FRESHWATER ECOSYSTEM SCOPING REPORT

Lydenburg Mashishing Township Establishment

Project Ref No. 170055

Prepared for:
Environmental Impact Management Services (Pty) Ltd
P.O. Box 2083
Pinegowrie
2123
Tel: +27 11 789 7170
Email: mail@eims.co.za

Prepared by:
Ecology International (Pty) Ltd
P.O. Box 145202
Brackengardens
1452
Tel. No.: (+27) 82 863 0769
Email: info@ecologyinternational.net

In association with

January 2018 (revised August 2018)

Declaration of Independence by Specialist

I, **BYRON GRANT**, in my capacity as a specialist consultant, hereby declare that I -

- act as an independent consultant;
- will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- declare that there are no circumstances that may compromise my objectivity in performing such work;
- do not have any financial interest in the undertaking of the activity, other than remuneration for the work performed in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake to disclose, to the competent authority, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- have expertise in conducting the specialist report relevant to this application, including knowledge of the National Environmental Management Act, 1998 (Act No. 107 of 1998), regulations and any guidelines that have relevance to the proposed activity;
- based on information provided to me by the project proponent and in addition to information obtained during the course of this study, have presented the results and conclusion within the associated document to the best of my professional ability;
- undertake to have my work peer reviewed on a regular basis by a competent specialist in the field of study for which I am registered; and
- as a registered member of the South African Council for Natural Scientific Professions, will undertake my profession in accordance with the Code of Conduct of the Council, as well as any other societies to which I am a member.

______________________	08/08/2018
Byron Grant Pr.Sci.Nat.	**Date**
Director & Principal Specialist	
SACNASP Reg. No. 400275/08	

Declaration of Independence by Specialist

I, **WILLEM LUBBE**, in my capacity as a specialist consultant, hereby declare that I -

- act as an independent consultant;
- will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- declare that there are no circumstances that may compromise my objectivity in performing such work;
- do not have any financial interest in the undertaking of the activity, other than remuneration for the work performed in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake to disclose, to the competent authority, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- have expertise in conducting the specialist report relevant to this application, including knowledge of the National Environmental Management Act, 1998 (Act No. 107 of 1998), regulations and any guidelines that have relevance to the proposed activity;
- based on information provided to me by the project proponent and in addition to information obtained during the course of this study, have presented the results and conclusion within the associated document to the best of my professional ability;
- undertake to have my work peer reviewed on a regular basis by a competent specialist in the field of study for which I am registered; and
- as a registered member of the South African Council for Natural Scientific Professions, will undertake my profession in accordance with the Code of Conduct of the Council, as well as any other societies to which I am a member.

______________________	08/08/2018 ______________
Willem Lubbe Cert.Sci.Nat Wetland Specialist SACNASP Reg. No. 100064/08	**Date**

EXECUTIVE SUMMARY

Environmental Impact Management Services (Pty) Ltd (EIMS) has been appointed to undertake an application for Environmental Authorisation (EA) for the proposed Mashishing Township Establishment in Lydenburg (Mashishing), following a full Environmental Impact Assessment (EIA) process (i.e. Scoping and EIA Phases). The proposed township establishment comprises of two phases, namely Phases A and B.

Based on results obtained during the present study, it was determined that the diversity of aquatic biota associated with the reaches of the Marambane River and Dorps River associated with the proposed Mashishing Phase A and Phase B township areas was lower than that expected, which was strongly influenced by the nature of upstream and adjacent impacts (including the inflow of sewage as a result of failing infrastructure). Moreover, results obtained further indicate that a higher diversity of fish species are present within the Dorps River relative to the Marambane River, which is likely attributed to the different sizes of the watercourses assessed and habitat preferences of the individual species. However, data obtained during the present study suggested that the abundance of fish is lower within the Dorps River relative to the reaches of the Marambane River directly adjacent to the proposed Mashishing Phase A and Phase B township areas, despite there being a higher degree of suitable habitat within the Dorps River. This was attributed to the impacts presentin with the Dorps River catchment upstream of the present study area, which is likely to have impacted on the fish assemblage present.

