commission and Department of Water Affairs and Forestry Report, Pretoria, South Africa.

KLEYNHANS, C.J. (2008). Module D: Volume 1 Fish Response Assessment Index (FRAI). In: River EcoClassification: Manual for EcoStatus determination (Version 2). WRC Report No.TT 330/08, Joint Water Research Commission and Department of Water Affairs and Forestry Report, Pretoria, South Africa.

McMILLAN, P.H. (1998). An Integrated Habitat Assessment System (IHAS v2), for the rapid biological assessment of rivers and streams. A CSIR research project. ENV-P-I 98132 for the Water Resources Management Programme. CSIR. ii+ 44pp.

MUCINA L, RUTHERFORD MC (eds). 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.

REPUBLIC OF SOUTH AFRICA (1998). National Water Act (Act No 36 of 1998).

ROWNTREE, K.M., 2013. Geomorphology Driver Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) (Water Research Commission No. WRC Report No. TT 551/13).

ROWNTREE, K.M., WADESON, R.A., 1999. A hierarchical geomorphological model for the classification of selected South African rivers (Water Research Commission No. WRC Report No. 497/1/99). Pretoria.

SKELTON, P. H. 1993 A Complete Guide to the Freshwater Fishes of Southern Africa. Southern Book Publishers (PTY) Ltd. Halfway House. South Africa.

THIRION C. 2008. River Ecoclassification: Manual for EcoStatus Determination. Version 2. Module E: Volume 1 Macroinvertebrate Response Assessment Index (MIRAI). WRC Report No TT 332/08.

APPENDIX A

HYDRAULICS RESULTS

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
0.01	0	0	0.4	0.4	0	0.01	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.02	0.01	0	0.8	0.8	0	0.01	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.03	0.02	0	1.2	1.2	0	0.02	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.04	0.02	0	1.6	1.6	0.01	0.02	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.05	0.02	0	2	2	0.01	0.02	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.06	0.03	0.001	2.4	2.4	0.01	0.03	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.07	0.04	0.001	2.7	2.7	0.01	0.03	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.08	0.04	0.001	2.9	2.9	0.01	0.04	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.09	0.05	0.002	3	3	0.01	0.04	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.1	0.06	0.002	3.2	3.2	0.01	0.04	99	1	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.11	0.06	0.003	3.4	3.4	0.01	0.05	88	12	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.12	0.07	0.003	3.5	3.6	0.01	0.05	77	23	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.13	0.08	0.004	3.7	3.7	0.01	0.05	69	31	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.14	0.08	0.005	3.9	3.9	0.02	0.06	59	41	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.15	0.09	0.006	4.1	4.1	0.02	0.06	52	48	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.16	0.09	0.007	4.5	4.5	0.02	0.06	48	52	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.17	0.09	0.007	4.9	5	0.02	0.06	45	55	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.18	0.09	0.008	5.6	5.6	0.02	0.06	48	52	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.19	0.09	0.009	6.3	6.3	0.02	0.06	52	48	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.2	0.09	0.01	7	7.1	0.02	0.06	54	46	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.21	0.09	0.012	7.8	7.8	0.02	0.06	56	44	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.22	0.09	0.013	8.5	8.5	0.02	0.06	58	42	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.23	0.1	0.015	9.2	9.3	0.02	0.06	59	41	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
0.24	0.1	0.017	10	10	0.02	0.06	61	39	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.25	0.1	0.019	10.7	10.7	0.02	0.07	61	39	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.26	0.1	0.022	11.4	11.4	0.02	0.07	61	39	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.27	0.11	0.025	12	12.1	0.02	0.07	58	42	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.28	0.11	0.028	12.7	12.8	0.02	0.07	56	44	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.29	0.12	0.031	13.4	13.5	0.02	0.07	53	47	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.3	0.12	0.035	14.1	14.2	0.02	0.08	50	50	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.31	0.12	0.039	14.7	14.8	0.02	0.08	47	53	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.32	0.13	0.043	15.4	15.5	0.02	0.08	44	56	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.33	0.13	0.048	16.1	16.2	0.02	0.08	42	58	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.34	0.14	0.053	16.7	16.9	0.02	0.08	40	60	0	0	0	0	0	87	1	0	0	12	0	0	0	0	0	0	0
0.35	0.14	0.058	17.4	17.6	0.02	0.09	38	62	0	0	0	0	0	87	1	0	0	12	0	0	0	0	0	0	0
0.36	0.15	0.065	17.7	17.9	0.02	0.09	36	64	0	0	0	0	0	87	1	0	0	12	0	0	0	0	0	0	0
0.37	0.16	0.071	18	18.2	0.03	0.09	32	68	0	0	0	0	0	87	1	0	0	12	0	0	0	0	0	0	0
0.38	0.16	0.079	18.3	18.5	0.03	0.1	29	71	0	0	0	0	0	86	2	0	0	12	0	0	0	0	0	0	0
0.39	0.17	0.086	18.7	18.9	0.03	0.1	28	72	0	0	0	0	0	86	2	0	0	12	0	0	0	0	0	0	0
0.4	0.18	0.094	19	19.2	0.03	0.1	26	74	0	0	0	0	0	85	3	0	0	12	0	0	0	0	0	0	0
0.41	0.18	0.101	19.8	20	0.03	0.1	26	74	0	0	0	0	0	85	3	0	0	12	0	0	0	0	0	0	0
0.42	0.18	0.108	20.5	20.7	0.03	0.1	25	75	0	0	0	0	0	85	3	0	0	12	0	0	0	0	0	0	0
0.43	0.19	0.116	21.2	21.5	0.03	0.11	23	77	0	0	0	0	0	84	4	0	0	12	0	0	0	0	0	0	0
0.44	0.19	0.124	22.1	22.4	0.03	0.11	24	76	0	0	0	0	0	84	4	0	0	11	1	0	0	0	0	0	0
0.45	0.19	0.132	23	23.3	0.03	0.11	24	76	0	0	0	0	0	84	4	0	0	11	1	0	0	0	0	0	0
0.46	0.2	0.143	23.4	23.7	0.03	0.11	24	76	0	0	0	0	0	83	5	0	0	11	1	0	0	0	0	0	0
0.47	0.21	0.154	23.8	24.1	0.03	0.11	21	79	0	0	0	0	0	83	5	0	0	11	1	0	0	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
0.48	0.21	0.165	24.2	24.6	0.03	0.12	23	77	0	0	0	0	0	82	6	0	0	11	1	0	0	0	0	0	0
0.49	0.22	0.177	24.6	25	0.03	0.12	24	76	0	0	0	0	0	81	7	0	0	11	1	0	0	0	0	0	0
0.5	0.23	0.189	25.1	25.4	0.03	0.12	24	76	1	0	0	0	0	81	7	0	0	11	1	0	0	0	0	0	0
0.51	0.23	0.202	25.5	25.9	0.03	0.13	23	75	2	0	0	0	0	80	8	0	0	11	1	0	0	0	0	0	0
0.52	0.24	0.216	25.9	26.3	0.04	0.13	20	76	4	0	0	0	0	80	8	0	0	11	1	0	0	0	0	0	0
0.53	0.24	0.23	26.3	26.8	0.04	0.13	19	76	5	0	0	0	0	79	9	0	0	11	1	0	0	0	0	0	0
0.54	0.25	0.244	26.8	27.3	0.04	0.13	18	76	6	0	0	0	0	79	9	0	0	11	1	0	0	0	0	0	0
0.55	0.25	0.258	27.4	27.9	0.04	0.14	17	76	7	0	0	0	0	78	10	0	0	11	1	0	0	0	0	0	0
0.56	0.26	0.272	28	28.6	0.04	0.14	16	76	8	0	0	0	0	78	10	0	0	11	1	0	0	0	0	0	0
0.57	0.26	0.286	28.7	29.3	0.04	0.14	16	75	9	0	0	0	0	78	10	0	0	11	1	0	0	0	0	0	0
0.58	0.26	0.301	29.5	30.1	0.04	0.14	15	75	10	0	0	0	0	77	10	0	0	11	1	0	0	0	0	0	0
0.59	0.27	0.316	30.3	31	0.04	0.14	16	73	11	0	0	0	0	77	10	0	0	11	2	0	0	0	0	0	0
0.6	0.27	0.331	31.1	31.8	0.04	0.15	20	70	10	0	0	0	0	75	11	0	0	12	2	0	0	0	0	0	0
0.61	0.27	0.349	31.8	32.5	0.04	0.14	19	71	11	0	0	0	0	75	11	0	0	12	2	0	0	0	0	0	0
0.62	0.28	0.368	32.3	33.1	0.04	0.15	21	68	11	0	0	0	0	74	12	0	0	12	2	0	0	0	0	0	0
0.63	0.29	0.387	32.9	33.7	0.04	0.15	18	71	12	0	0	0	0	73	12	0	0	13	2	0	0	0	0	0	0
0.64	0.29	0.407	33.5	34.3	0.04	0.15	19	69	12	0	0	0	0	72	13	0	0	13	2	0	0	0	0	0	0
0.65	0.29	0.428	34.1	35	0.04	0.16	21	67	12	0	0	0	0	72	13	0	0	13	2	0	0	0	0	0	0
0.66	0.3	0.449	34.7	35.6	0.04	0.16	20	67	13	0	0	0	0	71	13	0	0	13	3	0	0	0	0	0	0
0.67	0.3	0.471	35.3	36.3	0.04	0.16	14	72	14	0	0	0	0	71	13	0	0	14	2	0	0	0	0	0	0
0.68	0.31	0.493	35.9	37	0.04	0.16	17	67	16	0	0	0	0	70	14	0	0	14	3	0	0	0	0	0	0
0.69	0.31	0.516	36.6	37.7	0.05	0.17	15	68	17	0	0	0	0	69	14	0	0	14	3	0	0	0	0	0	0
0.7	0.32	0.537	37.5	38.7	0.05	0.17	17	65	18	0	0	0	0	68	14	0	0	15	3	0	0	0	0	0	0
0.71	0.32	0.559	38.6	39.8	0.05	0.17	18	62	21	0	0	0	0	68	14	0	0	15	3	0	0	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
0.72	0.32	0.582	39.5	40.8	0.05	0.17	23	56	21	0	0	0	0	67	14	0	0	16	3	0	0	0	0	0	0
0.73	0.32	0.607	40.3	41.6	0.05	0.17	22	56	22	0	0	0	0	66	14	0	0	16	3	0	0	0	0	0	0
0.74	0.33	0.633	41.2	42.5	0.05	0.17	19	57	24	0	0	0	0	66	14	0	0	16	4	0	0	0	0	0	0
0.75	0.33	0.66	42	43.5	0.05	0.18	21	55	24	0	0	0	0	65	15	0	0	17	4	0	0	0	0	0	0
0.76	0.33	0.687	42.9	44.4	0.05	0.18	21	53	26	0	0	0	0	64	15	0	0	17	4	0	0	0	0	0	0
0.77	0.34	0.717	43.7	45.3	0.05	0.18	18	54	29	0	0	0	0	64	14	0	0	18	4	0	0	0	0	0	0
0.78	0.34	0.747	44.5	46.2	0.05	0.18	19	52	29	0	0	0	0	63	14	0	0	18	4	0	0	0	0	0	0
0.79	0.34	0.778	45.4	47.1	0.05	0.19	19	51	29	0	0	0	0	62	15	0	0	18	4	0	0	0	0	0	0
0.8	0.35	0.81	46.2	48	0.05	0.18	16	53	31	0	0	0	0	62	14	0	0	19	4	0	0	0	0	0	0
0.81	0.35	0.844	47	48.8	0.05	0.19	18	49	33	0	0	0	0	62	15	0	0	19	5	0	0	0	0	0	0
0.82	0.36	0.879	47.7	49.7	0.05	0.19	16	52	32	0	0	0	0	61	15	0	0	19	5	0	0	0	0	0	0
0.83	0.36	0.916	48.5	50.5	0.05	0.2	20	48	32	0	0	0	0	60	15	0	0	20	5	0	0	0	0	0	0
0.84	0.36	0.948	49.7	51.8	0.05	0.19	17	50	33	0	0	0	0	60	15	0	0	20	5	0	0	0	0	0	0
0.85	0.36	0.974	51.6	53.7	0.05	0.19	19	48	32	0	0	0	0	58	15	0	0	21	5	0	0	0	0	0	0
0.86	0.36	1.008	52.9	55.1	0.05	0.2	22	46	32	0	0	0	0	57	15	0	0	22	6	0	0	0	0	0	0
0.87	0.36	1.044	54.2	56.4	0.05	0.19	15	50	35	0	0	0	0	58	14	0	0	23	6	0	0	0	0	0	0
0.88	0.36	1.081	55.6	57.9	0.05	0.2	22	44	34	0	0	0	0	56	14	0	0	23	6	0	0	0	0	0	0
0.89	0.36	1.121	56.8	59.2	0.05	0.2	18	49	34	0	0	0	0	56	14	0	0	24	6	0	0	0	0	0	0
0.9	0.36	1.162	58.1	60.5	0.05	0.19	19	46	35	0	0	0	0	55	14	0	0	25	6	0	0	0	0	0	0
0.91	0.37	1.205	59.4	61.9	0.06	0.2	21	46	33	0	0	0	0	54	14	0	0	25	7	0	0	0	0	0	0
0.92	0.37	1.25	60.6	63.1	0.06	0.21	23	43	34	0	0	0	0	53	15	0	0	25	7	0	0	0	0	0	0
0.93	0.37	1.3	61.5	64.2	0.06	0.21	22	46	33	0	0	0	0	52	15	0	0	26	7	0	0	0	0	0	0
0.94	0.38	1.352	62.5	65.2	0.06	0.22	22	44	34	0	0	0	0	51	15	0	0	26	8	0	0	0	0	0	0
0.95	0.38	1.397	64.1	66.9	0.06	0.21	17	48	34	0	0	0	0	51	14	0	0	27	8	0	0	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
0.96	0.38	1.433	66.1	68.9	0.06	0.21	22	42	36	0	0	0	0	50	14	0	0	28	8	0	0	0	0	0	0
0.97	0.38	1.473	68	70.9	0.06	0.22	23	43	34	0	0	0	0	48	14	0	0	29	8	0	0	0	0	0	0
0.98	0.38	1.525	69.2	72.1	0.06	0.21	18	45	37	0	0	0	0	49	13	0	0	30	8	0	0	0	0	0	0
0.99	0.39	1.585	70	72.9	0.06	0.22	19	46	34	0	0	0	0	47	14	0	0	30	9	0	0	0	0	0	0
1	0.39	1.649	70.4	73.4	0.06	0.22	17	47	36	0	0	0	0	47	14	0	0	30	9	0	0	0	0	0	0
1.01	0.4	1.716	70.9	73.9	0.06	0.22	18	46	35	0	0	0	0	47	14	0	0	30	9	0	0	0	0	0	0
1.02	0.41	1.784	71.3	74.4	0.06	0.22	13	49	37	0	0	0	0	47	14	0	0	30	9	0	0	0	0	0	0
1.03	0.41	1.854	71.8	74.8	0.06	0.23	14	49	37	0	0	0	0	46	14	0	0	30	9	0	0	0	0	0	0
1.04	0.42	1.924	72.2	75.3	0.06	0.22	10	52	37	0	0	0	0	46	14	0	0	30	9	0	0	0	0	0	0
1.05	0.43	1.997	72.6	75.7	0.06	0.23	10	52	38	0	0	0	0	45	14	0	0	30	10	0	0	0	0	0	0
1.06	0.44	2.072	73	76.2	0.06	0.23	9	52	39	0	0	0	0	45	14	0	0	31	10	0	0	0	0	0	0
1.07	0.45	2.148	73.4	76.6	0.07	0.24	8	53	38	0	0	0	0	44	15	0	0	30	10	0	0	0	0	0	0
1.08	0.45	2.225	73.7	77	0.07	0.25	11	51	38	0	0	0	0	44	15	0	0	30	10	0	0	0	0	0	0
1.09	0.46	2.304	74.1	77.4	0.07	0.24	7	51	41	0	0	0	0	44	15	0	0	31	10	0	0	0	0	0	0
1.1	0.47	2.384	74.5	77.9	0.07	0.24	6	50	43	0	0	0	0	44	15	0	0	31	10	0	0	0	0	0	0
1.11	0.48	2.466	74.8	78.2	0.07	0.25	7	49	43	0	0	0	0	43	15	0	0	31	11	0	0	0	0	0	0
1.12	0.48	2.55	75.2	78.6	0.07	0.25	4	52	43	0	0	0	0	43	15	0	0	31	11	0	0	0	0	0	0
1.13	0.49	2.636	75.5	79	0.07	0.25	5	51	43	0	0	0	1	42	15	0	0	31	11	0	0	0	0	0	0
1.14	0.5	2.723	75.8	79.3	0.07	0.26	7	49	43	0	0	0	1	42	16	1	0	30	11	0	0	0	0	0	0
1.15	0.51	2.812	76.1	79.7	0.07	0.26	4	51	44	0	0	0	1	41	16	1	0	30	11	0	0	0	0	0	0
1.16	0.52	2.902	76.5	80	0.07	0.26	3	52	45	0	0	0	1	41	15	1	0	31	11	0	0	0	0	0	0
1.17	0.52	2.996	76.7	80.3	0.07	0.27	4	52	43	0	0	0	1	41	16	1	0	30	12	1	0	0	0	0	0
1.18	0.53	3.093	76.9	80.5	0.08	0.27	6	47	45	0	0	0	1	40	16	1	0	30	12	1	0	0	0	0	0
1.19	0.54	3.192	77	80.7	0.08	0.28	3	49	47	0	0	0	1	40	16	1	0	30	12	1	0	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VCSS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
1.2	0.55	3.293	77.2	80.9	0.08	0.28	2	48	48	0	0	0	1	40	16	1	0	30	12	1	0	0	0	0	0
1.21	0.56	3.395	77.3	81	0.08	0.28	2	47	50	0	0	0	1	40	16	1	0	30	12	1	0	0	0	0	0
1.22	0.57	3.499	77.5	81.2	0.08	0.28	1	46	51	0	0	0	2	39	16	1	0	30	13	1	0	0	0	0	0
1.23	0.58	3.604	77.6	81.4	0.08	0.28	0	46	52	0	0	0	2	39	17	1	0	30	13	1	0	0	0	0	0
1.24	0.59	3.711	77.8	81.6	0.08	0.29	4	43	51	0	0	0	2	38	17	1	0	30	13	1	0	0	0	0	0
1.25	0.6	3.82	77.9	81.7	0.08	0.29	3	40	54	0	0	0	2	38	17	1	0	29	13	1	0	0	0	0	0
1.26	0.6	3.93	78.1	81.9	0.08	0.3	2	41	54	0	0	0	2	38	17	2	0	29	13	1	0	0	0	0	0
1.27	0.61	4.042	78.2	82.1	0.08	0.3	0	39	58	0	0	0	2	38	17	2	0	29	13	1	0	0	0	0	0
1.28	0.62	4.155	78.4	82.2	0.09	0.3	0	39	57	0	0	0	3	37	17	2	0	29	13	1	0	0	0	0	0
1.29	0.63	4.27	78.5	82.4	0.09	0.31	0	38	58	0	0	0	3	37	17	2	0	29	13	1	0	0	0	0	0
1.3	0.64	4.387	78.7	82.6	0.09	0.31	2	37	58	0	0	0	3	37	17	2	0	29	14	2	0	0	0	0	0
1.31	0.65	4.505	78.8	82.8	0.09	0.31	2	33	61	0	0	0	3	37	17	2	0	29	14	1	0	0	0	0	0
1.32	0.66	4.625	79	82.9	0.09	0.32	5	30	61	0	0	0	3	36	18	2	0	29	14	2	0	0	0	0	0
1.33	0.67	4.746	79.1	83.1	0.09	0.32	2	31	63	0	0	0	3	36	18	2	0	29	14	2	0	0	0	0	0
1.34	0.67	4.869	79.3	83.3	0.09	0.32	0	33	63	0	0	0	4	36	18	2	0	29	14	2	0	0	0	0	0
1.35	0.68	4.994	79.4	83.4	0.09	0.32	0	31	65	0	0	0	4	36	18	2	0	29	14	2	0	0	0	0	0
1.36	0.69	5.121	79.6	83.6	0.09	0.33	0	30	65	0	0	0	4	35	18	2	0	28	14	2	0	0	0	0	0
1.37	0.7	5.249	79.7	83.8	0.09	0.34	2	28	65	0	0	0	4	35	18	3	0	28	15	2	0	0	0	0	0
1.38	0.71	5.378	79.9	84	0.09	0.34	2	27	67	0	0	0	4	35	18	3	0	28	15	2	0	0	0	0	0
1.39	0.72	5.51	80	84.1	0.1	0.34	3	25	67	0	0	0	5	34	18	3	0	28	15	2	0	0	0	0	0
1.4	0.73	5.643	80.2	84.3	0.1	0.35	2	25	68	0	0	0	5	34	18	3	0	28	15	2	0	0	0	0	0
1.41	0.74	5.778	80.3	84.5	0.1	0.35	1	25	68	0	0	0	5	34	18	3	0	28	15	2	0	0	0	0	0
1.42	0.74	5.914	80.5	84.6	0.1	0.35	1	22	72	0	0	0	5	33	18	3	0	27	15	3	0	0	0	0	0
1.43	0.75	6.053	80.6	84.8	0.1	0.36	1	20	73	0	0	0	5	33	18	3	0	27	15	3	0	0	0	0	0