Nevertheless, the integrated ecological state of the Marambane River was generally considered to be largely modified (i.e. Ecological Category D), with the inflow of sewage within the lower reaches determined to have a significant impact on the instream biota. The reach of the Dorps River associated with the proposed township establishment was similarly considered to be in a largely modified state, with the instream component downstream of the proposed township being in a better state due to the presence of a Department of Water and Sanitation (DWS) gauging weir that presents a movement barrier to fish attempting to access the upper reaches of the Dorps River. Nevertheless, Ecological Importance for both watercourses was determined to be moderate, whereas the Ecological Sensitivity was determined to be high.

In addition, two fish species of conservation concern were confirmed within the reaches of watercourses assessed during the present study. Of particular relevance is the fact that the designation of the associated catchment as a Fish Support Area (i.e. fish sanctuary in an ecological class lower than an A or B) was originally established based on the potential support for *Enteromius sp. 'Ohrigstad'*, for which there is taxonomic uncertainty, and thus uncertainty regarding the conservation status. However, given the dominance of *Enteromius sp. nov. 'South Africa'* within the study area and in consideration of the recent conservation assessment which assessed the species as Near-Threatened, as well as the EcoStatus results obtained during the present study, the retention of the catchment associated with the proposed township establishment as a Fish Support Area (i.e. fish sanctuary in an ecological class lower than an A or B) is supported.

Further, one hydro-geomorphic (HGM) type, a hillslope seepage connected to a watercourse was delineated during the present study, and classified into four separate HGM units. In addition to the wetland units delineated, two sections of riparian habitat were also delineated, one section on the eastern boundary associated with the Dorps River and the other section on the western boundary associated with the Marambane River. Results indicated that wetlands within the study area have been largely altered as a result of changes in water inputs (derived from its catchment) and water retention and distribution patterns within the wetland unit itself, as well as vegetation changes due to several historic and current anthropogenic impacts. The identified wetlands are therefore considered to be in a largely modified state (i.e. Ecological Category D), and thus reflective of the riverine ecosystem.

The hillslope seepage wetlands present within the study area were assigned a low Ecological Importance and Sensitivity, mostly due to the lack of species of conservation concern present. The hillslope seepage wetlands were further regarded as having a moderate Hydrological and Functional Importance due to the potential ecosystem services they provide, especially in terms of phosphate trapping and nitrate removal. In addition, direct human benefits were regarded as moderate within HGM 1 due to the grazing, stock watering and production of cultivated crops within the wetland unit, whereas direct human benefits associated with HGM 2, HGM 3 and HGM 4 were regarded as very low due to the hillslope seepage wetlands not being fully utilised at present.

Determination of the preliminary buffer requirements for riverine and wetland features associated with the proposed Mashishing Township Establishment followed the approach of Macfarlane & Bredin (2016), whereby the required buffers were developed based on various factors, including assumed housing densities, slope, annual precipitation, rainfall intensity, channel width, catchment to wetland ratio, etc. Given that the slope in the study area is not consistent, a variable buffer width was applied to the identified watercourses, resulting in preliminary riverine buffers which ranged from 61m to 75m, whereas the preliminary wetland buffers ranged from 52m to 55m. The final integrated watercourse buffer determinations for the watercourses associated with the proposed Mashishing Township Establishment was therefore taken to include the extent of the riparian area, buffer area for riverine components, or the buffer area determined for the wetland components, whichever was greater. Subsequently, the sensitivity of the buffer zones should be regarded as very high (pending the provision of additional information pertaining to the proposed activity) given proposed functionality for which the buffer zone was determined and the purpose of limiting impacts on the associated watercourses.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

a.m.s.l.	above mean sea level
ASPT	Average Score Per Taxon
CMA	Catchment Management Agency
CPUE	Catch Per Unit Effort
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EC	Ecological Category
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
FEPA	Freshwater Ecosystem Priority Area
FRAI	Fish Response Assessment Index
GPS	Global Positioning System
HGM	Hydrogeomorphic
IHAS	Invertebrate Habitat Assessment System
IHI	Index for Habitat Integrity
MIRAI	Macro-Invertebrate Response Assessment Index
NBA	National Biodiversity Assessment
NFEPA	National Freshwater Ecosystem Priority Areas project
NWRS	National Water Resource Strategy
PES	Present Ecological State
REMP	River EcoStatus Monitoring Programme
RHP	River Health Programme
RQO	Resource Quality Objective
SAIAB	South African Institute for Aquatic Biodiversity
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SASS5	South African Scoring System, Version 5
VEGRAI	Vegetation Reponses Assessment Index
WMA	Water Management Areas
WRC	Water Research Commission
WWF	Worldwide Fund for Nature
WWTW	Waste Water Treatment Works