HIGH FLOW HABFlo RESULTS																									
Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
1.44	0.76	6.193	80.8	85	0.1	0.35	1	18	76	0	0	0	5	33	18	3	0	27	15	3	0	0	0	0	0
1.45	0.77	6.334	80.9	85.2	0.1	0.36	2	17	75	0	0	0	6	33	19	3	0	27	15	3	0	0	0	0	0
1.46	0.78	6.478	81.1	85.3	0.1	0.36	2	16	76	0	0	0	6	32	19	3	0	27	16	3	0	0	0	0	0
1.47	0.79	6.623	81.2	85.5	0.1	0.37	1	16	77	0	0	0	6	32	19	3	0	27	16	3	0	0	0	0	0
1.48	0.8	6.77	81.4	85.7	0.1	0.37	2	14	77	0	0	0	7	32	19	4	0	27	16	3	0	0	0	0	0
1.49	0.8	6.919	81.5	85.9	0.11	0.37	1	14	78	0	0	0	6	32	19	4	0	27	16	3	0	0	0	0	0
1.5	0.81	7.069	81.7	86	0.11	0.38	1	12	80	0	0	0	7	31	19	4	0	27	16	3	0	0	0	0	0
1.51	0.82	7.222	81.8	86.2	0.11	0.38	1	10	82	0	0	0	7	31	19	4	0	27	16	3	0	0	0	0	0
1.52	0.83	7.377	81.9	86.4	0.11	0.39	2	10	81	0	0	0	7	31	19	4	0	26	16	3	0	0	0	0	0
1.53	0.84	7.535	82.1	86.5	0.11	0.38	1	10	82	0	0	0	7	31	19	4	0	26	16	3	0	0	0	0	0
1.54	0.85	7.695	82.2	86.6	0.11	0.39	2	9	82	0	0	0	7	31	19	4	0	26	16	3	0	0	0	0	0
1.55	0.86	7.857	82.3	86.8	0.11	0.39	2	9	81	0	0	0	7	30	19	4	0	26	17	4	0	0	0	0	0
1.56	0.86	8.021	82.4	86.9	0.11	0.39	1	10	81	0	0	0	8	30	19	4	0	26	17	4	0	0	0	0	0
1.57	0.87	8.188	82.5	87	0.11	0.4	1	9	82	0	0	0	8	30	19	4	0	26	17	4	0	0	0	0	0
1.58	0.88	8.357	82.6	87.1	0.11	0.4	0	8	84	0	0	0	8	30	19	4	0	26	17	4	0	0	0	0	0
1.59	0.89	8.531	82.7	87.2	0.12	0.41	1	8	82	0	0	0	8	29	20	5	0	25	17	4	0	0	0	0	0
1.6	0.9	8.706	82.7	87.2	0.12	0.42	1	8	82	0	0	0	8	29	20	5	0	25	17	4	0	0	0	0	0
1.61	0.91	8.884	82.8	87.3	0.12	0.42	1	8	82	0	0	0	9	29	20	5	0	25	17	4	0	0	0	0	0
1.62	0.92	9.064	82.8	87.4	0.12	0.42	2	7	82	0	0	0	9	29	20	5	0	25	17	4	0	0	0	0	0
1.63	0.93	9.245	82.9	87.5	0.12	0.42	2	7	82	0	0	0	9	28	20	5	0	25	17	4	0	0	0	0	0
1.64	0.94	9.429	82.9	87.5	0.12	0.43	2	7	82	0	0	0	9	28	20	5	0	25	18	4	0	0	0	0	0
1.65	0.95	9.616	83	87.6	0.12	0.43	0	7	84	0	0	0	9	28	20	5	0	25	18	4	0	0	0	0	0
1.66	0.96	9.806	83	87.6	0.12	0.43	0	7	84	0	0	0	9	28	20	5	0	25	18	4	0	0	0	0	0
1.67	0.97	9.999	83	87.7	0.12	0.44	0	7	84	0	0	0	9	28	20	5	0	24	18	5	0	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
1.68	0.98	10.194	83.1	87.7	0.13	0.44	0	6	84	0	0	0	10	28	20	5	0	24	18	5	0	0	0	0	0
1.69	0.99	10.391	83.1	87.7	0.13	0.45	1	6	83	0	0	0	10	27	20	5	0	24	18	5	0	0	0	0	0
1.7	1	10.59	83.1	87.7	0.13	0.44	0	6	84	0	0	0	10	27	20	5	0	24	18	5	0	0	0	0	0
1.71	1.01	10.791	83.1	87.8	0.13	0.45	1	6	83	0	0	0	10	27	21	5	0	24	18	5	0	0	0	0	0
1.72	1.02	10.994	83.2	87.8	0.13	0.46	1	5	83	0	0	0	10	27	21	6	0	24	18	5	0	0	0	0	0
1.73	1.03	11.2	83.2	87.8	0.13	0.46	1	5	84	0	0	0	11	27	21	6	0	24	18	5	0	0	0	0	0
1.74	1.04	11.408	83.2	87.9	0.13	0.47	1	5	84	0	0	0	11	27	21	6	0	23	18	5	0	0	0	0	0
1.75	1.05	11.618	83.2	87.9	0.13	0.47	1	5	83	0	0	0	11	26	21	6	0	23	18	5	0	0	0	0	0
1.76	1.05	11.83	83.3	87.9	0.13	0.48	1	5	83	0	0	0	11	26	21	6	0	23	18	5	0	0	0	0	0
1.77	1.06	12.045	83.3	88	0.14	0.48	1	5	83	0	0	0	11	26	21	6	0	23	18	5	0	0	0	0	0
1.78	1.07	12.261	83.3	88	0.14	0.48	1	5	83	0	0	0	11	26	21	6	0	23	19	5	0	0	0	0	0
1.79	1.08	12.481	83.3	88	0.14	0.48	1	5	83	0	0	0	12	26	21	6	0	23	19	5	0	0	0	0	0
1.8	1.09	12.702	83.4	88.1	0.14	0.49	1	5	83	0	0	0	12	25	21	6	0	23	19	5	0	0	0	0	0
1.81	1.1	12.926	83.4	88.1	0.14	0.49	1	5	83	0	0	0	12	25	21	6	0	22	19	5	0	0	0	0	0
1.82	1.11	13.152	83.4	88.1	0.14	0.5	1	5	82	0	0	0	12	25	21	6	0	22	19	5	0	0	0	0	0
1.83	1.12	13.38	83.4	88.2	0.14	0.5	1	5	82	0	0	0	12	25	21	6	0	22	19	6	0	0	0	0	0
1.84	1.13	13.611	83.5	88.2	0.14	0.51	1	5	82	0	0	0	12	25	21	6	0	22	19	6	0	0	0	0	0
1.85	1.14	13.845	83.5	88.2	0.15	0.51	1	5	82	0	0	0	12	25	21	6	0	22	19	6	0	0	0	0	0
1.86	1.15	14.08	83.5	88.3	0.15	0.51	1	3	84	0	0	0	13	25	22	6	0	22	19	6	0	0	0	0	0
1.87	1.16	14.319	83.5	88.3	0.15	0.51	1	3	83	0	0	0	13	24	22	6	1	22	19	6	0	0	0	0	0
1.88	1.17	14.559	83.6	88.3	0.15	0.52	1	3	83	0	0	0	13	24	22	7	1	22	19	6	0	0	0	0	0
1.89	1.18	14.802	83.6	88.4	0.15	0.52	1	3	83	0	0	0	13	24	22	7	1	21	19	6	1	0	0	0	0
1.9	1.19	15.048	83.6	88.4	0.15	0.53	1	3	83	0	0	0	14	24	22	7	1	21	19	6	1	0	0	0	0
1.91	1.2	15.296	83.6	88.4	0.15	0.53	1	3	83	0	0	0	14	24	22	7	1	21	19	6	1	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
1.92	1.21	15.543	83.7	88.5	0.15	0.53	1	2	83	0	0	0	14	24	22	7	1	21	19	6	1	0	0	0	0
1.93	1.22	15.792	83.8	88.6	0.15	0.54	1	2	83	0	0	0	14	24	22	7	1	21	19	6	1	0	0	0	0
1.94	1.23	16.044	83.8	88.6	0.16	0.53	0	2	84	0	0	0	14	24	22	7	1	21	19	6	1	0	0	0	0
1.95	1.24	16.298	83.9	88.7	0.16	0.54	0	2	84	0	0	0	14	23	22	7	1	21	19	6	1	0	0	0	0
1.96	1.25	16.555	84	88.8	0.16	0.55	1	2	82	0	0	0	15	23	22	7	1	21	19	6	1	0	0	0	0
1.97	1.25	16.814	84	88.8	0.16	0.56	1	2	82	0	0	0	15	23	22	7	1	20	19	6	1	0	0	0	0
1.98	1.26	17.077	84.1	88.9	0.16	0.56	1	2	82	0	0	0	15	23	22	7	1	20	19	6	1	0	0	0	0
1.99	1.27	17.341	84.1	89	0.16	0.56	0	1	84	0	0	0	15	23	22	7	1	20	20	6	1	0	0	0	0
2	1.28	17.609	84.2	89	0.16	0.56	0	1	83	0	0	0	15	23	22	7	1	20	20	6	1	0	0	0	0
2.01	1.29	17.879	84.3	89.1	0.16	0.57	1	1	82	0	0	0	16	23	22	7	1	20	20	7	1	0	0	0	0
2.02	1.3	18.152	84.3	89.2	0.17	0.58	1	2	81	0	0	0	16	22	22	7	1	20	19	7	1	0	0	0	0
2.03	1.31	18.428	84.4	89.2	0.17	0.58	1	2	81	0	0	0	16	22	22	7	1	20	20	7	1	0	0	0	0
2.04	1.32	18.707	84.5	89.3	0.17	0.58	0	2	82	0	0	0	16	22	22	7	1	20	20	7	1	0	0	0	0
2.05	1.33	18.988	84.5	89.4	0.17	0.58	0	2	82	0	0	0	16	22	22	7	1	20	20	7	1	0	0	0	0
2.06	1.34	19.273	84.6	89.5	0.17	0.59	1	2	81	0	0	0	17	22	22	8	1	19	20	7	1	0	0	0	0
2.07	1.34	19.56	84.7	89.5	0.17	0.59	1	2	81	0	0	0	17	22	22	8	1	19	20	7	1	0	0	0	0
2.08	1.35	19.85	84.7	89.6	0.17	0.6	1	2	81	0	0	0	17	22	22	8	1	19	20	7	1	0	0	0	0
2.09	1.36	20.143	84.8	89.7	0.17	0.6	0	1	82	0	0	0	17	22	22	8	1	19	20	7	1	0	0	0	0
2.1	1.37	20.439	84.9	89.7	0.18	0.6	0	1	81	0	0	0	17	22	22	8	1	19	20	7	1	0	0	0	0
2.11	1.38	20.738	84.9	89.8	0.18	0.61	1	1	80	0	0	0	18	21	22	8	2	19	20	7	1	0	0	0	0
2.12	1.39	21.04	85	89.9	0.18	0.61	1	1	80	0	0	0	18	21	22	8	2	19	20	7	1	0	0	0	0
2.13	1.4	21.346	85	89.9	0.18	0.62	1	2	79	0	0	0	18	21	22	8	2	19	20	7	1	0	0	0	0
2.14	1.41	21.654	85.1	90	0.18	0.61	0	2	80	0	0	0	18	21	22	8	2	19	20	7	1	0	0	0	0
2.15	1.42	21.965	85.2	90.1	0.18	0.62	0	2	80	0	0	0	19	21	22	8	2	19	20	7	1	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
2.16	1.42	22.28	85.2	90.1	0.18	0.63	1	2	78	0	0	0	19	21	22	8	2	18	19	8	2	0	0	0	0
2.17	1.43	22.598	85.3	90.2	0.18	0.63	1	2	78	0	0	0	19	21	22	9	2	18	19	8	2	0	0	0	0
2.18	1.44	22.919	85.4	90.3	0.19	0.64	1	2	78	0	0	0	19	21	22	9	2	18	19	8	2	0	0	0	0
2.19	1.45	23.243	85.4	90.3	0.19	0.64	0	1	79	0	0	0	20	21	22	9	2	18	19	8	2	0	0	0	0
2.2	1.46	23.571	85.5	90.4	0.19	0.64	0	1	78	0	0	0	20	20	22	9	2	18	19	8	2	0	0	0	0
2.21	1.47	23.902	85.6	90.5	0.19	0.65	1	1	77	0	0	0	20	20	22	9	2	18	19	8	2	0	0	0	0
2.22	1.48	24.236	85.6	90.5	0.19	0.65	1	1	77	0	0	0	20	20	22	9	2	18	19	8	2	0	0	0	0
2.23	1.49	24.574	85.7	90.6	0.19	0.66	1	1	77	0	0	0	21	20	22	9	2	18	19	8	2	0	0	0	0
2.24	1.5	24.915	85.8	90.7	0.19	0.66	0	1	78	0	0	0	21	20	22	9	2	18	19	8	2	0	0	0	0
2.25	1.51	25.259	85.8	90.7	0.2	0.66	0	1	77	0	0	0	21	20	22	9	2	18	19	8	2	0	0	0	0
2.26	1.51	25.608	85.9	90.8	0.2	0.67	1	1	76	0	0	0	22	20	22	9	2	17	19	8	2	0	0	0	0
2.27	1.52	25.959	85.9	90.9	0.2	0.68	1	2	75	0	0	0	22	20	22	10	2	17	19	8	2	0	0	0	0
2.28	1.53	26.315	86	90.9	0.2	0.68	1	2	75	0	0	0	22	19	22	10	2	17	19	9	2	0	0	0	0
2.29	1.54	26.674	86.1	91	0.2	0.68	0	2	76	0	0	0	22	19	22	10	2	17	19	9	2	0	0	0	0
2.3	1.55	27.036	86.1	91.1	0.2	0.69	0	2	75	0	0	0	23	19	22	10	2	17	19	9	2	0	0	0	0
2.31	1.56	27.403	86.2	91.2	0.2	0.68	0	2	76	0	0	0	23	19	22	10	2	17	19	8	2	0	0	0	0
2.32	1.57	27.773	86.3	91.2	0.21	0.7	0	2	74	0	0	0	23	19	22	10	3	17	19	9	2	0	0	0	0
2.33	1.58	28.147	86.3	91.3	0.21	0.71	0	2	74	0	0	0	23	19	22	10	3	17	19	9	2	0	0	0	0
2.34	1.58	28.525	86.4	91.4	0.21	0.7	0	2	75	0	0	0	24	19	22	10	3	17	19	9	2	0	0	0	0
2.35	1.59	28.906	86.5	91.4	0.21	0.71	0	2	74	0	0	0	24	19	21	10	3	17	19	9	2	0	0	0	0
2.36	1.6	29.292	86.5	91.5	0.21	0.72	0	2	74	0	0	0	24	19	21	10	3	17	19	9	2	0	0	0	0
2.37	1.61	29.682	86.6	91.6	0.21	0.73	0	2	73	0	0	0	25	19	21	10	3	16	19	9	3	0	0	0	0
2.38	1.62	30.069	86.7	91.7	0.21	0.73	0	3	72	0	0	0	25	18	21	11	3	16	19	9	3	0	0	0	0
2.39	1.63	30.46	86.8	91.8	0.22	0.73	0	2	72	0	0	0	25	18	21	11	3	16	19	9	3	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
2.4	1.64	30.854	86.9	91.9	0.22	0.74	0	2	72	0	0	0	26	18	21	11	3	16	19	9	3	0	0	0	0
2.41	1.64	31.253	87	92	0.22	0.74	0	2	70	0	0	0	26	18	21	11	3	16	18	10	3	0	0	0	0
2.42	1.65	31.656	87.1	92.1	0.22	0.75	0	2	70	0	0	0	26	18	21	11	3	16	18	10	3	0	0	0	0
2.43	1.66	32.063	87.2	92.2	0.22	0.75	0	2	71	0	0	0	27	18	21	11	3	16	19	10	3	0	0	0	0
2.44	1.67	32.475	87.3	92.3	0.22	0.75	0	2	71	0	0	0	27	18	21	11	3	16	18	10	3	0	0	0	0
2.45	1.68	32.89	87.4	92.4	0.22	0.76	0	2	69	0	0	0	27	18	21	11	3	16	18	10	3	0	0	0	0
2.46	1.68	33.311	87.5	92.5	0.23	0.77	0	2	69	0	0	0	27	18	20	12	3	16	18	10	3	0	0	0	0
2.47	1.69	33.736	87.6	92.6	0.23	0.77	0	2	70	0	0	0	28	18	21	12	3	16	18	10	3	0	0	0	0
2.48	1.7	34.165	87.7	92.7	0.23	0.77	0	2	69	0	0	0	28	18	20	12	3	16	18	10	3	0	0	0	0
2.49	1.71	34.599	87.8	92.8	0.23	0.78	0	2	68	0	0	0	28	17	20	12	4	15	18	11	3	0	0	0	0
2.5	1.72	35.037	87.9	92.9	0.23	0.79	0	2	68	0	0	0	29	17	20	12	4	15	18	11	3	0	0	0	0
2.51	1.72	35.481	88	93	0.23	0.78	0	2	68	0	0	0	29	17	20	12	4	15	18	11	3	0	0	0	0
2.52	1.73	35.929	88.1	93.1	0.24	0.79	0	2	68	0	0	0	29	17	20	12	4	15	18	11	3	0	0	0	0
2.53	1.74	36.382	88.2	93.2	0.24	0.8	0	2	67	0	0	0	30	17	20	13	4	15	18	11	3	0	0	0	0
2.54	1.75	36.84	88.3	93.3	0.24	0.81	1	2	66	0	0	0	30	17	20	13	4	15	17	11	3	0	0	0	0
2.55	1.76	37.303	88.4	93.4	0.24	0.81	0	2	67	0	0	0	30	17	20	13	4	15	18	11	3	0	0	0	0
2.56	1.76	37.77	88.5	93.5	0.24	0.81	0	2	67	0	0	0	31	17	20	13	4	15	17	11	3	0	0	0	0
2.57	1.77	38.244	88.6	93.6	0.24	0.82	1	2	65	0	0	0	31	17	19	13	4	15	17	12	3	0	0	0	0
2.58	1.78	38.722	88.7	93.7	0.25	0.83	1	2	65	0	0	0	31	17	19	13	4	15	17	12	4	0	0	0	0
2.59	1.79	39.205	88.8	93.8	0.25	0.82	0	2	66	0	0	0	32	17	19	13	4	15	17	12	3	0	0	0	0
2.6	1.8	39.694	88.9	93.9	0.25	0.82	0	2	66	0	0	0	32	16	19	13	4	14	17	12	4	0	0	0	0
2.61	1.8	40.188	89	94	0.25	0.84	1	2	64	0	0	0	32	16	19	14	4	14	17	12	4	0	0	0	0
2.62	1.81	40.688	89.1	94.1	0.25	0.84	0	2	64	0	0	0	33	16	19	14	4	14	17	12	4	0	0	0	0
2.63	1.82	41.194	89.2	94.2	0.25	0.85	0	2	64	0	0	0	33	16	19	14	4	14	17	12	4	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
2.64	1.83	41.705	89.3	94.3	0.26	0.86	1	2	62	0	0	0	34	16	19	14	4	14	17	12	4	0	0	0	0
2.65	1.84	42.221	89.4	94.4	0.26	0.87	1	2	62	0	0	0	34	16	19	14	4	14	17	12	4	0	0	0	0
2.66	1.84	42.744	89.5	94.5	0.26	0.87	0	2	63	0	0	0	34	16	19	14	4	14	17	12	4	0	0	0	0
2.67	1.85	43.273	89.6	94.6	0.26	0.87	0	2	62	0	0	0	35	16	19	14	4	14	17	13	4	0	0	0	0
2.68	1.86	43.807	89.7	94.7	0.26	0.89	1	2	61	0	0	0	35	16	18	14	5	14	16	13	4	0	0	0	0
2.69	1.87	44.348	89.8	94.8	0.26	0.89	1	2	61	0	0	0	35	16	18	15	5	14	16	13	4	0	0	0	0
2.7	1.88	44.895	89.9	94.9	0.27	0.88	0	2	62	0	0	0	35	15	19	15	5	14	16	13	4	0	0	0	0
2.71	1.88	45.448	90	95	0.27	0.89	0	2	61	0	0	0	36	15	18	15	5	14	16	13	4	0	0	0	0
2.72	1.89	46.007	90.1	95.1	0.27	0.9	1	2	60	0	0	0	36	15	18	15	5	13	16	13	4	0	0	0	0
2.73	1.9	46.573	90.2	95.2	0.27	0.91	1	2	59	0	0	0	36	15	18	15	5	13	16	13	4	0	0	0	0
2.74	1.91	47.145	90.3	95.3	0.27	0.92	1	2	59	0	0	0	37	15	18	15	5	13	16	13	4	0	0	0	0
2.75	1.92	47.724	90.4	95.4	0.28	0.93	1	2	59	0	0	0	37	15	18	15	5	13	16	14	4	0	0	0	0
2.76	1.92	48.31	90.5	95.5	0.28	0.94	1	2	58	0	0	0	38	15	18	15	5	13	16	14	5	0	0	0	0
2.77	1.93	48.902	90.6	95.6	0.28	0.94	1	2	58	0	0	0	38	15	17	16	5	13	16	14	5	0	0	0	0
2.78	1.94	49.502	90.7	95.7	0.28	0.95	1	2	58	0	0	0	38	15	17	16	5	13	15	14	5	0	0	0	0
2.79	1.95	50.109	90.8	95.8	0.28	0.95	1	2	57	0	0	0	39	15	17	16	5	13	15	14	5	0	0	0	0
2.8	1.95	50.723	90.9	95.9	0.29	0.95	1	2	57	0	0	0	39	14	18	16	5	12	16	14	5	0	0	0	0
2.81	1.96	51.344	91	96	0.29	0.96	1	2	57	0	0	0	39	14	18	16	5	12	16	14	5	0	0	0	0
2.82	1.97	51.973	91.1	96.1	0.29	0.96	1	2	57	0	0	0	39	14	18	16	5	12	16	14	5	0	0	0	0
2.83	1.98	52.609	91.2	96.2	0.29	0.97	1	2	56	0	0	0	40	14	17	16	6	12	15	14	5	0	0	0	0
2.84	1.99	53.253	91.3	96.3	0.29	0.98	1	2	56	0	0	0	40	14	17	16	6	12	15	14	5	0	0	0	0
2.85	1.99	53.905	91.4	96.5	0.3	0.99	1	2	55	0	0	0	41	14	17	16	6	12	15	15	5	0	0	0	0
2.86	2	54.565	91.5	96.6	0.3	1	1	2	55	0	0	0	41	14	17	17	6	12	15	15	5	0	0	0	0
2.87	2.01	55.233	91.6	96.7	0.3	1	1	2	54	0	0	0	41	14	17	17	6	12	15	15	5	0	0	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
2.88	2.02	55.91	91.7	96.8	0.3	1.01	1	2	54	0	0	0	42	13	17	17	6	12	15	15	5	0	0	0	0
2.89	2.03	56.594	91.8	96.9	0.3	1.01	1	2	54	0	0	0	42	13	17	17	6	11	15	15	5	0	0	0	0
2.9	2.03	57.288	91.9	97	0.31	1.02	1	2	53	0	0	0	42	13	17	17	6	11	15	15	6	0	0	0	0
2.91	2.04	57.99	92	97.1	0.31	1.02	1	2	53	0	0	0	43	13	17	17	6	11	15	15	6	0	0	0	0
2.92	2.05	58.701	92.1	97.2	0.31	1.03	1	2	53	0	0	0	43	13	17	17	6	11	15	15	6	0	0	0	0
2.93	2.06	59.421	92.2	97.3	0.31	1.03	1	2	53	0	0	0	43	13	17	17	6	11	15	15	6	0	0	0	0
2.94	2.06	60.15	92.3	97.4	0.32	1.04	1	2	52	0	0	0	44	13	17	17	7	11	15	15	6	0	0	0	0
2.95	2.07	60.888	92.4	97.5	0.32	1.05	1	2	52	0	0	0	44	13	16	17	7	11	15	15	6	0	0	0	0
2.96	2.08	61.637	92.5	97.6	0.32	1.05	1	2	52	0	0	0	44	12	16	17	7	11	14	15	6	0	0	0	0
2.97	2.09	62.394	92.6	97.7	0.32	1.06	1	2	51	0	0	0	45	12	16	18	7	11	14	16	6	0	0	0	0
2.98	2.09	63.162	92.7	97.8	0.33	1.07	1	2	51	0	0	0	45	12	16	18	7	11	15	16	6	0	0	0	0
2.99	2.1	63.94	92.8	97.9	0.33	1.07	1	2	50	0	0	0	45	12	16	18	7	10	14	16	6	0	0	0	0
3	2.11	64.728	92.9	98	0.33	1.08	1	2	50	0	0	0	46	12	16	18	7	10	14	16	6	0	0	0	0
3.01	2.12	65.526	93	98.1	0.33	1.09	1	2	50	0	0	0	46	12	16	18	7	10	14	16	6	0	2	0	0
3.02	2.13	66.335	93.1	98.2	0.34	1.1	1	2	49	0	0	0	47	12	16	18	7	10	14	16	7	0	2	0	0
3.03	2.13	67.155	93.2	98.3	0.34	1.11	1	2	49	0	0	0	47	11	16	18	7	10	14	16	7	1	2	0	0
3.04	2.14	67.986	93.3	98.4	0.34	1.12	1	2	49	0	0	0	47	11	16	18	8	10	14	16	7	1	2	0	0
3.05	2.15	68.828	93.4	98.5	0.34	1.13	1	2	48	0	0	0	48	11	15	18	8	10	14	16	7	1	2	0	0
3.06	2.16	69.682	93.5	98.6	0.35	1.13	0	2	48	0	0	0	48	11	15	18	8	10	14	16	7	1	2	0	0
3.07	2.16	70.548	93.6	98.7	0.35	1.14	0	2	47	0	0	0	49	11	15	18	8	10	14	16	7	1	2	0	0
3.08	2.17	71.425	93.7	98.8	0.35	1.15	0	2	47	0	0	0	49	11	15	18	8	9	14	16	7	2	2	0	0
3.09	2.18	72.315	93.8	98.9	0.35	1.15	0	2	47	0	0	0	49	11	15	18	8	9	13	16	7	2	2	0	0
3.1	2.19	73.217	93.9	99	0.36	1.16	0	2	47	0	0	0	50	10	15	18	8	9	13	16	7	2	2	0	0
3.11	2.19	74.132	94	99.1	0.36	1.17	0	2	46	0	0	0	50	10	15	18	9	9	13	16	8	2	2	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
3.12	2.2	75.06	94.1	99.2	0.36	1.17	0	2	46	0	0	0	50	10	15	18	9	9	13	16	8	2	2	0	0
3.13	2.21	76.001	94.2	99.3	0.37	1.18	0	2	46	0	0	0	50	10	15	18	9	9	13	16	8	3	2	0	0
3.14	2.22	76.956	94.3	99.4	0.37	1.19	0	2	45	1	1	1	51	10	14	18	9	9	13	16	8	3	2	0	0
3.15	2.23	77.925	94.4	99.5	0.37	1.2	0	2	45	1	1	1	51	10	14	18	9	9	13	16	8	3	2	0	0
3.16	2.23	78.907	94.5	99.6	0.37	1.21	0	2	45	1	1	1	52	10	14	18	9	9	13	16	8	3	2	0	0
3.17	2.24	79.904	94.6	99.7	0.38	1.22	0	2	44	1	1	1	52	10	14	18	9	8	13	16	8	3	2	0	0
3.18	2.25	80.916	94.7	99.8	0.38	1.22	0	2	44	1	1	1	52	9	14	18	10	8	13	16	8	4	2	0	0
3.19	2.26	81.943	94.8	99.9	0.38	1.23	0	2	44	1	1	1	53	9	14	18	10	8	12	16	9	4	2	0	0
3.2	2.26	82.986	94.9	100	0.39	1.24	0	2	43	1	1	1	53	9	14	18	10	8	12	16	9	4	2	0	0
3.21	2.27	84.044	95	100.1	0.39	1.25	0	2	43	1	1	1	53	9	14	18	10	8	12	16	9	4	2	0	0
3.22	2.28	85.118	95.1	100.3	0.39	1.26	0	2	43	1	1	1	54	9	13	18	10	8	12	16	9	4	2	0	0
3.23	2.29	86.209	95.2	100.4	0.4	1.27	0	2	42	1	1	1	54	9	13	18	11	8	12	16	9	5	2	0	0
3.24	2.29	87.316	95.3	100.5	0.4	1.28	0	2	42	1	1	1	55	9	13	18	11	8	12	16	9	5	2	0	0
3.25	2.3	88.441	95.4	100.6	0.4	1.29	0	2	41	1	1	1	55	9	13	18	11	8	12	16	10	5	2	0	0
3.26	2.31	89.594	95.5	100.6	0.41	1.31	1	2	40	1	1	1	55	8	13	18	11	8	12	16	10	5	2	0	0
3.27	2.32	90.767	95.6	100.7	0.41	1.33	1	2	40	1	1	1	56	8	13	18	11	7	11	16	10	5	2	0	0
3.28	2.33	91.958	95.7	100.8	0.41	1.34	1	2	40	1	1	1	56	8	13	17	12	7	11	16	10	6	2	0	0
3.29	2.33	93.168	95.7	100.9	0.42	1.33	0	2	40	1	1	1	57	8	13	17	12	7	11	15	10	6	2	0	0
3.3	2.34	94.398	95.8	101	0.42	1.34	0	2	40	1	1	1	57	8	12	17	12	7	11	15	11	6	2	0	0
3.31	2.35	95.648	95.9	101.1	0.42	1.35	0	1	39	1	1	1	57	8	12	17	12	7	11	15	11	6	2	0	0
3.32	2.36	96.918	96	101.1	0.43	1.36	0	1	39	1	1	1	58	8	12	18	12	7	11	16	11	6	2	0	0
3.33	2.37	98.21	96.1	101.2	0.43	1.38	0	1	38	1	1	1	58	8	12	17	12	7	11	15	11	6	2	0	0
3.34	2.37	99.523	96.1	101.3	0.44	1.4	1	2	38	1	1	1	58	8	12	17	13	7	11	15	11	7	2	0	0
3.35	2.38	100.858	96.2	101.4	0.44	1.41	1	2	37	1	1	1	58	8	12	17	13	7	11	15	11	7	2	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
3.36	2.39	102.216	96.3	101.5	0.44	1.42	1	2	37	1	1	1	59	7	12	17	13	7	10	15	12	7	2	0	0
3.37	2.4	103.597	96.4	101.6	0.45	1.43	1	2	37	1	1	1	59	7	12	17	13	7	10	15	12	7	2	0	0
3.38	2.41	105.001	96.5	101.6	0.45	1.44	0	2	36	1	1	1	60	7	11	17	14	6	10	15	12	7	2	0	0
3.39	2.41	106.431	96.5	101.7	0.46	1.44	0	2	36	0	0	1	61	7	12	17	14	6	10	15	12	8	2	0	0
3.4	2.42	107.885	96.6	101.8	0.46	1.45	0	2	36	0	0	1	61	7	11	16	14	6	10	15	12	8	2	0	0
3.41	2.43	109.366	96.7	101.9	0.47	1.46	0	1	36	0	0	1	61	7	11	16	14	6	10	14	13	8	2	0	0
3.42	2.44	110.873	96.8	102	0.47	1.47	0	1	35	0	0	1	62	7	11	16	14	6	10	14	13	8	2	0	0
3.43	2.45	112.407	96.9	102	0.47	1.49	0	1	35	0	0	1	62	7	11	16	15	6	10	14	13	8	2	0	0
3.44	2.45	113.969	96.9	102.1	0.48	1.51	0	2	34	1	1	1	62	7	11	16	15	6	10	14	13	9	2	0	0
3.45	2.46	115.56	97	102.2	0.48	1.52	0	2	34	1	1	1	62	7	11	16	15	6	10	14	14	9	2	0	0
3.46	2.47	117.18	97.1	102.3	0.49	1.54	0	2	33	1	1	1	63	6	11	15	16	6	10	14	14	9	2	0	0
3.47	2.48	118.831	97.2	102.4	0.49	1.55	0	2	33	1	1	1	63	6	11	15	16	6	9	14	14	9	2	0	0
3.48	2.49	120.514	97.3	102.5	0.5	1.56	0	2	33	1	1	1	63	6	10	15	16	5	9	13	14	9	2	0	0
3.49	2.49	122.228	97.3	102.5	0.5	1.58	0	2	33	1	1	1	64	6	10	15	16	5	9	13	15	9	2	0	0
3.5	2.5	123.976	97.4	102.6	0.51	1.57	0	1	33	0	0	1	65	6	10	15	17	5	9	13	15	10	2	0	0
3.51	2.51	125.758	97.5	102.7	0.51	1.59	0	1	32	0	0	1	65	6	10	15	17	5	9	13	15	10	2	0	0
3.52	2.52	127.575	97.6	102.8	0.52	1.6	0	1	32	0	0	1	65	6	10	15	17	5	9	13	15	10	2	0	0
3.53	2.53	129.429	97.7	102.9	0.52	1.62	0	1	32	0	0	1	66	6	10	15	17	5	9	13	15	10	2	0	0
3.54	2.53	131.32	97.7	103	0.53	1.63	0	1	31	0	0	1	66	6	10	14	18	5	9	13	16	10	2	0	0
3.55	2.54	133.249	97.8	103	0.54	1.67	0	1	30	1	1	1	66	6	10	14	18	5	9	13	16	11	2	0	0
3.56	2.55	135.218	97.9	103.1	0.54	1.68	0	1	30	1	1	1	67	5	10	14	18	5	8	12	16	11	2	0	0
3.57	2.56	137.228	98	103.2	0.55	1.69	0	1	30	1	1	1	67	5	9	14	19	5	8	12	17	11	2	0	0
3.58	2.56	139.281	98.1	103.3	0.55	1.7	0	1	30	1	1	1	67	5	9	14	19	5	8	12	17	11	2	0	0
3.59	2.57	141.378	98.1	103.4	0.56	1.72	0	1	29	1	1	1	68	5	9	14	19	5	8	12	17	11	2	0	0

HIGH FLOW HABFlo RESULTS

Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
3.6	2.58	143.519	98.2	103.5	0.57	1.72	0	1	29	0	0	0	69	5	9	14	19	4	8	12	17	11	2	0	0
3.61	2.59	145.707	98.3	103.5	0.57	1.74	0	1	29	0	0	0	69	5	9	13	19	4	8	12	17	12	2	0	0
3.62	2.6	147.944	98.4	103.6	0.58	1.76	0	1	29	0	0	0	69	5	9	13	20	4	8	12	17	12	2	0	0
3.63	2.6	150.231	98.5	103.7	0.59	1.77	0	1	28	0	0	0	70	5	9	13	20	4	8	12	18	12	2	0	0
3.64	2.61	152.569	98.5	103.8	0.59	1.79	0	1	28	0	0	0	70	5	9	13	20	4	8	11	18	12	2	0	0
3.65	2.62	154.961	98.6	103.9	0.6	1.82	0	1	27	1	1	1	70	5	8	12	21	4	8	11	18	12	2	0	0
3.66	2.63	157.408	98.7	103.9	0.61	1.84	0	1	27	1	1	1	70	5	8	12	21	4	7	11	19	13	2	0	0
3.67	2.64	159.912	98.8	104	0.61	1.85	0	1	26	1	1	1	71	4	8	12	21	4	7	11	19	13	2	0	0
3.68	2.64	162.476	98.9	104.1	0.62	1.87	0	1	26	1	1	1	71	4	8	12	22	4	7	11	19	13	2	0	0
3.69	2.65	165.101	98.9	104.2	0.63	1.89	0	1	26	1	1	1	71	4	8	12	22	4	7	10	19	13	2	0	0
3.7	2.66	167.791	99	104.3	0.64	1.91	0	1	25	0	0	0	72	4	8	12	22	4	7	10	20	13	2	0	0
3.71	2.67	170.547	99.1	104.4	0.65	1.91	0	1	25	0	0	0	73	4	8	12	22	4	7	10	20	13	2	0	0
3.72	2.68	173.371	99.2	104.4	0.65	1.92	0	1	25	0	0	0	73	4	8	11	23	4	7	10	20	14	2	0	0
3.73	2.68	176.268	99.3	104.5	0.66	1.94	0	1	25	0	0	0	74	4	8	11	23	4	7	10	20	14	2	0	0
3.74	2.69	179.238	99.3	104.6	0.67	1.96	0	1	24	0	0	0	74	4	7	11	23	3	7	10	21	14	2	0	0
3.75	2.7	182.286	99.4	104.7	0.68	1.99	0	1	24	0	0	0	74	4	7	11	23	3	6	10	21	14	2	0	0
3.76	2.71	185.415	99.5	104.8	0.69	2.03	0	1	23	1	1	1	74	4	7	11	24	3	6	9	21	14	2	0	0
3.77	2.71	188.627	99.6	104.9	0.7	2.04	0	1	23	1	1	1	75	4	7	10	24	3	6	9	21	15	2	0	0
3.78	2.72	191.927	99.7	104.9	0.71	2.06	0	1	22	1	1	1	75	4	7	10	25	3	6	9	22	15	2	0	0
3.79	2.73	195.317	99.7	105	0.72	2.08	0	1	22	1	1	1	75	3	7	10	25	3	6	9	22	15	2	0	0
3.8	2.74	198.803	99.8	105.1	0.73	2.11	0	1	22	1	1	1	76	3	7	10	25	3	6	9	22	15	2	0	0
3.81	2.75	202.387	99.9	105.2	0.74	2.11	0	1	21	0	0	0	77	3	7	10	25	3	6	9	22	15	2	0	0
3.82	2.75	206.075	100	105.3	0.75	2.12	0	1	21	0	0	0	77	3	6	10	26	3	6	9	23	15	2	0	0
3.83	2.76	209.871	100.1	105.3	0.76	2.14	0	1	21	0	0	0	78	3	6	9	26	3	6	8	23	16	2	0	0

HIGH FLOW HABFlo RESULTS																									
Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel 98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
3.84	2.77	213.78	100.1	105.4	0.77	2.17	0	1	20	0	0	0	78	3	6	9	26	3	5	8	23	16	2	0	0
3.85	2.78	217.807	100.2	105.5	0.78	2.19	0	1	20	0	0	0	78	3	6	9	26	3	5	8	23	16	2	0	0

LOW FLOW HABFlo RESULTS																									
Max depth	Av depth	Discharge	Width	Perim	Av Vel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VEG	#Int	Vveg	Vint
0.01	0.01	0	0.2	0.2	0.01	0.04	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.02	0.01	0	0.3	0.3	0.02	0.07	100	0	0	0	0	0	0	88	0	0	0	12	0	0	0	0	0	0	0
0.03	0.01	0	0.5	0.5	0.02	0.09	100	0	0	0	0	0	0	87	1	0	0	12	0	0	0	0	0	0	0
0.04	0.02	0	0.7	0.7	0.03	0.11	100	0	0	0	0	0	0	85	3	0	0	12	0	0	0	0	0	0	0
0.05	0.02	0.001	1.2	1.2	0.03	0.1	100	0	0	0	0	0	0	86	2	0	0	12	0	0	0	0	0	0	0
0.06	0.02	0.001	1.9	1.9	0.03	0.11	100	0	0	0	0	0	0	84	4	0	0	11	1	0	0	0	0	0	0
0.07	0.02	0.002	2.4	2.4	0.04	0.13	100	0	0	0	0	0	0	82	6	0	0	11	1	0	0	0	0	0	0
0.08	0.03	0.003	3.1	3.1	0.04	0.14	100	0	0	0	0	0	0	80	8	0	0	11	1	0	0	0	0	0	0
0.09	0.03	0.005	3.8	3.8	0.04	0.15	100	0	0	0	0	0	0	79	9	0	0	11	1	0	0	0	0	0	0
0.1	0.04	0.008	4.2	4.2	0.05	0.17	100	0	0	0	0	0	0	76	12	0	0	10	2	0	0	0	0	0	0
0.11	0.05	0.011	4.4	4.5	0.05	0.19	97	3	0	0	0	0	0	73	15	0	0	10	2	0	0	0	0	0	0
0.12	0.05	0.015	4.7	4.8	0.06	0.21	92	7	0	0	0	0	0	70	18	0	0	10	2	0	0	0	0	0	0
0.13	0.06	0.02	5	5	0.07	0.23	90	10	0	0	0	0	0	68	20	0	0	9	3	0	0	0	0	0	0
0.14	0.07	0.025	5.2	5.3	0.07	0.25	85	14	0	1	0	0	0	65	22	1	0	9	3	0	0	0	0	0	0
0.15	0.07	0.031	5.5	5.6	0.08	0.26	76	22	0	1	0	0	0	63	24	1	0	9	3	0	0	0	0	0	0
0.16	0.08	0.037	5.8	5.9	0.08	0.28	68	30	0	1	1	0	0	60	26	2	0	8	4	0	0	0	0	0	0
0.17	0.09	0.044	6	6.1	0.09	0.3	59	38	0	2	1	0	0	58	28	2	0	8	4	0	0	0	0	0	0
0.18	0.09	0.052	6.4	6.5	0.09	0.31	49	47	0	2	2	0	0	57	28	3	0	8	4	0	0	0	0	0	0
0.19	0.1	0.06	6.7	6.9	0.09	0.32	42	54	0	2	2	0	0	55	29	3	0	8	4	0	0	0	0	0	0
0.2	0.1	0.068	7.2	7.4	0.1	0.34	41	55	0	2	3	0	0	54	30	4	0	7	4	1	0	0	0	0	0
0.21	0.1	0.077	7.8	8	0.1	0.34	41	54	0	2	3	0	0	53	31	4	0	7	4	1	0	0	0	0	0
0.22	0.11	0.088	8.1	8.3	0.1	0.35	39	55	0	2	3	0	0	52	31	5	0	7	4	1	0	0	0	0	0