1. INTRODUCTION

1.1 Project Description

Environmental Impact Management Services (Pty) Ltd (EIMS) has been appointed to undertake an application for Environmental Authorisation (EA) for the proposed Mashishing Township Establishment in Lydenburg (Mashishing), following a full Environmental Impact Assessment (EIA) process (i.e. Scoping and EIA Phases). The proposed township establishment comprises of two phases, namely Phases A and B.

In order to inform the required regulatory processes, EIMS appointed Ecology International (Pty) Ltd to conduct the necessary biodiversity-related specialist studies for the freshwater ecosystem associated with the proposed Mashishing Township Establishment. The present report represents the baseline assessment in the form of a Scoping Report for the freshwater ecosystem associated with Phases A and B, and includes the assessment of both the associated aquatic ecosystem (i.e. riverine ecosystem) as well as wetlands associated with the proposed study area.

1.2 Scope of Work

1.2.1 Aquatic Assessment

Assessment of the aquatic ecosystem associated with the proposed activity would entail the characterisation of the aquatic environment, aquatic habitat and associated biota. In order to enable an adequate description and the determination of the present ecological state, the following indicators were to be evaluated:

- *In situ* water quality assessment;
- Habitat assessment, utilizing the Invertebrate Habitat Assessment Systems (IHAS version 2.2) and the Index for Habitat Integrity (IHI);
- Macroinvertebrate assessment, including the generation of reference conditions and determination of Present Ecological State utilizing the South African Scoring System Version 5 (SASS5) and the Macro-Invertebrate Response Assessment Index (MIRAI) within lotic systems (rivers);
- Ichthyofaunal assessment, including the evaluation of reference conditions and determination of Present Ecological State utilizing the Fish Response Assessment Index (FRAI) in the lotic systems (rivers);
- Determination of the integrated Present Ecological State (PES) through the latest EcoStatus approach;
- Identification of any aquatic species of conservation concern and/or Protected species;
- Identification of any non-native (alien invasive or extralimital) aquatic species;
- Assessment of Ecological Importance and Sensitivity of the river reaches associated with the study area; and
- Determination of appropriate buffer zones for the protection of the associated riverine ecosystem.

It was further noted that the catchment in question is regarded as a Fish Support Area for an as yet undescribed fish species according to the current outputs of the National Freshwater Ecosystem Priority Areas (NFEPA) project, as well as the Mpumalanga Biodiversity Sector Plan. Accordingly, due consideration with regards to determining the presence and distribution of this species within the study area was to be considered during the aquatic specialist assessment.

1.2.2 Wetland Assessment

In order to enable an adequate description of potential wetland habitat and so as to ensure that the wetland study conducted is applicable for both an Environmental Authorisation as well as a Water Use Licence Application, the following approach was to be undertaken:

- Desktop assessment;
- Site assessment for Identification and delineation of wetland habitat;
- Classification of identified wetland habitat (including high-level description of hydropedological processes supporting wetlands);
- Identification of wetland goods and services by means of the Wet-EcoServices approach;
- Determination of the Present Ecological State of identified wetlands by means of the Wet-Health approach;
- Determination of the Ecological Importance and Sensitivity of identified wetlands; and
- Determination of appropriate buffer zones for the protection of the associated wetland systems.

A site visit to the area to be affected by the proposed activity was undertaken from the 7th to 9th of November 2017 (aquatic assessment) and again from the 10th to the 15th of November 2017 (wetland assessment). A detailed description of the methodology used to address the above Terms of Reference is provided in Appendix A.

1.3 Assumptions and Limitations

During the course of the present study, the following limitations were experienced:

- In order to obtain definitive data regarding the biodiversity, hydrology and functioning of rivers and wetlands, studies should ideally be conducted over a number of seasons and over a number of years. The current study relied on information gained during a field survey conducted over several days during a single season, desktop information for the area as well as professional judgment and experience;
- Wetland and riparian assessments are based on a selection of available techniques that have been developed through the Department of Water and Sanitation (DWS). These methods are, however, largely qualitative in nature with associated limitations due to the range of interdisciplinary aspects that have to be taken into consideration. Current and historic anthropogenic disturbance within and surrounding the study area has resulted in soil profile disturbances as well as successional changes in species composition in relation to its original /expected benchmark condition;
- Wetland and riparian areas within transformed landscapes, such as urban, agricultural settings, or mining areas with existing infrastructure, are often affected by disturbances that restrict the use of available wetland indicators, such as hydrophytic vegetation or soil indicators (e.g. dense stands of alien vegetation, vegetation removal, dumping, sedimentation, infrastructure encroachment, infilling, etc.). In addition, failing infrastructure within the study area presented artificially saturated areas or areas of prolonged saturation that are not reminiscent of natural wetland features; and
- Delineations of wetland areas were largely dependent on the extrapolation of field indicator data obtained during field surveys, 5m contour data for the study area, and from interpretation of geo-referenced orthophotos and satellite imagery. As such, inherent ortho-rectification errors associated with data capture and transfer to electronic format are likely to decrease the accuracy of wetland boundaries in many instances.

2. GENERAL CHARACTERISTICS

2.1 Location

The study area is located approximately 4km north-east of the town of Lydenburg, and immediately north and adjacent to Mashishing and Kellysville, Mpumalanga (Figure 1). More specifically, the study area is located south-west of the R37 road on the Townlands of Lydenburg 31 JT.

2.2 Biophysical Attributes

2.2.1 Climate

According to Kleynhans et al. (2007), the study area occurs on the Eastern Bankenveld ecoregion, and more specifically within the Level 2 ecoregion 9.02, which typically occurs at altitudes between 700m and 1700m above mean sea level (a.m.s.l.). Mean annual temperatures within the study area range from 10°C to 22°C, with mean daily maximum temperatures in February ranging from 18°C to 30°C, and mean daily minimum temperatures in July ranging from 0°C to 7°C (Kleynhans et al., 2007b). Mean annual precipitation of the quaternary catchment ranges from 725 mm/annum to 897mm/annum, with potential evaporation from 1867 mm/annum to 1943mm/annum (Macfarlane et al., 2008).

2.2.2 Geology

Geology underlying the study area is made up of elements from the Lydenburg and Machadodorp members of the Silverton formation, Pretoria Group (Transvaal Sequence, Figure 2). As such, lithology associated with the area consists of pale-green tuff with pyroclastic layers as well as greenish, fine-grained, laminated shale and subordinate mudstone. Several intrusive diabase elements from the Vaalian Era are further present within the study area.

2.2.3 Bioregional Context

The study area is located within the Southern Temperate Highveld freshwater ecoregion, which is delimited by the South African interior plateau sub-region of the Highveld aquatic ecoregion, of which the main habitat type, in terms of watercourses, is regarded as Savannah-Dry Forest Rivers. Aquatic biotas within this bioregion have mixed tropical and temperate affinities, sharing species between the Limpopo and Zambezi systems. The Southern Temperate Highveld freshwater ecoregion is considered to be bio-regionally outstanding in its biological distinctiveness, and its conservation status is regarded as Endangered. The ecoregion is defined by the temperate upland rivers and seasonal pans (Nel et al., 2004; Darwall et al., 2009; Scott, 2013).

2.2.4 Associated Aquatic Ecosystems

The NWRS-1 (National Water Resource Strategy, Version 1) originally established 19 Water Management Areas (WMA) within South Africa and proposed the establishment of the 19 Catchment Management Agencies (CMA) to correspond to these areas. In rethinking the management model and based on viability assessments with respect to water resources management, available funding, capacity, skills and expertise in regulation and oversight, as well as to improve integrated water systems management, the original 19 designated WMAs have been consolidated into nine WMAs.