0.23	0.11	0.101	8.4	8.7	0.11	0.36	38	56	0	2	3	0	0	51	32	5	0	7	4	1	0	0	0	0	0
0.24	0.12	0.114	8.7	9.1	0.11	0.38	36	57	0	3	4	1	0	49	33	6	0	7	4	1	0	0	0	0	0
0.25	0.12	0.128	9.1	9.4	0.11	0.39	36	57	0	3	3	1	0	48	33	6	0	7	5	1	0	0	0	0	0
0.26	0.13	0.143	9.4	9.8	0.12	0.41	35	57	0	3	3	2	0	47	34	7	0	6	5	1	0	0	0	0	0
0.27	0.14	0.16	9.7	10.1	0.12	0.42	34	58	0	3	3	2	0	46	35	7	0	6	5	1	0	0	0	0	0
0.28	0.14	0.177	10	10.5	0.13	0.43	32	59	0	3	3	3	0	45	35	8	0	6	5	1	0	0	0	0	0
0.29	0.15	0.196	10.4	10.9	0.13	0.45	30	60	0	3	3	4	0	44	35	9	0	6	5	1	0	0	0	0	0
0.3	0.15	0.216	10.7	11.2	0.13	0.46	28	61	0	3	3	4	0	43	36	9	0	6	5	1	0	0	0	0	0
0.31	0.16	0.237	11	11.6	0.14	0.47	27	62	0	3	3	4	0	42	36	9	0	6	5	1	0	0	0	0	0
0.32	0.16	0.259	11.4	12	0.14	0.49	25	64	0	3	4	4	0	41	36	10	1	6	5	1	0	0	0	0	0
0.33	0.17	0.282	11.8	12.4	0.14	0.49	23	65	0	3	4	4	0	41	37	10	1	6	5	1	0	0	0	0	0
0.34	0.17	0.303	12.3	13.1	0.15	0.5	25	63	0	3	3	5	1	40	37	10	1	6	5	1	0	0	0	0	0
0.35	0.17	0.324	13.1	13.8	0.15	0.5	25	62	0	4	3	4	1	40	37	10	1	5	5	1	0	0	0	0	0
0.36	0.17	0.349	13.7	14.5	0.15	0.52	28	59	0	4	4	4	2	39	37	11	1	5	5	1	0	0	0	0	0
0.37	0.17	0.378	14.2	15.1	0.15	0.53	29	57	0	5	3	3	2	39	37	11	1	5	5	1	0	0	0	0	0
0.38	0.18	0.41	14.6	15.6	0.16	0.54	27	59	0	4	3	4	3	38	37	11	1	5	5	2	0	0	0	0	0
0.39	0.18	0.442	15.1	16.1	0.16	0.56	27	58	0	5	4	3	4	38	37	12	2	5	5	2	0	0	0	0	0
0.4	0.19	0.476	15.6	16.7	0.16	0.57	27	57	0	5	3	3	4	37	37	12	2	5	5	2	0	0	0	0	0
0.41	0.19	0.513	16.1	17.2	0.17	0.57	26	58	0	5	3	3	4	37	38	12	2	5	5	2	0	0	0	0	0
0.42	0.2	0.552	16.6	17.7	0.17	0.59	26	57	0	5	3	3	5	36	38	12	2	5	5	2	0	0	0	0	0
0.43	0.2	0.593	17.1	18.3	0.17	0.61	25	57	0	5	4	3	5	35	37	13	2	5	5	2	0	0	0	0	0
0.44	0.2	0.636	17.6	18.8	0.18	0.61	24	57	0	5	4	4	6	35	37	13	3	5	5	2	0	0	0	0	0
0.45	0.21	0.682	18.1	19.4	0.18	0.6	19	63	0	4	4	4	6	35	38	13	2	5	5	2	0	0	0	0	0
0.46	0.21	0.732	18.5	19.8	0.19	0.63	21	60	0	5	4	4	6	34	37	14	3	5	5	2	0	0	0	0	0
0.47	0.22	0.784	18.9	20.3	0.19	0.65	20	59	0	5	5	4	7	33	36	15	3	5	5	2	0	0	0	0	0
0.48	0.22	0.838	19.4	20.8	0.19	0.67	20	58	0	6	5	4	7	33	36	15	4	4	5	2	1	0	0	0	0
0.49	0.23	0.896	19.8	21.3	0.2	0.67	18	60	0	5	5	4	8	33	36	15	4	4	5	2	0	0	0	0	0
0.5	0.23	0.956	20.3	21.8	0.2	0.7	17	59	0	5	6	3	8	32	36	16	4	4	5	2	1	0	0	0	0
0.51	0.24	1.019	20.7	22.3	0.21	0.71	16	58	1	5	6	4	9	31	35	17	5	4	5	2	1	0	0	0	0
0.52	0.24	1.083	21.2	22.8	0.21	0.7	15	60	1	5	6	4	9	31	36	17	4	4	5	2	1	0	0	0	0
0.53	0.25	1.15	21.7	23.4	0.21	0.72	16	57	1	5	5	4	10	31	35	17	5	4	5	2	1	0	0	0	0
0.54	0.25	1.221	22.2	23.9	0.22	0.74	14	57	3	5	6	5	10	30	35	18	5	4	5	2	1	0	0	0	0
0.55	0.26	1.296	22.7	24.5	0.22	0.76	14	54	4	5	6	5	11	30	34	19	5	4	5	3	1	0	0	0	0
0.56	0.26	1.374	23.2	25	0.23	0.77	13	53	6	5	7	5	11	29	34	19	6	4	5	3	1	0	0	0	0
0.57	0.26	1.456	23.7	25.5	0.23	0.79	14	50	7	6	6	6	12	29	33	20	6	4	5	3	1	0	0	0	0
0.58	0.27	1.542	24.2	26	0.24	0.79	12	49	8	5	6	6	12	28	32	20	6	5	5	3	1	0	0	0	0
0.59	0.27	1.613	25.1	27	0.24	0.82	15	44	9	7	6	5	13	26	30	20	6	6	7	4	1	0	0	0	0
0.6	0.26	1.649	26.7	28.7	0.24	0.79	17	43	10	7	5	5	12	24	28	17	5	8	10	6	2	0	0	0	0

0.61	0.26	1.696	28.2	30.2	0.23	0.78	18	41	11	8	5	5	12	22	26	15	4	11	12	7	2	0	0	0	0
0.62	0.26	1.766	29.3	31.3	0.23	0.78	18	41	11	8	5	5	12	20	24	14	4	12	14	8	2	0	0	0	0
0.63	0.27	1.865	29.6	31.7	0.24	0.81	19	39	12	8	4	6	13	20	23	14	4	12	14	9	3	0	0	0	0
0.64	0.27	1.973	29.8	31.9	0.24	0.83	17	38	13	8	5	5	13	19	22	15	5	13	14	10	3	0	0	0	0
0.65	0.28	2.088	29.9	32	0.25	0.83	17	37	13	8	5	5	15	19	22	15	5	12	14	10	3	0	0	0	0
0.66	0.29	2.206	29.9	32.1	0.25	0.85	14	39	13	7	6	5	15	19	21	15	5	12	14	10	3	0	0	0	0
0.67	0.3	2.325	30	32.2	0.26	0.88	13	39	13	7	6	5	16	18	21	16	5	12	14	11	4	0	0	0	0
0.68	0.31	2.447	30.1	32.2	0.26	0.88	12	39	13	7	6	5	18	18	20	16	5	12	14	11	4	0	0	0	0
0.69	0.32	2.572	30.1	32.3	0.27	0.9	9	40	14	5	7	6	18	17	20	16	5	12	14	11	4	0	0	0	0
0.7	0.33	2.698	30.2	32.4	0.27	0.9	6	43	15	3	8	6	20	17	20	16	5	12	14	12	4	0	0	0	0
0.71	0.34	2.827	30.3	32.5	0.28	0.92	3	43	16	2	10	6	20	16	20	17	5	12	14	12	4	0	0	0	0
0.72	0.35	2.958	30.3	32.6	0.28	0.92	2	44	16	1	10	5	22	16	20	17	5	11	14	12	4	0	0	0	0
0.73	0.36	3.091	30.4	32.7	0.28	0.94	2	43	16	1	10	6	23	15	20	17	5	11	14	13	4	0	0	0	0
0.74	0.37	3.227	30.5	32.8	0.29	0.95	1	42	17	0	10	7	24	15	19	18	6	11	14	13	4	0	0	0	0
0.75	0.38	3.364	30.5	32.9	0.29	0.96	1	42	16	0	10	7	24	15	19	18	6	11	14	14	4	0	0	0	0
0.76	0.39	3.504	30.6	33	0.3	0.98	1	39	17	1	10	6	26	14	18	18	6	11	14	14	5	0	0	0	0
0.77	0.39	3.645	30.7	33.1	0.3	0.98	1	38	18	1	8	7	27	14	19	18	6	10	15	14	5	0	0	0	0
0.78	0.4	3.789	30.7	33.2	0.31	0.99	1	37	19	1	7	8	28	13	18	18	6	10	14	14	5	0	0	0	0
0.79	0.41	3.934	30.8	33.3	0.31	1	0	37	19	0	7	8	29	13	18	18	6	10	14	15	5	0	0	0	0
0.8	0.42	4.082	30.9	33.4	0.31	1.03	1	35	18	1	7	7	31	13	18	19	7	10	14	15	5	0	0	0	0
0.81	0.43	4.232	30.9	33.5	0.32	1.04	1	34	19	1	6	8	31	12	17	19	7	10	14	15	5	0	0	0	0
0.82	0.44	4.387	31	33.5	0.32	1.05	1	32	20	1	4	10	32	12	17	19	7	10	14	16	6	0	0	0	0
0.83	0.45	4.545	31	33.6	0.33	1.05	1	31	20	1	3	10	33	12	17	19	7	10	14	16	6	0	0	0	0
0.84	0.46	4.707	31	33.6	0.33	1.06	1	30	21	1	1	11	34	12	17	19	7	9	14	16	6	0	0	0	0
0.85	0.47	4.871	31	33.6	0.33	1.08	1	28	21	1	1	11	36	11	17	20	7	9	14	16	6	0	0	0	0
0.86	0.48	5.036	31	33.6	0.34	1.1	1	28	21	1	2	11	36	11	16	20	8	9	13	16	6	0	0	0	0
0.87	0.49	5.204	31	33.7	0.34	1.1	0	28	22	0	2	11	38	11	16	20	8	9	13	16	6	0	0	0	0
0.88	0.5	5.373	31	33.7	0.35	1.11	0	26	23	0	2	9	40	11	16	20	8	9	13	16	7	0	0	0	0
0.89	0.51	5.544	31	33.7	0.35	1.13	0	24	23	1	2	8	42	10	16	20	8	9	13	17	7	0	0	0	0
0.9	0.52	5.717	31	33.7	0.35	1.13	0	24	24	0	2	5	45	10	16	20	8	8	13	17	7	0	0	0	0
0.91	0.53	5.891	31	33.7	0.36	1.13	0	23	25	0	1	4	47	10	16	20	8	8	13	17	7	0	0	0	0
0.92	0.54	6.068	31	33.8	0.36	1.15	0	22	24	1	1	3	49	10	16	20	9	8	13	17	7	0	0	0	0
0.93	0.55	6.246	31	33.8	0.37	1.16	0	20	25	1	1	2	50	10	15	20	9	8	13	17	8	0	0	0	0
0.94	0.56	6.425	31	33.8	0.37	1.16	0	20	26	0	0	2	52	10	16	20	9	8	13	17	8	0	0	0	0
0.95	0.57	6.607	31	33.8	0.37	1.18	0	19	26	0	0	2	52	9	15	20	10	8	13	17	8	0	0	0	0
0.96	0.58	6.79	31	33.8	0.38	1.2	0	18	26	1	0	2	53	9	15	20	10	8	12	17	8	0	0	0	0
0.97	0.59	6.974	31	33.9	0.38	1.2	0	16	27	1	0	2	53	9	15	20	10	8	12	17	9	0	0	0	0
0.98	0.6	7.16	31	33.9	0.39	1.2	0	16	28	0	0	2	54	9	15	20	10	8	12	17	9	0	0	0	0

0.99	0.61	7.348	31	33.9	0.39	1.21	0	15	28	0	0	2	55	9	15	20	11	7	12	17	9	0	0	0	0
1	0.62	7.537	31.1	33.9	0.39	1.22	0	14	28	1	0	1	55	9	14	20	11	7	12	17	9	0	0	0	0
1.01	0.63	7.728	31.1	33.9	0.4	1.23	0	14	28	1	0	1	56	9	14	20	11	7	12	17	9	0	0	0	0
1.02	0.64	7.92	31.1	34	0.4	1.23	0	13	29	0	0	1	57	9	14	20	11	7	12	17	9	0	0	0	0
1.03	0.65	8.114	31.1	34	0.4	1.24	0	13	29	0	0	1	58	8	14	20	11	7	12	17	9	0	0	0	0
1.04	0.66	8.309	31.1	34	0.41	1.26	0	12	29	1	0	1	58	8	14	20	12	7	12	17	10	0	0	0	0
1.05	0.67	8.506	31.1	34	0.41	1.27	0	11	29	1	0	0	58	8	14	20	12	7	11	17	10	0	0	0	0
1.06	0.68	8.704	31.1	34	0.41	1.27	0	10	30	0	0	0	59	8	14	20	12	7	12	17	10	0	0	0	0
1.07	0.69	8.903	31.1	34.1	0.42	1.28	0	10	30	0	0	0	60	8	14	20	13	7	11	17	10	0	0	0	0
1.08	0.7	9.104	31.1	34.1	0.42	1.3	0	9	30	1	0	0	60	8	13	20	13	7	11	17	11	0	0	0	0
1.09	0.71	9.306	31.1	34.1	0.42	1.3	0	8	31	1	0	0	60	8	13	20	13	7	11	17	11	0	0	0	0
1.1	0.72	9.509	31.1	34.1	0.43	1.3	0	7	32	0	0	0	61	8	13	21	13	6	11	17	11	0	0	0	0
1.11	0.73	9.714	31.1	34.2	0.43	1.31	0	6	32	0	0	0	62	8	13	20	13	6	11	17	11	0	0	0	0
1.12	0.74	9.92	31.1	34.2	0.43	1.33	0	4	33	1	0	0	62	8	13	20	14	6	11	17	11	0	0	0	0
1.13	0.75	10.127	31.1	34.2	0.44	1.33	0	3	34	1	0	0	62	8	13	20	14	6	11	17	11	0	0	0	0
1.14	0.76	10.336	31.1	34.2	0.44	1.33	0	3	35	0	0	0	62	8	13	20	14	6	11	17	11	0	0	0	0
1.15	0.77	10.545	31.1	34.2	0.44	1.33	0	2	35	0	0	0	63	7	13	20	14	6	11	17	12	0	0	0	0
1.16	0.78	10.756	31.1	34.3	0.44	1.35	0	2	35	1	0	0	63	7	13	20	14	6	11	17	12	0	0	0	0
1.17	0.79	10.968	31.1	34.3	0.45	1.36	0	1	35	1	0	0	63	7	13	20	14	6	11	17	12	0	0	0	0
1.18	0.8	11.181	31.1	34.3	0.45	1.35	0	1	35	0	0	0	64	7	13	20	15	6	11	17	12	0	0	0	0
1.19	0.81	11.396	31.1	34.3	0.45	1.36	0	1	35	0	0	0	64	7	12	20	15	6	10	17	12	0	0	0	0
1.2	0.82	11.611	31.1	34.3	0.46	1.38	0	1	35	1	0	0	64	7	12	19	15	6	10	16	13	0	0	0	0
1.21	0.83	11.828	31.2	34.4	0.46	1.38	0	1	35	0	0	0	64	7	12	19	15	6	10	16	13	0	0	0	0
1.22	0.84	12.045	31.2	34.4	0.46	1.39	0	1	35	0	0	0	65	7	12	19	16	6	10	16	13	0	0	0	0
1.23	0.85	12.264	31.2	34.4	0.47	1.41	0	1	34	1	0	0	64	7	12	19	16	6	10	16	14	0	0	0	0
1.24	0.86	12.484	31.2	34.4	0.47	1.42	0	1	34	1	0	0	65	7	12	19	16	6	10	16	14	0	0	0	0
1.25	0.87	12.705	31.2	34.4	0.47	1.41	0	0	34	0	0	0	65	7	12	19	16	6	10	16	14	0	0	0	0
1.26	0.88	12.927	31.2	34.5	0.47	1.42	0	0	34	0	0	0	66	7	12	19	17	6	10	16	14	0	0	0	0
1.27	0.89	13.149	31.2	34.5	0.48	1.44	0	0	33	1	0	0	65	7	12	19	17	6	10	16	14	0	0	0	0
1.28	0.9	13.373	31.2	34.5	0.48	1.45	0	0	33	1	0	0	66	7	12	19	17	6	10	16	15	0	0	0	0
1.29	0.91	13.598	31.2	34.5	0.48	1.43	0	0	34	0	0	0	66	7	12	19	17	6	10	16	14	0	0	0	0
1.3	0.92	13.824	31.2	34.5	0.48	1.44	0	0	34	0	0	0	66	7	12	19	17	6	10	16	15	0	0	0	0
1.31	0.93	14.05	31.2	34.6	0.49	1.45	0	0	33	1	0	0	66	6	12	18	18	5	10	16	15	0	0	0	0
1.32	0.93	14.278	31.2	34.6	0.49	1.46	0	0	33	1	0	0	66	6	12	18	18	5	10	16	15	0	0	0	0
1.33	0.94	14.506	31.2	34.6	0.49	1.45	0	0	33	0	0	0	67	6	12	18	18	5	10	16	15	0	0	0	0
1.34	0.95	14.736	31.2	34.6	0.49	1.46	0	0	33	0	0	0	67	6	12	18	18	5	10	16	15	0	0	0	0
1.35	0.96	14.966	31.2	34.6	0.5	1.48	0	0	32	1	0	0	67	6	11	18	18	5	10	15	16	0	0	0	0
1.36	0.97	15.197	31.2	34.7	0.5	1.48	0	0	32	1	0	0	67	6	11	18	18	5	10	15	16	0	0	0	0

1.37	0.98	15.429	31.2	34.7	0.5	1.47	0	0	32	0	0	0	68	6	11	18	18	5	10	15	16	0	0	0	0
1.38	0.99	15.662	31.2	34.7	0.5	1.48	0	0	32	0	0	0	68	6	11	18	18	5	10	15	16	0	0	0	0
1.39	1	15.895	31.2	34.7	0.51	1.5	0	0	32	1	0	0	67	6	11	18	19	5	9	15	16	0	0	0	0
1.4	1.01	16.129	31.2	34.7	0.51	1.51	0	0	31	1	0	0	68	6	11	18	19	5	9	15	16	0	0	0	0
1.41	1.02	16.364	31.2	34.8	0.51	1.5	0	0	32	0	0	0	68	6	11	18	19	5	9	15	16	0	0	0	0
1.42	1.03	16.6	31.2	34.8	0.51	1.5	0	0	32	0	0	0	68	6	11	18	19	5	9	15	16	0	0	0	0
1.43	1.04	16.837	31.3	34.8	0.52	1.52	0	0	31	1	0	0	68	6	11	17	20	5	9	15	17	0	0	0	0
1.44	1.05	17.074	31.3	34.8	0.52	1.53	0	0	31	1	0	0	68	6	11	17	20	5	9	15	17	0	0	0	0
1.45	1.06	17.312	31.3	34.9	0.52	1.53	0	0	31	0	0	0	69	6	11	17	20	5	9	15	17	0	0	0	0
1.46	1.07	17.55	31.3	34.9	0.52	1.53	0	0	31	0	0	0	69	6	11	17	20	5	9	15	17	0	0	0	0
1.47	1.08	17.789	31.3	34.9	0.53	1.55	0	0	30	1	0	0	69	6	11	17	20	5	9	15	17	0	0	0	0
1.48	1.09	18.029	31.3	34.9	0.53	1.56	0	0	30	1	0	0	69	6	11	17	20	5	9	15	18	0	0	0	0
1.49	1.1	18.27	31.3	34.9	0.53	1.55	0	0	31	0	0	0	69	6	11	17	20	5	9	15	17	0	0	0	0
1.5	1.11	18.511	31.3	35	0.53	1.55	0	0	30	0	0	0	70	6	11	17	20	5	9	15	18	0	0	0	0
1.51	1.12	18.753	31.3	35	0.53	1.57	0	0	30	1	0	0	69	6	11	17	21	5	9	15	18	0	0	0	0
1.52	1.13	18.995	31.3	35	0.54	1.56	0	0	30	0	0	0	70	6	11	17	21	5	9	15	18	0	0	0	0
1.53	1.14	19.238	31.3	35	0.54	1.57	0	0	30	0	0	0	70	6	10	17	21	5	9	15	18	0	0	0	0
1.54	1.15	19.482	31.3	35	0.54	1.59	0	0	29	1	0	0	70	6	10	17	21	5	9	14	18	0	0	0	0
1.55	1.16	19.726	31.3	35.1	0.54	1.6	0	0	29	1	0	0	70	6	10	16	21	5	9	14	18	0	0	0	0
1.56	1.17	19.97	31.3	35.1	0.54	1.58	0	0	30	0	0	0	70	6	10	17	21	5	9	14	18	0	0	0	0
1.57	1.18	20.215	31.3	35.1	0.55	1.59	0	0	30	0	0	0	70	6	10	17	21	5	9	14	18	0	0	0	0
1.58	1.19	20.461	31.3	35.1	0.55	1.61	0	0	29	1	0	0	70	5	10	16	21	5	9	14	19	0	0	0	0
1.59	1.2	20.707	31.3	35.1	0.55	1.61	0	0	29	1	0	0	70	5	10	16	22	5	9	14	19	0	0	0	0
1.6	1.21	20.954	31.3	35.2	0.55	1.6	0	0	29	0	0	0	71	5	10	16	21	5	9	14	19	0	0	0	0
1.61	1.22	21.201	31.3	35.2	0.55	1.6	0	0	29	0	0	0	71	5	10	16	22	5	9	14	19	0	0	0	0
1.62	1.23	21.448	31.3	35.2	0.56	1.63	0	0	29	1	0	0	70	5	10	16	22	5	9	14	19	0	0	0	0
1.63	1.24	21.696	31.3	35.2	0.56	1.62	0	0	28	1	0	0	71	5	10	16	22	5	9	14	19	0	0	0	0
1.64	1.25	21.944	31.4	35.2	0.56	1.61	0	0	29	0	0	0	71	5	10	16	22	5	9	14	19	0	0	0	0
1.65	1.26	22.193	31.4	35.3	0.56	1.62	0	0	29	0	0	0	71	5	10	16	22	5	9	14	19	0	0	0	0
1.66	1.27	22.442	31.4	35.3	0.56	1.64	0	0	28	1	0	0	71	5	10	16	22	5	9	14	19	0	0	0	0
1.67	1.28	22.691	31.4	35.3	0.57	1.65	0	0	28	1	0	0	71	5	10	16	22	5	9	14	20	0	0	0	0
1.68	1.29	22.941	31.4	35.3	0.57	1.64	0	0	28	0	0	0	72	5	10	16	22	5	9	14	19	0	0	0	0
1.69	1.3	23.191	31.4	35.3	0.57	1.64	0	0	28	0	0	0	72	5	10	16	22	5	9	14	20	0	0	0	0
1.7	1.31	23.442	31.4	35.4	0.57	1.66	0	0	28	1	0	0	71	5	10	16	23	5	9	14	20	0	0	0	0
1.71	1.32	23.692	31.4	35.4	0.57	1.67	0	0	28	1	0	0	71	5	10	16	23	5	9	14	20	0	0	0	0
1.72	1.33	23.943	31.4	35.4	0.57	1.66	0	0	28	0	0	0	72	5	10	16	23	5	9	14	20	0	0	0	0
1.73	1.34	24.195	31.4	35.4	0.58	1.66	0	0	28	0	0	0	72	5	10	16	23	5	9	14	20	0	0	0	0
1.74	1.35	24.446	31.4	35.4	0.58	1.69	0	0	27	1	0	0	72	5	10	15	23	4	8	14	20	0	0	0	0