As such, the present study is located within the newly revised Olifants Water Management Area (WMA), which now also includes the Letaba River catchment. Accordingly, the main rivers include the Elands River, the Wilge River, the Steelpoort River, the Olifants River, and the Letaba River. More specifically, the study area was located adjacent to two watercourses, namely the Dorps River which represents the eastern boundary of Phase B, and the Marambane River which forms the western boundary of Phase A and which confluences with the Dorps River approximately 3km downstream of the study site (Figure 1).

A Topographical Wetness Index was generated for the study area in order to determine possible location of wetland features within the landscape associated with the proposed Mashishing Township based on topographical features. This was done using several spatial software programmes (including QGIS, ArcGIS and SAGA) as well as the 5m contour data obtained from the Chief Surveyor: Survey and Mapping. Results obtained following the development of the Topographical Wetness Index model are presented in Figure 3, and indicate the potential for several wetland features within the study area. These areas later formed the focus of the field verification exercise that was undertaken as part of the study.

2.2.5 National Freshwater Ecosystem Priority Areas

The National Freshwater Ecosystem Priority Areas (NFEPA) project represents a multi-partner project between the Council for Scientific and Industrial Research (CSIR), South African National Biodiversity Institute (SANBI), Water Research Commission (WRC), Department of Water Affairs (DWA; now Department of Water and Sanitation, or DWS), Department of Environmental Affairs (DEA), Worldwide Fund for Nature (WWF), South African Institute of Aquatic Biodiversity (SAIAB) and South African National Parks (SANParks). More specifically, the NFEPA project aims to:

- Identify Freshwater Ecosystem Priority Areas (hereafter referred to as 'FEPAs') to meet national biodiversity goals for freshwater ecosystems; and
- Develop a basis for enabling effective implementation of measures to protect FEPAs, including free-flowing rivers.

The first aim uses systematic biodiversity planning to identify priorities for conserving South Africa's freshwater biodiversity, within the context of equitable social and economic development. The second aim comprises a national and sub-national component. The national component aims to align DWS and DEA policy mechanisms and tools for managing and conserving freshwater ecosystems. The sub-national component aims to use three case study areas to demonstrate how NFEPA products should be implemented to influence land and water resource decision-making processes at a sub-national level (Driver et al., 2011). The project further aims to maximize synergies and alignment with other national level initiatives such as the National Biodiversity Assessment (NBA) and the Cross-Sector Policy Objectives for Inland Water Conservation.

Based on current outputs of the NFEPA project (Nel et al., 2011; Figure 4), it was determined that while no FEPA-designated wetlands or wetland clusters were noted within the present study area, the study area is located within a designated Fish Support Area for a Vulnerable or Near-Threatened fish species. Fish sanctuaries are rivers that are essential for protecting Threatened and/or Near-threatened freshwater fish that are indigenous to South Africa. Fish sanctuaries in a good condition (A or B ecological category) were identified as FEPAs, whereas Fish Support Areas are fish sanctuaries that are in an ecological class lower than an A or B ecological condition. Further interrogation of the data associated with the outputs of the NFEPA project indicated that the *Enteromius sp. 'Ohrigstad'*, a species regarded as Data Deficient. A FEPA-designated Fish Sanctuary for the species was noted to be present on the Dorps River downstream of the study area prior to the confluence of the Dorps and Spekbook rivers (Figure 5), which is likely the reason for the designation of the catchment associated with the study area as a Fish Support Area.

Table 1 presents a summary of the attributes associated with the area under study.