1.75	1.36	24.698	31.4	35.5	0.58	1.69	0	0	27	1	0	0	72	5	10	15	23	4	8	14	20	0	0	0	0
1.76	1.37	24.95	31.4	35.5	0.58	1.68	0	0	28	0	0	0	72	5	10	15	23	4	8	14	20	0	0	0	0
1.77	1.38	25.202	31.4	35.5	0.58	1.68	0	0	28	0	0	0	72	5	10	15	23	4	8	14	20	0	0	0	0
1.78	1.39	25.455	31.4	35.5	0.58	1.7	0	0	27	1	0	0	72	5	9	15	23	4	8	13	21	0	0	0	0
1.79	1.4	25.708	31.4	35.6	0.59	1.71	0	0	27	1	0	0	72	5	9	15	23	4	8	13	21	0	0	0	0
1.8	1.41	25.96	31.4	35.6	0.59	1.69	0	0	27	0	0	0	73	5	9	15	23	4	8	13	21	0	0	0	0
1.81	1.42	26.213	31.4	35.6	0.59	1.7	0	0	27	0	0	0	73	5	9	15	23	4	8	13	21	0	0	0	0
1.82	1.43	26.467	31.4	35.6	0.59	1.72	0	0	27	1	0	0	72	5	9	15	24	4	8	13	21	0	0	0	0
1.83	1.44	26.72	31.4	35.6	0.59	1.7	0	0	27	0	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.84	1.45	26.973	31.4	35.7	0.59	1.7	0	0	27	0	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.85	1.46	27.227	31.4	35.7	0.59	1.72	0	0	27	1	0	0	72	5	9	15	24	4	8	13	21	0	0	0	0
1.86	1.47	27.481	31.5	35.7	0.6	1.72	0	0	27	1	0	0	72	5	9	15	24	4	8	13	21	0	0	0	0
1.87	1.48	27.734	31.5	35.7	0.6	1.71	0	0	27	0	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.88	1.48	27.988	31.5	35.7	0.6	1.71	0	0	27	0	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.89	1.49	28.242	31.5	35.8	0.6	1.73	0	0	26	1	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.9	1.5	28.496	31.5	35.8	0.6	1.73	0	0	26	1	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.91	1.51	28.75	31.5	35.8	0.6	1.72	0	0	27	0	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.92	1.52	29.004	31.5	35.8	0.6	1.72	0	0	27	0	0	0	73	5	9	15	24	4	8	13	21	0	0	0	0
1.93	1.53	29.257	31.5	35.8	0.61	1.74	0	0	26	1	0	0	73	5	9	15	24	4	8	13	22	0	0	0	0
1.94	1.54	29.511	31.5	35.9	0.61	1.75	0	0	26	1	0	0	73	5	9	15	24	4	8	13	22	0	0	0	0
1.95	1.55	29.765	31.5	35.9	0.61	1.74	0	0	26	0	0	0	74	5	9	15	24	4	8	13	21	0	0	0	0
1.96	1.56	30.019	31.5	35.9	0.61	1.74	0	0	26	0	0	0	74	5	9	15	24	4	8	13	22	0	0	0	0
1.97	1.57	30.273	31.5	35.9	0.61	1.76	0	0	26	1	0	0	73	5	9	15	25	4	8	13	22	0	0	0	0
1.98	1.58	30.526	31.5	35.9	0.61	1.77	0	0	26	1	0	0	73	5	9	14	25	4	8	13	22	0	0	0	0
1.99	1.59	30.78	31.5	36	0.61	1.75	0	0	26	0	0	0	74	5	9	15	24	4	8	13	22	0	0	0	0
2	1.6	31.033	31.5	36	0.61	1.76	0	0	26	0	0	0	74	5	9	15	25	4	8	13	22	0	0	0	0
2.01	1.61	31.287	31.5	36	0.62	1.78	0	0	26	1	0	0	73	5	9	14	25	4	8	13	22	0	0	0	0
2.02	1.62	31.54	31.5	36	0.62	1.78	0	0	26	1	0	0	73	5	9	14	25	4	8	13	22	0	0	0	0
2.03	1.63	31.793	31.5	36	0.62	1.77	0	0	26	0	0	0	74	5	9	14	25	4	8	13	22	0	0	0	0
2.04	1.64	32.046	31.5	36.1	0.62	1.77	0	0	26	0	0	0	74	5	9	14	25	4	8	13	22	0	0	0	0
2.05	1.65	32.299	31.5	36.1	0.62	1.79	0	0	26	1	0	0	73	5	9	14	25	4	8	13	22	0	0	0	0
2.06	1.66	32.551	31.5	36.1	0.62	1.8	0	0	25	1	0	0	74	5	9	14	25	4	8	13	22	0	0	0	0
2.07	1.67	32.803	31.6	36.1	0.62	1.78	0	0	26	0	0	0	74	5	9	14	25	4	8	13	22	0	0	0	0
2.08	1.68	33.055	31.6	36.1	0.62	1.79	0	0	26	0	0	0	74	5	9	14	25	4	8	13	22	0	0	0	0
2.09	1.69	33.307	31.6	36.2	0.62	1.81	0	0	25	1	0	0	74	5	9	14	25	4	8	12	23	0	0	0	0
2.1	1.7	33.559	31.6	36.2	0.63	1.81	0	0	25	1	0	0	74	5	9	14	25	4	8	12	23	0	0	0	0
2.11	1.71	33.81	31.6	36.2	0.63	1.8	0	0	26	0	0	0	74	5	9	14	25	4	8	13	22	0	0	0	0
2.12	1.72	34.061	31.6	36.2	0.63	1.8	0	0	26	0	0	0	74	5	9	14	25	4	8	12	22	0	0	0	0

2.13	1.73	34.312	31.6	36.3	0.63	1.82	0	0	25	1	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.14	1.74	34.563	31.6	36.3	0.63	1.81	0	0	26	0	0	0	74	5	9	14	25	4	8	12	23	0	0	0	0
2.15	1.75	34.813	31.6	36.3	0.63	1.81	0	0	26	0	0	0	74	5	9	14	25	4	8	12	23	0	0	0	0
2.16	1.76	35.063	31.6	36.3	0.63	1.83	0	0	25	1	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.17	1.77	35.312	31.6	36.3	0.63	1.83	0	0	25	1	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.18	1.78	35.561	31.6	36.4	0.63	1.82	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.19	1.79	35.81	31.6	36.4	0.63	1.82	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.2	1.8	36.058	31.6	36.4	0.63	1.84	0	0	25	1	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.21	1.81	36.306	31.6	36.4	0.64	1.84	0	0	25	1	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.22	1.82	36.554	31.6	36.4	0.64	1.83	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.23	1.83	36.801	31.6	36.5	0.64	1.83	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.24	1.84	37.047	31.6	36.5	0.64	1.85	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.25	1.85	37.294	31.6	36.5	0.64	1.85	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.26	1.86	37.539	31.6	36.5	0.64	1.83	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.27	1.87	37.784	31.6	36.5	0.64	1.83	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.28	1.87	38.029	31.7	36.6	0.64	1.85	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.29	1.88	38.273	31.7	36.6	0.64	1.85	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.3	1.89	38.517	31.7	36.6	0.64	1.84	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.31	1.9	38.76	31.7	36.6	0.64	1.83	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.32	1.91	39.002	31.7	36.6	0.64	1.85	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.33	1.92	39.244	31.7	36.7	0.64	1.86	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.34	1.93	39.486	31.7	36.7	0.64	1.84	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.35	1.94	39.726	31.7	36.7	0.65	1.84	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.36	1.95	39.966	31.7	36.7	0.65	1.86	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.37	1.96	40.206	31.7	36.7	0.65	1.86	0	0	25	0	0	0	74	5	9	14	26	4	8	12	23	0	0	0	0
2.38	1.97	40.444	31.7	36.8	0.65	1.85	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.39	1.98	40.683	31.7	36.8	0.65	1.85	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.4	1.99	40.92	31.7	36.8	0.65	1.87	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.41	2	41.157	31.7	36.8	0.65	1.87	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.42	2.01	41.393	31.7	36.8	0.65	1.86	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.43	2.02	41.628	31.7	36.9	0.65	1.88	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.44	2.03	41.862	31.7	36.9	0.65	1.88	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.45	2.04	42.096	31.7	36.9	0.65	1.87	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.46	2.05	42.329	31.7	36.9	0.65	1.87	0	0	25	0	0	0	75	5	9	14	26	4	8	12	23	0	0	0	0
2.47	2.06	42.561	31.7	37	0.65	1.89	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.48	2.07	42.792	31.7	37	0.65	1.89	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.49	2.08	43.023	31.7	37	0.65	1.87	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.5	2.09	43.252	31.8	37	0.65	1.87	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0

2.51	2.1	43.481	31.8	37	0.65	1.89	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.52	2.11	43.709	31.8	37.1	0.65	1.9	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.53	2.12	43.936	31.8	37.1	0.65	1.88	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.54	2.13	44.162	31.8	37.1	0.65	1.88	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.55	2.14	44.387	31.8	37.1	0.65	1.9	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.56	2.15	44.611	31.8	37.1	0.65	1.91	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.57	2.16	44.834	31.8	37.2	0.65	1.89	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.58	2.17	45.056	31.8	37.2	0.65	1.89	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.59	2.18	45.277	31.8	37.2	0.65	1.92	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.6	2.19	45.498	31.8	37.2	0.65	1.92	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.61	2.19	45.717	31.8	37.2	0.65	1.9	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.62	2.2	45.935	31.8	37.3	0.65	1.9	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.63	2.21	46.152	31.8	37.3	0.66	1.92	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.64	2.22	46.368	31.8	37.3	0.66	1.92	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.65	2.23	46.583	31.8	37.3	0.66	1.9	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.66	2.24	46.797	31.8	37.3	0.66	1.9	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.67	2.25	47.009	31.8	37.4	0.66	1.92	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.68	2.26	47.221	31.8	37.4	0.66	1.92	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.69	2.27	47.431	31.8	37.4	0.66	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.7	2.28	47.64	31.8	37.4	0.66	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.71	2.29	47.848	31.9	37.4	0.66	1.93	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.72	2.3	48.054	31.9	37.5	0.66	1.93	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.73	2.31	48.26	31.9	37.5	0.66	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.74	2.32	48.464	31.9	37.5	0.66	1.93	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.75	2.33	48.667	31.9	37.5	0.66	1.93	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.76	2.34	48.869	31.9	37.5	0.66	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.77	2.35	49.069	31.9	37.6	0.66	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.78	2.36	49.268	31.9	37.6	0.65	1.93	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.79	2.37	49.465	31.9	37.6	0.65	1.93	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.8	2.38	49.661	31.9	37.6	0.65	1.92	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.81	2.39	49.856	31.9	37.7	0.65	1.92	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.82	2.4	50.05	31.9	37.7	0.65	1.94	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.83	2.41	50.242	31.9	37.7	0.65	1.93	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
2.84	2.42	50.432	31.9	37.7	0.65	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.85	2.43	50.621	31.9	37.7	0.65	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.86	2.44	50.809	31.9	37.8	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.87	2.45	50.995	31.9	37.8	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.88	2.46	51.179	31.9	37.8	0.65	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0

2.89	2.47	51.362	31.9	37.8	0.65	1.91	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
2.9	2.48	51.544	31.9	37.8	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.91	2.48	51.723	31.9	37.9	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.92	2.49	51.902	32	37.9	0.65	1.91	0	0	26	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.93	2.5	52.078	32	37.9	0.65	1.92	0	0	26	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.94	2.51	52.253	32	37.9	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.95	2.52	52.426	32	37.9	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.96	2.53	52.598	32	38	0.65	1.91	0	0	26	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.97	2.54	52.767	32	38	0.65	1.91	0	0	26	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.98	2.55	52.935	32	38	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
2.99	2.56	53.102	32	38	0.65	1.93	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
3	2.57	53.266	32	38	0.65	1.91	0	0	26	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
3.01	2.58	53.593	32	38.1	0.65	1.92	0	0	26	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
3.02	2.59	53.92	32	38.1	0.65	1.94	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
3.03	2.6	54.248	32	38.1	0.65	1.94	0	0	25	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
3.04	2.61	54.576	32	38.1	0.65	1.93	0	0	26	0	0	0	74	5	9	13	26	4	8	12	23	0	0	0	0
3.05	2.62	54.905	32	38.1	0.65	1.95	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
3.06	2.63	55.235	32	38.2	0.66	1.95	0	0	25	0	0	0	74	5	9	13	27	4	8	12	24	0	0	0	0
3.07	2.64	55.566	32	38.2	0.66	1.94	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
3.08	2.65	55.897	32	38.2	0.66	1.94	0	0	25	0	0	0	75	5	9	13	26	4	8	12	23	0	0	0	0
3.09	2.66	56.229	32	38.2	0.66	1.96	0	0	25	0	0	0	74	5	9	13	27	4	8	11	24	0	0	0	0
3.1	2.67	56.562	32	38.2	0.66	1.96	0	0	25	0	0	0	74	5	9	13	27	4	8	11	24	0	0	0	0
3.11	2.68	56.895	32	38.3	0.66	1.95	0	0	25	0	0	0	75	5	9	13	27	4	8	11	24	0	0	0	0
3.12	2.69	57.23	32	38.3	0.66	1.96	0	0	25	0	0	0	75	5	9	13	27	4	8	11	24	0	0	0	0
3.13	2.7	57.564	32	38.3	0.67	1.98	0	0	25	0	0	0	74	5	9	13	27	4	8	11	24	0	0	0	0
3.14	2.71	57.9	32.1	38.3	0.67	1.98	0	0	25	0	0	0	74	5	9	13	27	4	8	11	24	0	0	0	0
3.15	2.72	58.236	32.1	38.4	0.67	1.97	0	0	25	0	0	0	75	5	9	13	27	4	8	11	24	0	0	0	0
3.16	2.73	58.573	32.1	38.4	0.67	1.97	0	0	25	0	0	0	75	5	9	13	27	4	8	11	24	0	0	0	0
3.17	2.73	58.911	32.1	38.4	0.67	1.99	0	0	25	0	0	0	74	5	9	13	27	4	8	11	24	0	0	0	0
3.18	2.74	59.249	32.1	38.4	0.67	1.99	0	0	25	0	0	0	74	5	9	13	27	4	8	11	24	0	0	0	0
3.19	2.75	59.588	32.1	38.4	0.67	1.97	0	0	25	0	0	0	75	4	9	13	27	4	8	11	24	0	0	0	0
3.2	2.76	59.928	32.1	38.5	0.68	1.97	0	0	25	0	0	0	75	4	9	13	27	4	8	11	24	0	0	0	0
3.21	2.77	60.268	32.1	38.5	0.68	1.99	0	0	24	0	0	0	75	4	9	13	27	4	8	11	24	0	0	0	0
3.22	2.78	60.609	32.1	38.5	0.68	2	0	0	24	0	0	0	75	4	9	13	27	4	8	11	24	0	0	0	0
3.23	2.79	60.951	32.1	38.5	0.68	1.98	0	0	25	0	0	0	75	4	9	13	27	4	8	11	24	0	0	0	0
3.24	2.8	61.293	32.1	38.5	0.68	1.99	0	0	25	0	0	0	75	4	9	13	27	4	8	11	24	0	0	0	0
3.25	2.81	61.636	32.1	38.6	0.68	2.01	0	0	24	0	0	0	75	4	8	12	28	4	8	11	24	0	0	0	0
3.26	2.82	61.98	32.1	38.6	0.68	2.02	0	0	24	0	0	0	75	4	8	12	28	4	8	11	25	0	0	0	0

3.27	2.83	62.325	32.1	38.6	0.69	2	0	0	24	0	0	0	76	4	9	13	28	4	8	11	24	0	0	0	0
3.28	2.84	62.67	32.1	38.6	0.69	2	0	0	24	0	0	0	76	4	8	13	28	4	8	11	24	0	0	0	0
3.29	2.85	63.016	32.1	38.6	0.69	2.03	0	0	24	0	0	0	75	4	8	12	28	4	7	11	25	0	0	0	0
3.3	2.86	63.362	32.1	38.7	0.69	2.03	0	0	24	0	0	0	75	4	8	12	28	4	7	11	25	0	0	0	0
3.31	2.87	63.709	32.1	38.7	0.69	2.02	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.32	2.88	64.057	32.1	38.7	0.69	2.02	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.33	2.89	64.405	32.1	38.7	0.69	2.04	0	0	24	0	0	0	75	4	8	12	28	4	7	11	25	0	0	0	0
3.34	2.9	64.755	32.1	38.7	0.7	2.03	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.35	2.91	65.104	32.2	38.8	0.7	2.03	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.36	2.92	65.455	32.2	38.8	0.7	2.06	0	0	24	0	0	0	75	4	8	12	28	4	7	11	25	0	0	0	0
3.37	2.93	65.806	32.2	38.8	0.7	2.06	0	0	24	0	0	0	75	4	8	12	28	4	7	11	25	0	0	0	0
3.38	2.94	66.158	32.2	38.8	0.7	2.05	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.39	2.95	66.51	32.2	38.8	0.7	2.05	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.4	2.96	66.864	32.2	38.9	0.7	2.07	0	0	23	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.41	2.96	67.217	32.2	38.9	0.7	2.08	0	0	23	0	0	0	76	4	8	12	29	4	7	11	25	0	0	0	0
3.42	2.97	67.572	32.2	38.9	0.71	2.06	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.43	2.98	67.927	32.2	38.9	0.71	2.06	0	0	24	0	0	0	76	4	8	12	28	4	7	11	25	0	0	0	0
3.44	2.99	68.283	32.2	38.9	0.71	2.09	0	0	23	0	0	0	76	4	8	12	29	4	7	11	25	0	0	0	0
3.45	3	68.639	32.2	39	0.71	2.09	0	0	23	0	0	0	76	4	8	12	29	4	7	11	25	0	0	0	0

APPENDIX B

INVERTEBRATE ASSESSMENT

Table B1: SASS5 Datasheet for the Tsitsa River EWR site in T35L (26 August 2014)

SASS Version 5 Score Sheet

Version date: Sept 2005

Date (dd:mm:yr):	16/08/2014			(dd.ddddd)	**Biotopes Sampled (tick & rate)**	**Rating (1 - 5)**	**Time (min)**
RHP Site Code:		**Grid reference (dd mm ss.s) Lat:**	S	31.29407	Stones In Current (SIC)	4	2
Collector/Sampler:	J Tedder	**Long:**	E	29.99238	Stones Out Of Current (SOOC)	3	1
River:	Tsitsa	**Datum (WGS84/Cape):**	WGS84		Bedrock	4	1
Level 1 Ecoregion:	Eastern Coastal Belt (31.01)	**Altitude (m):**			Aquatic Veg	1	
Quaternary Catchment:	T35L	**Zonation:**			MargVeg In Current	1	
	Temp (°C): 15.6	**Routine or Project? (circle one)**	Flow:	low	MargVeg Out Of Current	1	
Site Description:	pH: 8.2	Project Name:	Clarity (cm):	88	Gravel	3	
Tsitsa Reserve Downstream of Falls, upstream of proposed hydro-power outflow	DO (mg/L): 11.5	Tsitsa Rapid III Reserve	Turbidity:	low	Sand	1	
	Cond (mS/m): 17.2		Colour:	Clear blue/green tinge	Mud	3	
	Riparian Disturbance:	Cattle and other livestock impacting marginal veg			Hand picking/Visual observation	Y	
	Instream Disturbance:						

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					**HEMIPTERA (Bugs)**						**DIPTERA (Flies)**					
COELENTERATA (Cnidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3	A			A	Corixidae* (Water boatmen)	3		A		A	Blepharoceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5	A		A	A
Oligochaeta (Earthworms)	1	1			1	Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2		A	A	A
Hirudinea (Leeches)	3					Naucoridae* (Creeping water bugs)	7	A	1	A	A	Culicidae* (Mosquitoes)	1		1		1
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midge)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3		1		1	Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3					Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8					Veliidae/M...veliidae* (Ripple bugs)	5		1		1	Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					**MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)**						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5			A	A
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				
Notonemouridae	14					**TRICHOPTERA (Caddisflies)**						Tabanidae (Horse flies)	5	1			1
Perlidae	12	A		1	A	Dipseudopsidae	10					Tipulidae (Crane flies)	5	A			A
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					**GASTROPODA (Snails)**					
Baetidae 1sp	4					Hydropsychidae 1 sp	4					Ancylidae (Limpets)	6	C		A	C
Baetidae 2 sp	6		B	B		Hydropsychidae 2 sp	6	B			B	Bulininae*	3				
Baetidae > 2 sp	12	B			C	Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Cainfles)	6	A		1	A	Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13	B		1	B	Psychomyiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9	B		A	B	**Cased caddis:**						Thiaridae* (=Melanidae)	3				
Oligoneuridae (Brushlegged mayflies)	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					**PELECYPODA (Bivalvles)**					
Prosopistomatidae (Water specs)	15	B			B	Glossosomatidae SWC	11					Corbiculidae (Clams)	5				
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9					Hydrosalpingidae SWC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					**SASS Score**					167
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6		A		A	**No. of Taxa**					27
Chlorocyphidae (Jewels)	10					Petrothrincidae SWC	11					**ASPT**					6.2
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					**Other biota:**					
Coenagrionidae (Sprites and blues)	4		A		A	Sericostomatidae SWC	13										
Lestidae (Emerald Damselflies/Spreadwings)	8					**COLEOPTERA (Beetles)**											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8	A			A						
Aeshnidae (Hawkers & Emperors)	8					Gyrinidae* (Whirligig beetles)	5	A			A	**Comments/Observations:**					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5										
Gomphidae (Clubtails)	6			A	A	Helodidae (Marsh beetles)	12										
Libellulidae (Darters/Skimmers)	4	B	A		B	Hydraenidae* (Minute moss beetles)	8										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Hydrophilidae* (Water scavenger beetles)	5										
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10										
						Psephenidae (Water Pennies)	10	1			1						

Procedure:

Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m ^{2}. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers

Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.

Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical

Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High

Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Table B2: Tsitsa River Flow Modification Metrics

FLOW MODIFICATION METRICS. **WITH REFERENCE TO VELOCITY PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?**	**RATING**	**RANKING OF METRICS**	**% Weight**
Presence of taxa with a preference for very fast flowing water	0.5	1	100
Abundance and/or frequency of occurrence of taxa with a preference for very fast flowing water			
Presence of taxa with a preference for moderately fast flowing water	0	2	90
Abundance and/or frequency of occurrence of taxa with a preference for moderately fast flowing water			
Presence of taxa with a preference for slow flowing water	0.5	3	70
Abundance and/or frequency of occurrence of taxa with a preference for slow flowing water			
Presence of taxa with a preference for standing water	0.5	4	60
Abundance and/or frequency of occurrence of taxa with a preference for standing water			
Overall % change in flow dependence of assemblage			7

Table B3: Tsitsa River Habitat Modification Metrics

HABITAT MODIFICATION METRICS. WITH REFERENCE TO INVERTEBRATE HABITAT PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	**RATING**	**RANKING OF METRICS**	**%WEIGHT**
Has the occurrence of invertebrates with a preference for bedrock/boulders changed relative to expected?	0	5	50
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for bedrock/boulders changed?			
Has the occurrence of invertebrates with a preference for loose cobbles changed relative to expected?	0.5	1	100
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for loose cobbles changed?			
Has the occurrence of invertebrates with a preference for vegetation changed relative to expected?	3	3	70
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for vegetation changed?			
Has the occurrence of invertebrates with a preference for sand, gravel or mud changed relative to expected?	0	2	90
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?			
Has the occurrence of invertebrates with a preference for the water column or water surface changed relative to expected?	0	4	60
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for the water column/water surface changed?			
Overall % change in flow dependence of assemblage			14

Table B4: Tsitsa River Water Quality Modification Metrics

WATER QUALITY METRICS. **WITH REFERENCE TO WATER QUALITY REQUIREMENTS, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?**	**RATING**	**RANKING OF METRICS**	**% WEIGHT**
Has the number of taxa with a high requirement for unmodified physico-chemical conditions changed?	0	4	70
Has the abundance and/or frequency of occurrence of the taxa with a high requirement for unmodified physico-chemical conditions changed?			
Has the number of taxa with a moderate requirement for unmodified physico-chemical conditions changed?	2	3	80
Has the abundance and/or frequency of occurrence of the taxa with a moderate requirement for modified physico-chemical conditions changed?			
Has the number of taxa with a low requirement for unmodified physico-chemical conditions changed?	0.5	5	60
Has the abundance and/or frequency of occurrence of the taxa with a low requirement for unmodified physico-chemical conditions changed?			
Has the number of taxa with a very low requirement for unmodified physico-chemical conditions changed?	0	6	50
Has the abundance and/or frequency of occurrence of the taxa with a very low requirement for unmodified physico-chemical conditions changed?			
How does the total SASS score differ from expected?	1	2	90
How does the total ASPT score differ from expected?	3	1	100
Overall change to indicators of modified water quality			26

APPENDIX C

GEOMORPHOLOGY ASSESSMENT

LaliniEWR Site Photos and particle size data

Figure C1: Pool-riffle sequence in confined valley (top left), embedded cobble in riffle (top right), high fine sediment concentration in riffle (bottom left) and silt drape smothering cobble habitat in pool (bottom left)

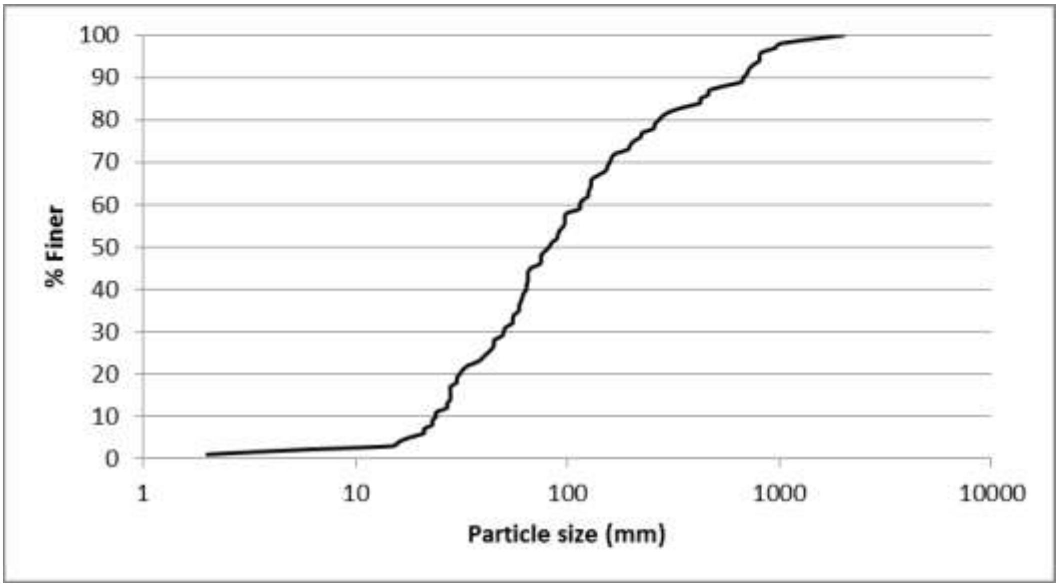

Figure C2: Particle size distribution along the hydraulic transect.

Table C1: GAI - Tsitsa River in T35L classification tab

RECORDER	B van der Waal	DATE (for field data)	26-Aug-14	
RIVER SYSTEM	Mzimvubu River	MAP REFERENCE	3128BD	
RIVER NAME	Tsitsa River	LATITUDE (S)	31.29408	
SITE NAME	LaliniEWR	LONGITUDE (E)	28.99246	
QUATERNARY CATCHMENT	T35L	SITE ALTITUDE (masl)	413 masl	
CATCHMENT AREA (km2)	4422	MAR (Mm3/a)	868.6	
FLOW REGIME	perrennial	perennial	intermittent	ephemeral

VALLEY CONFINEMENT	V shaped/Confined
CHANNEL PATTERN	Straight/wandering
REACH LENGTH (km)	14 km
REACH GRADIENT (m/m)	0.00666
RIVER ZONE	Rejuvinated foothills

STREAM DIMENSIONS	Range (m)		Range (m)
Channel width		Height of active channel bank	
- macro-channel width	80	- left bank	3
- active channel width	50	- right bank	3
- water surface width	30		

FLOW LEVEL	Low baseflow
FLOW CLARITY	Clear

channel type	**Mixed**
dominant sediment type	Boulder

Reach type
select one according to channel type
Pool-riffle

BANK SEDIMENT	LHB (tick)	RHB (tick)	BANK SLOPE	LHB (tick)	RHB (tick)
Sand /gravel	x	x	steep > 45o		
mixed e.g cobble in sandy matrix	x	x	moderate 20-45o	x	
silt/clay			gentle < 20o		x
weathered bedrock					
cohesive bedrock					

morphological ur

bedrock	tick
in-channel features	
waterfall	
rock steps	
rapid	
bedrock pool	
bedrock pavement	x
backwater	x
bedrock run	
bedrock bars	
bedrock island/ core bar	x

alluvial bars	
point bar	
lateral bar	x
mid-channel bar	
tributary bar	
lee bar	x
secondary channels	
islands (surface height = bankfull)	

alluvial	tick
in-channel features	
step	
rapid	
plane bed	
riffle	x
run	x
shallow pool	x
deep pool	x
flat' sand bed	
backwater	x

riparian	tick
inset bench (< bankfull)	
flood bench (= banlkull, narrow)	
floodplain (= bankfull, wide)	x
terrace (> bankfull)	

riparian vegetation

Morphol. Unit	Dominant Vegetation	Vegetation list
bars	Bare with the odd sedge	bare
inset bench	bare with some sedge	annual grass and forbes
flood bench	bare, perennial grass	perennial grass
floodplain	deep rooted with sparse grass	shallow rooted woody shrubs and trees
terrace		deep rooted woody shrubs and trees

geohabitat - fish and invertebrates

PREVALENCE OF IN-CHANNEL HABITATS

Indicate distribution as per scoring guidelines and dominant substrate

Scoring	widspread >49%	3	Frequent (10-49%	2	Infrequent (<10%	1
Substrate	sand/silt/mud	S	gravel	G	cobble/boulder	C
	pool	isolated pool	glide or run	broken water		
very shallow ("< ankle")						
shallow ("< knee")	2CBS		2CB			
deep	3CBS					

HABITAT COVER PREVALENCE

open interstitial spaces between coarse gravel or cobble	1	Scoring Guideline	
overhanging vegetation	0	Widespread (>49%)	3
marginal vegetation	1	Frequent (10-49%)	2
instream vegetation	1	Infrequent (<10%)	1
undercut banks	0		
snags (eg. woody debris)	1		

Table C2: GAI - Tsitsa River in T35L metrics tab

Connectivity						
COMPONENTS	rank	weighting	rating	flow related	confidence	Comment on reason for rating
HILLSLOPE-CHANNEL CONNECTIVITY	1	100	3	20	4	Highly altered in this catchment
LONGITUDINAL - UPSTREAM-DOWNSTREAM CONNECTIVITY	2	60	0.5	80	4	Altered due to increased runoff
LATERAL -CHANNEL-FLOOD ZONE CONNECTIVITY	3	50	0.5	80	3	Altered, but limited floodplain
VERTICAL CONNECTIVITY	4	30	1	0	3	limited change due to bedrock dominance
Sediment Supply						
COMPONENTS	rank	weighting	rating	flow-related	confidence	Comment on reason for rating
CHANGE IN HILLSLOPE EROSION (CATCHMENT)	1	100	3	30	4	Major change due to overgrazing and frequent burning
CHANGE IN BANK EROSION (REACH)	2	60	0	40	3	altered due to alien invasives
CHANGE IN CHANNEL SEDIMENT	3	0	0	0	4	Limited channel storage
Bed and bank stability						
CHANGES TO:	rank	weighting	rating	flow-related	confidence	**Comment on reason for rating**
BED & BAR STABILITY	1	70	1	20	4	Increased stability due to infilling with fines
BANK STABILITY	2	50	0.5	30	3	decreased in places due to grazing
FLOOD ZONE STABILITY	3	0	0.5	0	4	limited flood zone
Morphological change						
ASSESS HABITAT CHANGES TO:						
	rank	weighting	rating	flow-related	confidence	**Comment on reason for rating**
INSTREAM (BED, BARS)	1	100	2	30	4	large change due to increased sediment input
RIPARIAN (BANKS, FLOOD BENCHES, FLOODPLAIN, ISLANDS)	2	50	2	30	3	limited riparian and floodplain area due to confined channel

Table C3: GAI - Tsitsa River in T35L weights

DRIVER METRIC GROUP		
DRIVER RANKING & WEIGHTING	**Rank**	**Weighting**
SYSTEM CONNECTIVITY	1	100
SEDIMENT BALANCE	2	95
BED & BANK STABILITY	3	50
SYSTEM CONNECTIVITY	**Rank**	**Weighting**
HILLSLOPE-CHANNEL CONNECTIVITY	1	100
LONGITUDINAL - UPSTREAM-DOWNSTREAM CONNECTIVITY	2	60
LATERAL -CHANNEL-FLOOD ZONE CONNECTIVITY	3	50
VERTICAL CONNECTIVITY	4	30
SEDIMENT BALANCE	**Rank**	**Weighting**
HILLSLOPE EROSION (CATCHMENT)	1	100
BANK EROSION (REACH)	2	60
CHANNEL SEDIMENT	3	0
BED & BANK STABILITY	**Rank**	**Weighting**
BED & BAR STABILITY	1	70
BANK STABILITY	2	50
FLOOD ZONE STABILITY	3	0
CHANNEL MORPHOLOGY	**Rank**	**Weighting**
INSTREAM (BED, BARS)	1	100
RIPARIAN (BANKS, FLOOD BENCHES, FLOODPLAIN, ISLANDS)	2	50

Table C4: GAI - Tsitsa River in T35L final PES

FINAL DRIVER STATUS GEOMORPHOLOGY

This model (GAI level IV) is designed for specialist use by trained, experienced geomorphologists, for the purposes of determining the PES and geomorphic drivers of monitoring sites. Although the data/information driving this model will assist in Reserve studies, additional ESSENTIAL data are required for flow determinations.

SCORING GUIDELINES

GEOMORPHOLOGY DRIVERS

COMPONENTS	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.60	0.41	0.65	45.00	3.67
Sediment balance	2.00	95.00	1.88	0.39	0.73	33.75	3.63
Bed & bank stability	3.00	50.00	0.79	0.20	0.16	24.17	3.58
TOTALS		245.00		1.00	1.54		
System Driver status:							
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					69.13		
HABITAT DRIVER CATEGORY					**C**	36.39	3.63
					WEIGHED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					1.50	30.00	3.67
HABITAT CHANGE STATUS					70		
HABITAT CHANGE CATEGORY					**C**		

RIVER SYSTEM	River	Site	Quaternary	LAT	LONG	Date	Recorder	Reach gradient	Valley Form	Channel pattern	Reach type	PES score	PES class	Morphology score	Morphology class
Mzimvubu River	Tsitsa River	LaliniEWR	T35L	31.2941	28.99246	########	B van der Waal	0.00666	V shaped/ Confined	Straight/ wandering	Pool-riffle	69.13	C	70	C

APPENDIX D

RIPARIAN VEGETATION ASSESSMENT

Table D1: Description of the riparian vegetation present and reference states

Zones	Description of PRESENT STATE	Description of REFERENCE STATE
Marginal	Largely overgrazed. Scattered *Juncus sp., Cyprus sp, Senecio sp., Phragmites australis* and grasses clustered between boulder beds, bedrock and sand banks. Difference between present and reference states is the level of vegetation removal from overgrazing and trampling.	Mosaic of *Juncus sp., Cyprus sp, Senecio sp., Phragmites australis* and grasses clustered between boulder beds, bedrock and sand banks.
Non-marginal	Assemblage of opportunistic Eastern Valley Bushveld taxa and other generalists. Difference between present and reference states is the level of vegetation removal from overgrazing, trampling and sediment deposition.	Assemblage of opportunistic Eastern Valley Bushveld taxa and other generalists. Dense woody vegetation with grass basal cover.

Table D2: Changes in marginal zone vegetation

	MODIFICATION RATINGS					
CAUSES OF MODIFICATION	**INTENSITY**	**EXTENT**	**CONFIDENCE**			
REMOVAL	2.0	4.0	3.0			
EXOTIC INVASION	0.5		3.0			
WATER QUANTITY	1.0	1.0	3.0			
WATER QUALITY	1.0	1.0	3.0			
AVERAGE			3.0			
		RESPONSE METRIC RATINGS				
VEGETATION COMPONENTS	**RESPONSE METRIC**	**CONSIDER? (Y/N)**	**RATING**	**CONFIDENCE**		
WOODY	COVER	Y	0.5	2.0		
	ABUNDANCE	Y	0.5	2.0		
	SPECIES COMPOSITION	Y	0.5	2.0		
			0.5	2.0		
NON-WOODY	COVER	Y	3.0	2.0		
	ABUNDANCE	Y	3.0	2.0		
	SPECIES COMPOSITION	Y	0.0	2.0		
			2.0	1.3		
VEGETATION COMPONENTS	**CONSIDER? (Y/N)**	**RANK**	**WEIGHT**	**RATING**	**WEIGHTED RATING**	**MEAN CONFIDENCE**
WOODY	Y	2.0	20.0	0.5	0.10	2.0
NON-WOODY	Y	1.0	100.0	2.0	2.00	1.3
CHANGE (%) IN MARGINAL ZONE CONDITION	**35.0**				2.10	1.7

Table D3: Summary of changes in marginal zone vegetation

	MODIFICATION RATINGS					
CAUSES OF MODIFICATION	**INTENSITY**	**EXTENT**	**CONFIDENCE**			
REMOVAL	3.0	4.0	3.0			
EXOTIC INVASION	0.5		3.0			
WATER QUANTITY	1.0	1.0	3.0			
WATER QUALITY	1.0	1.0	3.0			
AVERAGE			3.0			
		RESPONSE METRIC RATINGS				
VEGETATION COMPONENTS	**RESPONSE METRIC**	**CONSIDER? (Y/N)**	**RATING**	**CONFIDENCE**		
WOODY	COVER	Y	1.5	2.0		
	ABUNDANCE	Y	2.0	2.0		
	SPECIES COMPOSITION	Y	0.5	2.0		
			1.3	2.0		
NON-WOODY	COVER	Y	3.5	2.0		
	ABUNDANCE	Y	3.5	2.0		
	SPECIES COMPOSITION	Y	0.0	2.0		
			2.3	1.3		
VEGETATION COMPONENTS	**CONSIDER? (Y/N)**	**RANK**	**WEIGHT**	**RATING**	**WEIGHTED RATING**	**MEAN CONFIDENCE**
WOODY	Y	1.0	100.0	1.3	1.33	2.0
NON-WOODY	Y	2.0	60.0	2.3	1.40	1.3
CHANGE (%) IN MARGINAL ZONE CONDITION	**34.2**				2.73	1.7

Table D4: Summary of changes in non-marginal zone vegetation

LEVEL 3 ASSESSMENT						
METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**% WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	65.0	18.6	1.7	2.0	40.0	Marginal zone naturally limited because of bedrock and boulder habitat.
NON MARGINAL	65.8	47.0	1.7	1.0	100.0	Non-marginal zone in the steep gorge acts as a critical buffer for instream ecological processes and functioning.
	2.0				140.0	
LEVEL 3 VEGRAI (%)				65.6		
VEGRAI EC				**C**		
AVERAGE CONFIDENCE				1.7		

APPENDIX E

FISH ASSESSMENT

Table E1: Automated and Adjusted FRAI percentage and ecological categories

AUTOMATED	
FRAI (%)	90.5
EC: FRAI	A/B
ADJUSTED	
FRAI (%)	86.3
EC: FRAI	B

Table E2: FRAI metric group weightings for t Tsitsa River

WEIGHT OF METRIC GROUPS	
METRIC GROUP	WEIGHT (%)
VELOCITY-DEPTH	66.13
COVER	100.00
FLOW MODIFICATION	80.65
PHYSICO-CHEMICAL	87.10
MIGRATION	80.65
IMPACT OF INTRODUCED EXOTIC SPECIES	72.58

Table E3: FRAI reference frequency of occurrence and observed species lists

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	PES:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE
AMAR	*Anguilla marmorata* (Quoy & Gaimard 1824)	4	2
AMOS	*Anguilla mossambica* (Peters 1852)	5	5
BANO	*Barbus anoplus* (Weber, 1897)	5	5

APPENDIX F

DESKTOP RESERVE MODEL RESULTS

Table F1: Summary of EWR estimates – Tsitsa River in T35L

Desktop Version 2, Printed on 9/1/2014
Summary of IFR estimate for: LaliniEWR in T35L
Determination based on defined BBM Table with site specific assurance rules.

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

MAR	=	868.632*
S.Dev.	=	373.467
CV	=	0.430
Q75	=	15.500
Q75/MMF	=	0.214
BFI Index	=	0.363
CV(JJA+JFM) Index	=	2.070

ERC = B/C

Total IFR	=	287.053 (33.05 %MAR)
Maint. Lowflow	=	136.868 (15.76 %MAR)
Drought Lowflow	=	52.012 (5.99 %MAR)
Maint. Highflow	=	150.186 (17.29 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : T Region

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	17.799	17.573	0.369	3.241	1.173	3.431	6.672
Nov	31.442	29.390	0.361	4.266	1.527	3.545	7.811
Dec	37.623	34.365	0.341	4.847	1.726	4.669	9.516
Jan	45.150	36.884	0.305	5.686	2.014	7.923	13.609
Feb	59.565	44.008	0.305	7.375	2.601	19.480	26.855
Mar	57.986	41.517	0.267	7.480	2.631	15.677	23.157
Apr	32.103	26.842	0.323	6.420	2.268	0.000	6.420
May	12.452	11.680	0.350	4.294	1.535	0.000	4.294
Jun	9.457	11.673	0.476	2.471	1.241	0.000	2.471
Jul	9.284	14.229	0.572	2.162	1.091	0.000	2.162
Aug	8.687	10.165	0.437	2.006	1.017	0.000	2.006
Sep	11.244	16.296	0.559	2.057	1.043	3.458	5.515

* Natural MAR at EWR site based on updated hydrology from Jeffares and Green, 2013 for period 1920-2009

Table F2: Summary of EWR rules – Tsitsa River in T35L

Desktop Version 2, Printed on 9/1/2014
Summary of IFR rule curves for : LaliniEWR in T35L
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : T Region

ERC = B/C

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

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	9.183	9.069	8.806	8.279	7.367	6.036	4.445	2.956	1.950	1.564
Nov	10.881	10.756	10.464	9.865	8.813	7.257	5.375	3.601	2.398	1.938
Dec	13.531	13.415	13.157	12.630	11.663	10.089	7.893	5.387	3.256	1.908
Jan	25.489	22.809	20.505	18.362	14.538	12.620	9.913	6.797	4.133	2.894
Feb	52.337	45.804	40.283	35.326	26.538	22.885	17.785	11.966	7.017	4.714
Mar	46.425	39.947	34.537	29.623	21.661	17.739	12.999	8.531	5.499	4.341
Apr	9.694	9.583	9.329	8.818	7.935	6.646	5.104	3.663	2.688	2.315
May	6.484	6.410	6.241	5.900	5.312	4.452	3.425	2.465	1.815	1.566
Jun	3.633	3.585	3.471	3.248	2.887	2.415	1.928	1.546	1.329	1.256
Jul	3.176	3.131	3.027	2.827	2.508	2.098	1.679	1.352	1.167	1.104
Aug	2.949	2.910	2.819	2.638	2.347	1.965	1.572	1.263	1.088	1.029
Sep	7.432	7.342	7.135	6.719	6.000	4.776	3.697	2.524	1.731	1.427

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.894	4.839	4.711	4.455	4.013	3.367	2.594	1.872	1.384	1.196
Nov	6.446	6.378	6.218	5.891	5.316	4.465	3.436	2.467	1.809	1.558
Dec	7.570	7.510	7.376	7.105	6.606	5.796	4.664	3.372	2.274	1.763
Jan	8.884	8.818	8.669	8.362	7.789	6.845	5.512	3.978	2.667	2.057
Feb	11.517	11.426	11.223	10.809	10.048	8.811	7.084	5.113	3.437	2.657
Mar	11.302	11.182	10.900	10.323	9.310	7.810	5.997	4.288	3.128	2.685
Apr	9.694	9.583	9.329	8.818	7.935	6.646	5.104	3.663	2.688	2.315
May	6.484	6.410	6.241	5.900	5.312	4.452	3.425	2.465	1.815	1.566
Jun	3.633	3.585	3.471	3.248	2.887	2.415	1.928	1.546	1.329	1.256
Jul	3.176	3.131	3.027	2.827	2.508	2.098	1.679	1.352	1.167	1.104
Aug	2.949	2.910	2.819	2.638	2.347	1.965	1.572	1.263	1.088	1.029
Sep	3.109	3.078	3.007	2.865	2.619	2.261	1.832	1.431	1.160	1.056

Natural Duration curves*

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	42.940	27.852	18.440	13.978	11.119	9.517	7.631	5.626	3.756	2.867
Nov	77.199	47.346	38.345	28.395	21.914	16.366	13.214	10.382	6.779	4.039
Dec	90.621	66.484	46.834	31.948	22.887	19.071	16.319	10.861	7.770	1.908
Jan	98.973	65.614	56.750	45.027	34.061	25.448	23.409	15.696	10.928	3.274
Feb	123.888	95.428	76.244	60.756	48.322	39.534	27.629	19.519	16.390	7.176
Mar	117.671	80.205	70.210	59.995	53.360	37.287	29.547	24.309	15.110	7.953
Apr	57.103	46.096	39.518	34.552	28.248	18.403	14.506	10.899	8.160	3.048
May	25.889	18.074	13.068	10.349	8.770	7.064	5.966	4.880	4.051	3.323
Jun	19.290	12.670	8.430	6.894	5.235	4.877	4.078	3.715	3.140	2.473
Jul	17.846	10.286	8.158	5.720	4.760	4.331	3.887	3.327	2.987	2.143
Aug	22.861	10.977	7.445	6.160	5.137	4.197	3.749	3.047	2.655	2.449
Sep	28.345	14.703	9.360	7.897	6.088	4.776	3.920	3.376	2.647	2.029

* Natural MAR at EWR site based on updated hydrology from Jeffares and Green, 2013 for period 1920-2009

APPENDIX G

REPORT BY DR NEELS KLEYNHANS, DWS

PRELIMINARY DETERMINATION OF THE INSTREAM FLOW REQUIREMENTS OF THE TSITSA RIVER AT THE LALINI HYDROPOWER RETURN FLOW

CJ Kleynhans
DWS
RQIS
September 2014

SUMMARY

The instream flow requirements of the Tsitsa River at the Lalini Hydropower return flow point were determined based on macro-invertebrate and fish habitat ecological requirements.

Flow requirements were determined using the Fish Invertebrate Flow Habitat Assessment (FIFHA) method.

The FIFHA is a modification of the Fish Flow Habitat Assessment (FFHA) that was previously used in several instream flow requirement determinations that used the Habitat Flow Stressor Response (HFSR) method for Ecological Water Requirements. FIFHA was developed as an MS Excel model.

The FIFHA is involves the following principles:

Hydrology:

Although natural daily flows are ideal, hydrology is usually only available for natural monthly hydrology (as Flow Duration Curves or Tables: FDC, or FDT). This is required at a particular site as the basis of the determination.

The maximum natural baseflow for respectively the wettest and driest month are considered as the flows that provide maximum habitat conditions for that site under natural conditions for both fish and macro-invertebrates. Clearly the geomorphic state (i.e. natural or modified) of the river will potentially influence the habitat template even if the flow regimes are still natural. However, it is assumed that the PES would be reasonable indication of, *inter alia*, the geomorphic condition of the river.

The determination of the maximum natural baseflow based on monthly flows is problematic and often only a crude determination can be done by assessing the shape of the FDC per month. Flood separation can be done by using several of the more objective approaches such as provided in SPATSIM.

Flood separation represents a particular problem when estimating baseflows for the wettest month as the monthly flows do not provide any information on spells when a particular discharge may occur continuously for a period, i.e. the time series information is “lost” in the summary of data in the flow duration curve.

FIFHA is usually based on baseflows and high flows (floods etc.) are usually not directly considered in the FIFHA. However, in the case of the Lalini site, high flows were included as hydropower generation will also include the regulation of high flows. February is considered to be the wettest month on average.

Although floods are on average not common in the driest month of the year (August in this case), high flows were included due to the likely influence of hydropower on such flows.

Hydraulics and Fish and Macro-invertebrate Habitat

Hydraulic parameters obtained and modelled using survey data from a particular site (preferably a “critical” site that may be representative of the river reach to some degree) form the basis of the interpretation of the fish and macro-invertebrate habitat.

The hydraulics software program, HABFLO is used to convert hydraulic data into a limited number of fish and macro-invertebrate habitat features and is used to model habitat responses at a range of different discharges. This enables the interpretation of instream habitat suitability for particular fish spp. and macro-invertebrate taxa and at the maximum natural baseflow in particular. In the case the Lalini, the flows occurring at the 0.1% percentile of the FDT were also included in the assessment due to the hydropower generation planned for the river.

The following Velocity-Depth and Velocity-Substrate classes are distinguished and modelled as a % of the width and wetted perimeter of the cross section(s) at the surveyed site by using HABFLO:

Fish Velocity-Depth (VD) classes

Fast: > 0.3 m/sec
Slow: <=0.3 m/sec

SVS: slow very shallow (<=0.1 m deep)
SS: slow shallow (>0.1 m, <=0.5 m deep)
SD: slow deep (>0.5 m deep)

FVS: fast very shallow (<=0.1 m deep)
FS: fast shallow (>0.1 m, <=0.2 m deep)
FI: fast intermediate (>0.2 m, <=0.3 m deep)
FD: fast deep (>0.3 m deep)

Macro-invertebrate Velocity-Substrate (VS) classes (Thirion pers. com. 2014)

Substrate:
Fine: Gravel, sand, mud, fines
Coarse: Cobbles, bedrock, boulders

Velocity:

Very slow: <=0.1 m/sec
Slow: >0.1-0.3 m/sec
Fast: >0.3 - 0.6 m/sec
Very fast: > 0.6 m/sec

VSCS: very slow, coarse substrate
SCS: slow, coarse substrate
FCS: fast, coarse substrate
VFCS: very fast, coarse substrate
VSFS: very slow, fine substrate
SFS: slow, fine substrate
FFS: fast, fine substrate

VFFS: very fast, fine substrate
INVEG: instream vegetation

HABFLO is based on the prediction of VD or VS classes in flowing water with riffles, runs and rapids with a predominantly coarse (cobbles, rocks boulders, etc.) substrate. Consequently it is not suitable for application in pools and it is not clear if it can be used in where soft substrates (sand, gravel etc.) occur.

These broad habitat attributes are used to assess the habitat suitability for various spp. or taxa that are present at the site or can be expected to occur there during particular life-stages. Suitability of these habitats is evaluated in terms of particular life-history requirements (e.g. spawning, breeding, feeding, requirements of certain life-history stages, etc.). It follows that the wet and dry season will imply different flow requirements for different life-history stages.

The abundance of VD and VS classes at various discharges are provided as a percentage of the wetted perimeter (or wetted width) in HABFLO. These percentages are used to calculate the amount of each VD or VS class in meter based on the stream width at the particular discharge in FIFHA. This provides a size dimension to each VD and VS class.

Habitat suitability for a spp. or taxon is rated according to the following categories related to the preference of spp & taxa:

Low (L), weight=0.25
Moderate (M), weight=0.5
High (H), weight =0.75
Very High (VH), weight =1.0

Where a VD or VS class are not relevant for the requirements of spp. or taxon, no rating is provided.

These ratings are based on the best available information or expert knowledge. Habitat suitability ratings can be based on a combination of the requirements of spp. or taxa at a site, i.e. the highest requirement for any of the VD or VS classes can be attributed to different spp. or taxa. If a particular phase in the life-cycle is of concern, this can be rated separately, e.g. where fish would require specific flow conditions to spawn.

Where VD or VS classes vary in their importance to a spp/taxon, the various classes would be rated and weighed as indicated above. If there is uncertainty regarding the suitability of a VD or VS class for a spp/taxon, all classes considered suitable can be awarded a rating of VH which would indicate that they all have an equal weight.

In the case of the Lalini site, after running several combinations of VD and VS classes for the various scenarios and for the spp. and taxa relevant for the Tsitsa River, it was decided that all the VD and VS should be included and at equal weights (i.e., VH).

<u>Fish Species and Macro-invertebrate SASS Taxa present at the Lalini Site</u>

Based on the PESEIS and recent surveys, the only indigenous fish spp. in the Tsitsa River are:

Barbus anoplus
and
Anguilla mossabica

Macro-invertebrate taxa sampled at the site and considered reasonable indicators of SV classes at the site are:

Perlidae
Heptageniidae
Leptophlebiidae and
Tipulidae

Due to the requirements of particular spp. and taxa it can happen that a reduction in flow (e.g. less than the natural) may cause in increase in the habitat for certain spp. or taxa (i.e. there will be a shift in VD and VS classes abundances as discharge change).

However, as indicated above, it was decided to assess flow modification impacts for both fish and macro-invertebrates based on the presence and extent of all VD and VS classes as compared against the natural occurrence of these at flow occurrence percentiles of:
0.10%
1.00%
5.00%
10.00%
15.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
80.00%
85.00%
90.00%
95.00%
99.00%
99.90%

Habitat suitability at various discharges is then compared with the habitat suitability at the maximum natural flow and the habitat suitability is expressed as a percentage of the suitability at this maximum baseflow. Habitat suitability (as a percentage of the baseflow reference) is expressed according to the Integrity categories as is used in the IHI and Ecoclassification-Ecostatus process of DWS (i.e. categories A, B, C, D, E, F).

These predictions are computed in FIFHA and follows a linear interpolation procedure (www.srs1software.com/DataCurveFitCreator.aspx), as well a multiple goal seek procedure (www.Add-Ins.com)

Flows and Flow scenarios

The natural flow regime and the present day flow regime were also provided. The present day flow is largely natural. However, measured flows indicate periods of no-flow conditions.

The following flow scenarios were provided and suggested for evaluation:

1. Category B/C flows (based on the combination of instream and riparian Ecostatus) and category B flows based on the instream Ecostatus for this river reach. These flows were derived from the SPATSIM model and provided by Ms R. Stassen. It must be emphasised that this B/C and B flow scenarios only takes into account associations based on previously determined flow-ecological category relationships, i.e. no direct ecological response of flow-habitat conditions are considered (Table 1, Dry season (August) & Table 2, Wet season (February)). Both these Tables also provide the Present day flows per percentile for the respective months.

2. The following scenarios based on various possible operational settings were provided:

   - Sc1: 1.5 MAR Ntabelanga Dam with full EWR. 0.15 MAR Lalini Dam with full EWR, hydropower discharges after EWR site. (Tables 3 & 4).

   - Sc2a: 1.5 MAR Ntabelanga Dam with full EWR. 0.28 MAR Lalini Dam with full EWR, hydropower discharge after EWR site (Tables 3 & 4).

   - Sc2b: 1.5 MAR Ntabelanga Dam with full EWR. 028 MAR Lalini Dam with maintenance flows (no floods), hydropower discharges after EWR site (Tables 3 & 4).

   - Sc3: 1.5 MAR Ntabelanga Dam with full EWR. 0.6 MAR Lalini Dam with full EWR, hydropower discharge after EWR site (Tables 5 & 6).

   - Sc4: 1.5 MAR Ntabelanga Dam with full EWR. 0.28 MAR Lalini Dam with full EWR, hydropower discharge before EWR site (Tables 5 & 6).

3. All these scenarios were assessed by using the FIFHA model. In addition, instream ecological categories for a B and B/C were also generated (Tables 7 & 8).

RESULTS

The following were obtained through executing the FIFHA:

1. Table 1, August: The B/C and B categories estimated from SPATSIM both relate to an overall category B for fish and macro-invertebrate VD and VS classes. There is some variation in ecological categories for some flow percentiles.

   Both B/C and B SPATSIM scenarios indicate that low flows (< 50% percentile) are generally more impacted than flows >= the 50% percentile flow.

TABLE 1: DRIEST MONTH: Mzim LALINI nat, Aug : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV. BC & B flows as proposed by R. Stassen.

FLOW DURATION	NATURAL TOTAL FLOW (cms) Aug	FISH FLOW cms: PRESENT	FISH: PRESENT CATEGORY PER %TILE: ALL VD	INV FLOW cms: PRESENT	INV: PRESENT CATEGORY PER %TILE: ALL VS	FISH FLOW cms: RETHA BC	FISH: RETHA B CATEGORY PER %TILE: ALL VD	INV FLOW cms: RETHA BC	INV: RETHA BC CATEGORY PER %TILE: ALL VS	FISH FLOW cms: RETHA B	FISH: RETHA B CATEGORY PER %TILE: ALL VD	INV FLOWS cms:RETHA B	INV: RETHA B CATEGORY PER %TILE: ALL VS
0.10%	59.440	59.040	A	59.040	A	2.960	B	2.960	B	3.860	B	3.860	B
1.00%	46.984	46.660	A	46.660	A	2.960	B	2.960	B	3.860	A/B	3.860	B
5.00%	31.131	30.790	A	30.790	A	2.960	A/B	2.960	A/B	3.860	A/B	3.860	A/B
10.00%	18.311	18.000	A	18.000	A	2.940	A	2.940	A/B	3.840	A	3.840	A
15.00%	12.297	11.900	A	11.900	A	2.930	A	2.930	A	3.820	A	3.820	A
20.00%	10.448	10.100	A	10.100	A	2.900	A	2.900	A	3.780	A	3.780	A
30.00%	7.338	6.980	A	6.980	A	2.810	A	2.810	A	3.650	A	3.650	A
40.00%	6.055	5.690	A	5.690	A	2.610	A	2.610	A	3.350	A	3.350	A
50.00%	5.093	4.720	A	4.720	A	2.330	A	2.330	A	2.940	A	2.940	A
60.00%	4.194	3.810	A	3.810	A	1.960	B	1.960	A/B	2.400	A	2.400	A
70.00%	3.733	3.350	A	3.350	A	1.570	C/B	1.570	C/B	1.820	B	1.820	B
80.00%	3.046	2.660	A	2.660	A	1.260	C	1.260	C	1.380	C	1.380	C
85.00%	2.873	2.480	A	2.480	A	1.180	C	1.180	C	1.250	C	1.250	C
90.00%	2.651	2.260	A	2.260	A	1.090	C	1.090	C	1.120	C	1.120	C
95.00%	2.526	2.140	A	2.140	A	1.050	C	1.050	C	1.060	C	1.060	C
99.00%	2.422	2.040	A	2.040	A	1.030	C	1.030	C	1.030	C	1.030	C
99.90%	2.221	1.840	A/B	1.840	A/B	1.030	C	1.030	C	1.030	C	1.030	C
		FISH CATEGORY	A	INV CATEGORY	A	CATEGORY	B	CATEGORY	B	CATEGORY	B	CATEGORY	B

2. <u>Table 2, February</u>:
The overall SPATSIM B/C category for both fish and invertebrates both relates to a B/C category in FIFHA. However, the categories per percentile vary widely from D to A.

The overall SPATSIM B category results in a C category for fish and a B category for invertebrates. Categories per percentile vary from an A to a D.

Both B/C and B SPATSIM scenarios indicate that high flows (> 50% percentile) are generally more impacted than flows <= the 50% percentile flow.

TABLE 2: WETTEST MONTH: Mzim LALINI nat, Feb : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV. BC & B flows as proposed by R. Stassen.

FLOW DURATION	NATURAL TOTAL FLOW (cms) Feb	FISH FLOW cms: PRESENT	FISH: PRESENT CATEGORY PER %TILE:	INV FLOW cms: PRESENT	INV: PRESENT CATEGORY PER %TILE: ALL VS	FISH FLOW cms: RETHA BC	FISH: RETHA BC CATEGORY PER %TILE: ALL VD	INV FLOW cms: RETHA BC	INV: RETHA BC CATEGORY PER %TILE: ALL VS	FISH FLOW cms: RETHA B	FISH: RETHA B CATEGORY PER %TILE: ALL VD	INV FLOWS cms:RETHA B	INV: RETHA B CATEGORY PER %TILE: ALL VS
0.10%	177.336	173.610	A	173.610	A	51.890	D	51.890	D	17.810	D	17.810	D
1.00%	173.506	169.780	A	169.780	A	51.890	D	51.890	D	17.810	D	17.810	D
5.00%	152.195	148.470	A	148.470	A	51.890	C/D	51.890	C/D	17.810	D	17.810	D
10.00%	122.405	118.680	A	118.680	A	51.810	C	51.810	C	17.790	C	17.790	C
15.00%	102.357	98.620	A	98.620	A	48.480	C	48.480	C	17.220	C	17.220	C
20.00%	93.174	89.400	A	89.400	A	45.080	C/B	45.080	C/B	16.620	C	16.620	C
30.00%	74.726	71.000	A	71.000	A	39.720	B	39.720	B	15.580	B	15.580	C/B
40.00%	59.338	55.580	A	55.580	A	34.390	A	34.390	A	14.340	A/B	14.340	A/B
50.00%	47.632	43.870	A	43.870	A	26.190	A	26.190	A	12.410	A	12.410	A/B
60.00%	38.945	35.170	A	35.170	A	22.600	A	22.600	A	10.830	A	10.830	A
70.00%	27.156	23.400	A	23.400	A	17.510	A	17.510	A	8.600	A	8.600	A
80.00%	19.300	15.520	A	15.520	A	11.770	A	11.770	A	6.080	A	6.080	A
85.00%	18.032	14.190	A	14.190	A	9.420	A	9.420	A	5.050	A	5.050	A
90.00%	16.220	12.450	A	12.450	A	6.940	A	6.940	A	3.960	A	3.960	A
95.00%	12.936	9.140	A	9.140	A	5.440	A	5.440	A	3.300	A	3.300	A
99.00%	6.793	3.230	A	3.230	A	4.620	A	4.620	A	2.960	A	2.960	A
99.90%	4.466	1.440	B	1.440	C/B	4.250	A	4.250	A	2.960	A	2.960	A
		FISH CATEG ORY	**A**	**INV CATEG ORY**	**A**	**CATEG ORY**	**C/B**	**CATEG ORY**	**C/B**	**CATEG ORY**	**C**	**CATEG ORY**	**B**

3. <u>Table 3, August</u>:

Scenario 1: Both Fish & Invertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with lower flows (>50% percentiles) being more influenced.

Scenario 2a: Both Fish & Invertebrate VD & VS classes indicate an overall category of A. There is very little variation of categories per percentile.

Scenario 2b: Both Fish & Invertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with lower flows (>50% percentiles) being more influenced.

TABLE 3: DRIEST MONTH: Mzim LALINI nat, Aug : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV Scenarios 1, 2a & 2b

FLOW DURATION	NATURAL TOTAL FLOW (cms) Aug	FISH FLOW cms: Sc1	FISH: Sc1 CATEGORY PER %TILE: ALL VD	INV FLOW cms: Sc1	INV: Sc1 CATEGORY PER %TILE: ALL VS	FISH FLOW cms: Sc2a	FISH: Sc2b CATEGORY PER %TILE: ALL VD	INV FLOW cms: Sc2a	INV: Sc2a CATEGORY PER %TILE: ALL VS	FISH FLOW cms: Sc2b	FISH: Sc2b CATEGORY PER %TILE: ALL VD	INV FLOWS cms:Sc2b	INV: Sc2b CATEGORY PER %TILE: ALL VS
0.10%	59.440	20.606	A/B	20.606	A	31.819	A	31.819	A	39.932	A	39.932	A
1.00%	46.984	10.531	A	10.531	A/B	17.249	A	17.249	A	7.415	A/B	7.415	A/B
5.00%	31.131	2.950	A/B	2.950	A/B	15.160	A	15.160	A	2.950	A/B	2.950	A/B
10.00%	18.311	2.946	A	2.946	A/B	15.014	A	15.014	A	2.946	A	2.946	A/B
15.00%	12.297	2.920	A	2.920	A	14.781	A	14.781	A	2.920	A	2.920	A
20.00%	10.448	2.906	A	2.906	A	14.577	A	14.577	A	2.906	A	2.906	A
30.00%	7.338	2.815	A	2.815	A	14.101	A	14.101	A	2.815	A	2.815	A
40.00%	6.055	2.632	A	2.632	A	12.938	A	12.938	A	2.632	A	2.632	A
50.00%	5.093	2.343	A	2.343	A	10.068	A	10.068	A	2.343	A	2.343	A
60.00%	4.194	1.965	A/B	1.965	A/B	8.163	A	8.163	A	1.965	A/B	1.965	A/B
70.00%	3.733	1.578	C/B	1.578	C/B	7.542	A	7.542	A	1.578	C/B	1.578	C/B
80.00%	3.046	1.262	C	1.262	C	4.372	A	4.372	A	1.262	C	1.262	C
85.00%	2.873	1.188	C	1.188	C	3.043	A	3.043	A	1.188	C	1.188	C
90.00%	2.651	1.089	C	1.089	C	2.693	A	2.693	A	1.089	C	1.089	C
95.00%	2.526	1.057	C	1.057	C	2.140	A	2.140	A	1.057	C	1.057	C
99.00%	2.422	1.026	C	1.026	C	1.776	B	1.776	B	1.026	C	1.026	C
99.90%	2.221	0.943	C	0.943	C	1.629	B	1.629	B	0.943	C	0.943	C
		FISH CATEG ORY	**B**	**INV CATEG ORY**	**B**	**CATEG ORY**	**A**	**CATEG ORY**	**A**	**CATEG ORY**	**B**	**CATEG ORY**	**B**

4. <u>Table 4, February</u>:

Scenario 1: Both Fish & Invertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with higher flows (<50% percentiles) being more influenced.

Scenario 2a: Both Fish & Invertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with higher flows (<50% percentiles) being more influenced.

Scenario 2b: Both Fish & Invertebrate VD & VS classes indicate an overall category of B/C. Variation of categories are similar with higher flows (<50% percentiles) being more influenced.

TABLE 4: WETTEST MONTH: Mzim LALINI nat, FEB : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV Scenarios 1, 2a & 2b

FLOW DURATION	NATURAL TOTAL FLOW (cms) Feb	FISH FLOW cms: Sc1	FISH: Sc1 CATEGORY PER %TILE: ALL VD	INV FLOW cms: Sc1	INV: Sc1 CATEGORY PER %TILE: ALL VS	FISH FLOW cms: Sc2a	FISH: Sc2a CATEGORY PER %TILE: ALL VD	INV FLOW cms: Sc2a	INV: Sc2a CATEGORY PER %TILE: ALL VS	FISH FLOW cms: Sc2b	FISH: Sc2b CATEGORY PER %TILE: ALL VD	INV FLOWS cms:Sc2b	INV: Sc2b CATEGORY PER %TILE: ALL VS
0.10%	177.336	91.587	C	91.587	C	106.991	C	106.991	C	89.137	C	89.137	C
1.00%	173.506	91.243	C	91.243	C	82.483	C	82.483	C	65.702	C/D	65.702	C/D
5.00%	152.195	64.645	C	64.645	C	70.967	C	70.967	C	51.616	C/D	51.616	C/D
10.00%	122.405	51.872	C	51.872	C	70.222	C	70.222	C	43.966	C	43.966	C
15.00%	102.357	47.525	C	47.525	C	66.367	B	66.367	B	32.457	C	32.457	C
20.00%	93.174	45.740	C/B	45.740	C/B	64.050	B	64.050	B	12.343	C	12.343	C
30.00%	74.726	39.920	B	39.920	B	56.487	A/B	56.487	A/B	11.137	C/B	11.137	C/B
40.00%	59.338	34.863	A	34.863	A	49.230	A	49.230	A	10.736	A/B	10.736	B
50.00%	47.632	26.348	A	26.348	A	40.352	A	40.352	A	9.950	A/B	9.950	A/B
60.00%	38.945	22.385	A	22.385	A	35.516	A	35.516	A	8.733	A	8.733	A
70.00%	27.156	17.019	A	17.019	A	27.513	A	27.513	A	7.005	A	7.005	A
80.00%	19.300	11.828	A	11.828	A	19.289	A	19.289	A	5.058	A	5.058	A
85.00%	18.032	9.840	A	9.840	A	16.368	A	16.368	A	4.383	A	4.383	A
90.00%	16.220	6.985	A	6.985	A	15.184	A	15.184	A	3.418	A	3.418	A
95.00%	12.936	6.159	A	6.159	A	12.988	A	12.988	A	3.137	A	3.137	A
99.00%	6.793	4.360	A	4.360	A	5.596	A	5.596	A	2.500	A	2.500	A
99.90%	4.466	1.527	B	1.527	B	1.651	A/B	1.651	A/B	1.341	C/B	1.341	C/B
		FISH CATEG ORY	**B**	**INV CATEG ORY**	**B**	**CATEG ORY**	**B**	**CATEG ORY**	**B**	**CATEG ORY**	**C/B**	**CATEG ORY**	**C/B**

5. Table 5, August:

Scenario 3: Both Fish & Invertebrate VD & VS classes indicate an overall category of B. Variation of categories are similar with lower flows (>50% percentile) being more influenced.

Scenario 4: Both Fish & Invertebrate VD & VS classes indicate an overall category of A. Flow Percentiles >95%, relates to a category of B.

TABLE 5: DRYEST MONTH: Mzim LALINI nat, Aug : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV. Scenarios 3 &4.

FLOW DURATION	NATURAL TOTAL FLOW (cms) Aug	FISH FLOW cms: Sc3	FISH: Sc4 CATEGORY PER %TILE: ALL VD	INV FLOW cms: Sc3	INV: Sc3 CATEGORY PER %TILE: ALL VS	FISH FLOW cms: Sc4	FISH: Sc4 CATEGORY PER %TILE: ALL VD	INV FLOWS cms:Sc4	INV: Sc4 CATEGORY PER %TILE: ALL VS
0.10%	59.440	2.950	B	2.950	B	31.819	A	31.819	A
1.00%	46.984	2.950	B	2.950	B	17.249	A	17.249	A
5.00%	31.131	2.950	A/B	2.950	A/B	15.160	A	15.160	A
10.00%	18.311	2.946	A	2.946	A/B	15.014	A	15.014	A
15.00%	12.297	2.920	A	2.920	A	14.781	A	14.781	A
20.00%	10.448	2.906	A	2.906	A	14.577	A	14.577	A
30.00%	7.338	2.815	A	2.815	A	14.101	A	14.101	A
40.00%	6.055	2.632	A	2.632	A	12.938	A	12.938	A
50.00%	5.093	2.343	A	2.343	A	10.068	A	10.068	A
60.00%	4.194	1.965	A/B	1.965	A/B	8.163	A	8.163	A
70.00%	3.733	1.578	C/B	1.578	C/B	7.542	A	7.542	A
80.00%	3.046	1.262	C	1.262	C	4.372	A	4.372	A
85.00%	2.873	1.188	C	1.188	C	3.043	A	3.043	A
90.00%	2.651	1.089	C	1.089	C	2.693	A	2.693	A
95.00%	2.526	1.057	C	1.057	C	2.140	A	2.140	A
99.00%	2.422	1.026	C	1.026	C	1.776	B	1.776	B
99.90%	2.221	0.943	C	0.943	C	1.629	B	1.629	B
		CATEGORY	**B**	**CATEGORY**	**B**	**CATEGORY**	**A**	**CATEGORY**	**A**

6. Table 6, February:

Scenario 3: Both Fish & Invertebrate VD & VS classes indicate an overall category of B/C. Generally, variation of categories are similar with higher flows (<40% percentiles) being more influenced.

Scenario 4: Both Fish & Invertebrate VD & VS classes indicate an overall category of B. Generally, variation of categories are similar with higher flows (<40% percentiles) being more influenced.

TABLE 6: DRYEST MONTH: Mzim LALINI nat, Aug : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV

FLOW DURATION	NATURAL TOTAL FLOW (cms) Feb	FISH FLOW cms: Sc3	FISH: Sc3 CATEGORY PER %TILE: ALL VD	INV FLOW cms: Sc3	INV: Sc3 CATEGORY PER %TILE: ALL VS	FISH FLOW cms: Sc4	FISH: Sc4 CATEGORY PER %TILE: ALL VD	INV FLOWS cms:Sc4	INV: Sc4 CATEGORY PER %TILE: ALL VS
0.10%	177.336	51.872	D	51.872	D	106.991	C	106.991	C
1.00%	173.506	51.872	D	51.872	D	82.483	C	82.483	C
5.00%	152.195	51.872	C/D	51.872	C/D	70.967	C	70.967	C
10.00%	122.405	51.865	C	51.865	C	70.222	C	70.222	C
15.00%	102.357	48.457	C	48.457	C	66.367	B	66.367	B
20.00%	93.174	45.795	C/B	45.795	C/B	64.050	B	64.050	B
30.00%	74.726	39.920	B	39.920	B	56.487	A/B	56.487	A/B
40.00%	59.338	34.863	A	34.863	A	49.230	A	49.230	A
50.00%	47.632	26.108	A	26.108	A	40.352	A	40.352	A
60.00%	38.945	21.307	A	21.307	A	35.516	A	35.516	A
70.00%	27.156	17.019	A	17.019	A	27.513	A	27.513	A
80.00%	19.300	11.828	A	11.828	A	19.289	A	19.289	A
85.00%	18.032	9.840	A	9.840	A	16.368	A	16.368	A
90.00%	16.220	6.985	A	6.985	A	15.184	A	15.184	A
95.00%	12.936	6.159	A	6.159	A	12.988	A	12.988	A
99.00%	6.793	3.010	A	3.010	A	5.596	A	5.596	A
99.90%	4.466	1.393	C/B	1.393	C/B	1.651	A/B	1.651	A/B
		CATEGORY	**C/B**	**CATEGORY**	**C/B**	**CATEGORY**	**B**	**CATEGORY**	**B**

7. Table 7, August:

FIFHA, B: The model was executed to achieve a minimum index value of B (82.1 % of the reference habitat suitability for the reference) for both VD and VS classes. The highest flow required to attain a minimum B category for either fish or invertebrates were taken as the integrated instream flow requirement

FIFHA, B/C: The model was executed to achieve a minimum index value of B/C (78.1 % of the reference habitat suitability for the reference) for both VD and VS classes. The highest flow required to attain a minimum B/C category for either fish or invertebrates were taken as the integrated instream flow requirement

TABLE 7: DRYEST MONTH: Mzim LALINI nat, Aug : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV (B & BC)

FLOW DURATION	NATURAL TOTAL FLOW (cms) Aug	FISH FLOW cms: FIFHA B	FISH: FIFHA BC CATEGORY PER	INV FLOW cms: FIFHA B	INV: FIFHA B CATEGORY PER	INTEGRATED FLOW FOR FISH & INV (HIGHEST OF FISH OR INV)	INTEGRATED CATEGORY B	FISH FLOW cms: FIFHA BC	FISH: FIFHA BC CATEGORY PER	INV FLOWS cms:FIFHA BC	INV: FIFHA BC CATEGORY PER %TILE: ALL VS	INTEGRATED FLOW FOR FISH & INV (HIGHEST OF FISH OR INV)	INTEGRATED CATEGORY B/C
0.10%	59.440	2.290	B	2.279	B	2.290	B	2.078	C/B	2.069	C/B	2.078	B/C
1.00%	46.984	2.147	B	2.211	B	2.211	B	1.941	C/B	2.004	C/B	2.004	B/C
5.00%	31.131	2.011	B	2.047	B	2.047	B	1.812	C/B	1.848	C/B	1.848	B/C
10.00%	18.311	1.914	B	1.941	B	1.941	B	1.720	C/B	1.747	C/B	1.747	B/C
15.00%	12.297	1.849	B	1.830	B	1.849	B	1.658	C/B	1.641	C/B	1.658	B/C
20.00%	10.448	1.829	B	1.796	B	1.829	B	1.639	C/B	1.609	C/B	1.639	B/C
30.00%	7.338	1.776	B	1.753	B	1.776	B	1.588	C/B	1.568	C/B	1.588	B/C
40.00%	6.055	1.750	B	1.738	B	1.750	B	1.564	C/B	1.554	C/B	1.564	B/C
50.00%	5.093	1.731	B	1.727	B	1.731	B	1.545	C/B	1.543	C/B	1.545	B/C
60.00%	4.194	1.690	B	1.691	B	1.691	B	1.507	C/B	1.509	C/B	1.509	B/C
70.00%	3.733	1.663	B	1.664	B	1.664	B	1.481	C/B	1.484	C/B	1.484	B/C
80.00%	3.046	1.622	B	1.625	B	1.625	B	1.442	C/B	1.446	C/B	1.446	B/C
85.00%	2.873	1.611	B	1.615	B	1.615	B	1.432	C/B	1.437	C/B	1.437	B/C
90.00%	2.651	1.598	B	1.602	B	1.602	B	1.419	C/B	1.425	C/B	1.425	B/C
95.00%	2.526	1.590	B	1.595	B	1.595	B	1.412	C/B	1.418	C/B	1.418	B/C
99.00%	2.422	1.584	B	1.589	B	1.589	B	1.406	C/B	1.412	C/B	1.412	B/C
99.90%	2.221	1.453	B	1.458	B	1.458	B	1.282	C/B	1.288	C/B	1.288	B/C
		CATEGORY	B	CATEGORY	B	INTEGRATED FISH-INV CATEGORY	B	CATEGORY	C/B	CATEGORY	C/B	INTEGRATED FISH-INV CATEGORY	B/C

8. Table 7, February:

FIFHA, B: The model was executed to achieve a minimum index value of B (82.1 % of the reference habitat suitability for the reference) for both VD and VS classes. The highest flow required to attain a minimum B category for either fish or invertebrates were taken as the integrated instream flow requirement

FIFHA, B/C: The model was executed to achieve a minimum index value of B/C (78.1 % of the reference habitat suitability for the reference) for both VD and VS classes. The highest flow required to attain a minimum B/C category for either fish or invertebrates were taken as the integrated instream flow requirement

TABLE 8: WETTEST MONTH: Mzim ILANI nat, Feb : ALL VS INTEGRITY CATEGORIES FOR FISH :ALL VD AND ALL VS FOR INV (B & BC)

FLOW DURATION	NATURAL TOTAL FLOW (cms) Feb	FISH FLOW cms: FIFHA B	FISH: FIFHA B CATEGORY PER	INV FLOW cms: FIFHA B	INV: FIFHA B CATEGORY PER	INTEGRATED FLOW FOR FISH & INV (HIGHEST OF FISH OR INV)	INTEGRATED CATEGORY B	FISH FLOW cms: FIFHA BC	FISH: FIFHA BC CATEGORY PER	INV FLOWS cms:FIFHA BC	INV: FIFHA BC CATEGORY PER	INTEGRATED FLOW FOR FISH & INV (HIGHEST OF FISH OR INV)	INTEGRATED CATEGORY B/C
0.10%	177.336	133.027	B	133.027	B	133.027	B	123.125	C/B	123.125	C/B	123.125	C/B
1.00%	173.506	129.883	B	129.883	B	129.883	B	120.134	C/B	120.134	C/B	120.134	C/B
5.00%	152.195	112.148	B	112.131	B	112.148	B	101.348	C/B	101.191	C/B	101.348	C/B
10.00%	122.405	82.454	B	82.053	B	82.454	B	73.100	C/B	72.578	C/B	73.100	C/B
15.00%	102.357	64.429	B	63.913	B	64.429	B	54.489	C/B	53.858	C/B	54.489	C/B
20.00%	93.174	56.889	B	55.990	B	56.889	B	34.102	C/B	39.316	C/B	39.316	C/B
30.00%	74.726	14.774	B	22.502	B	22.502	B	3.474	C/B	4.714	C/B	4.714	C/B
40.00%	59.338	2.199	B	2.866	B	2.866	B	1.673	C/B	1.765	C/B	1.765	C/B
50.00%	47.632	1.713	B	1.886	B	1.886	B	1.582	C/B	1.650	C/B	1.650	C/B
60.00%	38.945	1.663	B	1.714	B	1.714	B	1.535	C/B	1.580	C/B	1.580	C/B
70.00%	27.156	1.594	B	1.619	B	1.619	B	1.469	C/B	1.489	C/B	1.489	C/B
80.00%	19.300	1.547	B	1.584	B	1.584	B	1.424	C/B	1.456	C/B	1.456	C/B
85.00%	18.032	1.539	B	1.578	B	1.578	B	1.417	C/B	1.451	C/B	1.451	C/B
90.00%	16.220	1.528	B	1.570	B	1.570	B	1.406	C/B	1.443	C/B	1.443	C/B
95.00%	12.936	1.505	B	1.552	B	1.552	B	1.385	C/B	1.425	C/B	1.425	C/B
99.00%	6.793	1.452	B	1.503	B	1.503	B	1.334	C/B	1.380	C/B	1.380	C/B
99.90%	4.466	1.417	B	1.466	B	1.466	B	1.300	C/B	1.343	C/B	1.343	C/B
		CATEGORY	B	CATEGORY	B	INTEGRATED FISH-INV CATEGORY	B	CATEGORY	C/B	CATEGORY	C/B	INTEGRATED FISH-INV CATEGORY	C/B

CONCLUSIONS & COMMENTS

1. It must be emphasized that the approach followed here where high flows (floods) are included in the assessment is highly unlikely to provide representative view of the high flow requirements of the river. High flows must in this case only be regarded as a possible indication of the response of the VD classes for fish and VS classes for invertebrates.

   The average velocities modelled during high flows for both the dry (Table 9) and the wet season (Table 10), are high and generally unlikely to provide suitable conditions for both fish and invertebrates. However, even under such conditions, there are still suitable slow VD classes and VS classes present (information available on request from the author) that would provide refuge to very high velocities.

   The two fish species found in the river are limnophylics that do not require fast flows (i.e. rheophilic habitats). The main requirement that these 2 spp. would have is expected to relate to connectivity between pools or slow flowing habitats. Flow depth and the velocities present in fast flowing sections may become limiting during very high flows. During low flows, the body shape of both species (and small size of *B. anoplus* in particular) would not be particular restriction to movement into different habitat patches.

   There are a range of invertebrate taxa that require fast or very fast flows with a particular substrate. Floods are generally expected to disrupt invertebrate abundance and taxa extensively during high flows.

Table 9: Hydraulic attributes during August at the Lalini site as derived from HABFLO and interpolated in FIFHA.

FLOW DURATION	REFERENCE TOTAL BASEFLOW (cumec)	REFERENCE AVERAGE DEPTH (m)	REFERENCE MAX DEPTH (m)	REFERENCE WETTED PERIMETER WIDTH (m)	REFERENCE CHANNEL WIDTH (m)	REFERENCE AVERAGE VELOCITY (m/s)	REFERENCE MAXIMUM VELOCITY (m/s)
0.10%	59.440	2.746	3.186	38.400	32.100	0.670	1.979
1.00%	46.984	2.245	2.660	37.310	31.849	0.653	1.920
5.00%	31.131	1.602	2.005	36.019	31.555	0.604	1.745
10.00%	18.311	1.100	1.490	34.933	31.285	0.532	1.542
15.00%	12.297	0.840	1.223	34.364	31.159	0.462	1.377
20.00%	10.448	0.761	1.142	34.189	31.120	0.441	1.326
30.00%	7.338	0.603	0.983	33.872	31.054	0.384	1.193
40.00%	6.055	0.533	0.913	33.737	31.027	0.357	1.130
50.00%	5.093	0.481	0.861	33.636	31.007	0.337	1.082
60.00%	4.194	0.425	0.803	33.269	30.774	0.313	1.022
70.00%	3.733	0.395	0.770	32.998	30.589	0.300	0.986
80.00%	3.046	0.349	0.722	32.593	30.312	0.280	0.932
85.00%	2.873	0.337	0.709	32.492	30.242	0.275	0.919
90.00%	2.651	0.323	0.694	32.361	30.153	0.268	0.901
95.00%	2.526	0.314	0.685	32.287	30.103	0.264	0.892
99.00%	2.422	0.307	0.677	32.226	30.061	0.261	0.883
99.90%	2.221	0.297	0.656	31.079	28.982	0.254	0.860

Table 10: Hydraulic attributes during February at the Lalini site as derived from HABFLO and interpolated in FIFHA.

FLOW DURATION	REFERENCE TOTAL FLOW (cumec)	REFERENCE AVERAGE DEPTH (m)	REFERENCE MAX DEPTH (m)	REFERENCE WETTED PERIMETER WIDTH (m)	REFERENCE CHANNEL WIDTH (m)	REFERENCE AVERAGE VELOCITY (m/s)	REFERENCE MAXIMUM VELOCITY (m/s)
0.10%	177.336	6.053	6.503	69.533	32.200	0.710	2.090
1.00%	173.506	5.946	6.396	68.457	32.200	0.710	2.090
5.00%	152.195	5.347	5.797	62.471	32.200	0.710	2.090
10.00%	122.405	4.510	4.960	54.103	32.200	0.710	2.090
15.00%	102.357	3.949	4.395	48.981	32.161	0.700	2.063
20.00%	93.174	3.693	4.135	46.822	32.128	0.692	2.041
30.00%	74.726	3.178	3.614	42.483	32.063	0.676	1.997
40.00%	59.338	2.748	3.179	38.865	32.009	0.662	1.961
50.00%	47.632	2.296	2.717	37.467	31.839	0.641	1.882
60.00%	38.945	1.935	2.346	36.715	31.686	0.622	1.814
70.00%	27.156	1.447	1.845	35.697	31.474	0.591	1.706
80.00%	19.300	1.134	1.525	35.033	31.308	0.530	1.555
85.00%	18.032	1.083	1.473	34.925	31.281	0.520	1.530
90.00%	16.220	1.011	1.399	34.772	31.243	0.506	1.495
95.00%	12.936	0.871	1.256	34.477	31.165	0.472	1.411
99.00%	6.793	0.579	0.958	33.826	30.969	0.379	1.181
99.90%	4.466	0.444	0.818	33.256	30.726	0.322	1.037

2. It should also be considered that flood separation be conducted to obtain the maximum baseflows for various scenarios.
3. The impact of flow modification on particular physico-chemical conditions are not addressed in detail in the FIFHA. Based on the results emanating from HABFLO, some indication of the change in substrate at different flows can be obtained (not provided in this report). Clearly the impact of sedimentation and scouring should be considered and modelled by the appropriate specialists.
4. The rate of increase or decrease in flows for storage or power generation is an important consideration in the operation of the system. A gradual increase and decrease in flows are usually preferred to prevent biota becoming isolated form the main channel of the river. However, the possibility of releasing high flows to prevent sedimentation may be important. Likewise, the effect of scouring due to high flows is also an important consideration. None of these issues were addressed in any detail and probably require specific attention by appropriate specialists.