Table 1: Summary of relevant site attributes

Political Region	Mpumalanga
Level 1 Ecoregion	Eastern Bankenveld
Level 2 Ecoregion	9.02
Freshwater Ecoregion	Southern Temperate Highveld
Geomorphic Province	Mpumalanga Highlands
Geology	Lydenburg and Machadodorp members of the Silverton formation (Pretoria Group), and intrusive diabase
Vegetation Type	Lydenburg Thornveld
Water Management Area	Olifants
Secondary Catchment	B4
Quaternary Catchment	B42B & B42C
Watercourse	Marambane River & Dorps River
Slope Class	Upper Foothills
Wetland Vegetation Type	Mesic Highveld Grassland Group 7
NFEPA Status	Fish Support Area

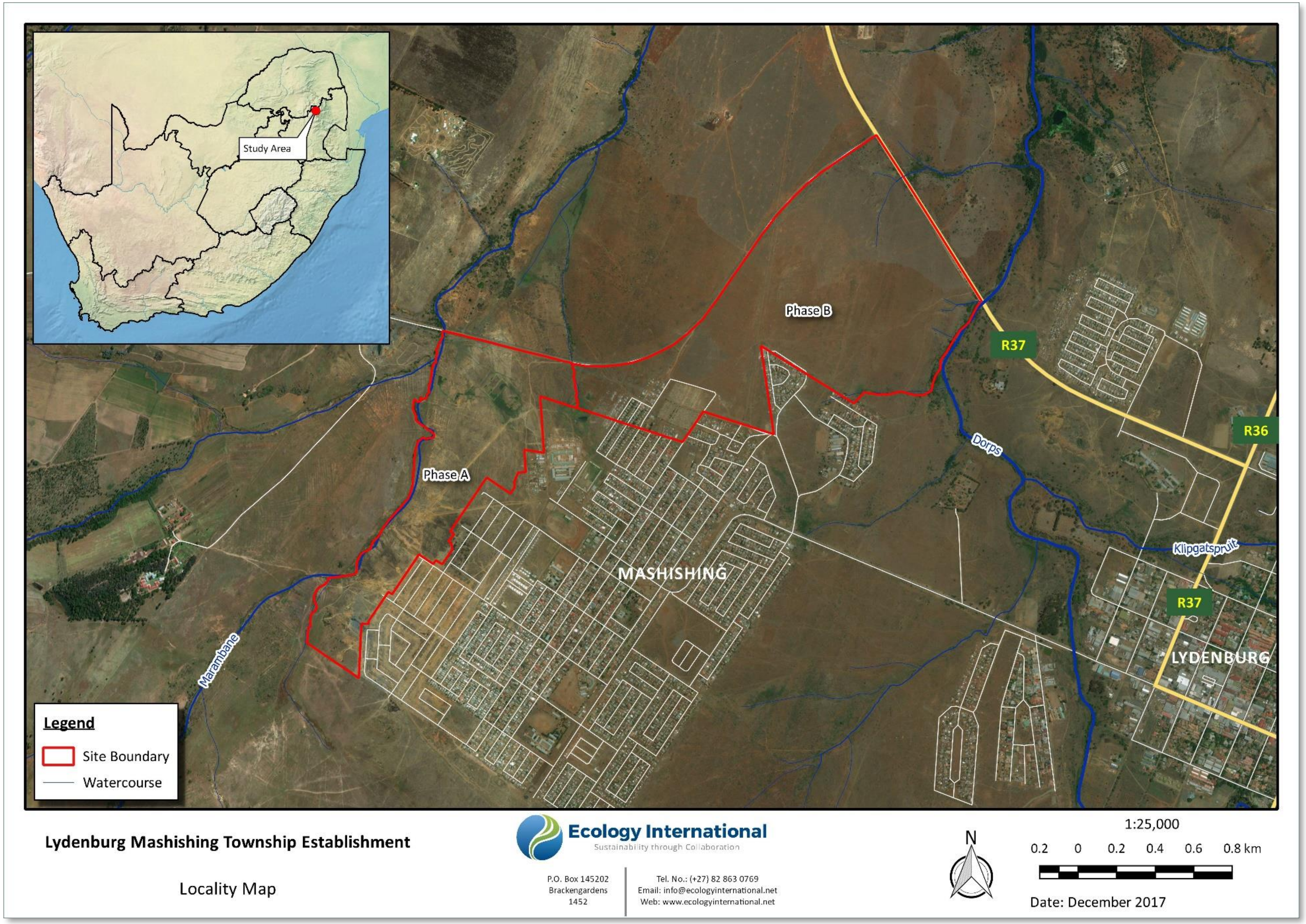


Figure 1: Locality Map

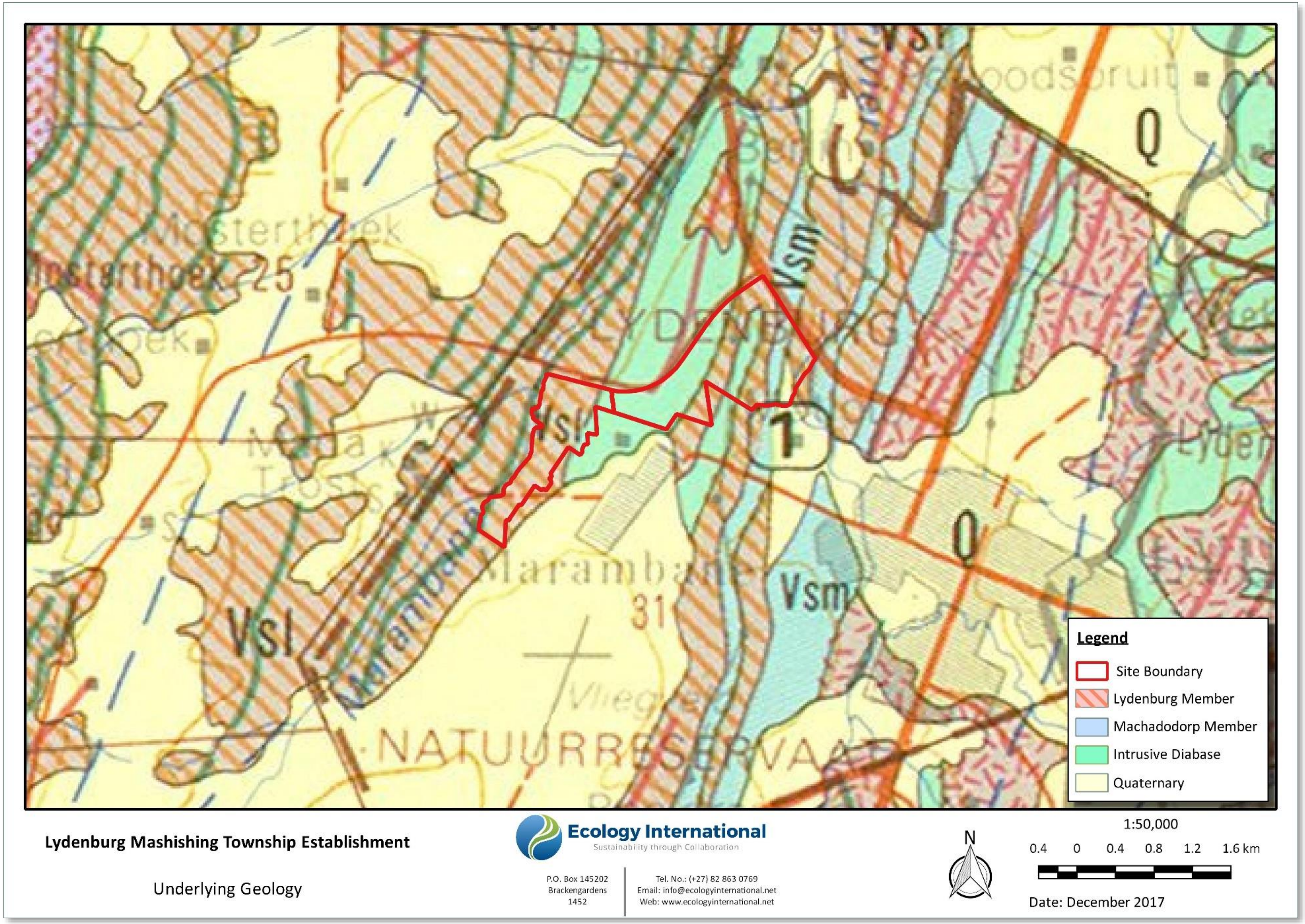


Figure 2: Geology underling the study area (based on 1:250,000 geological map series)

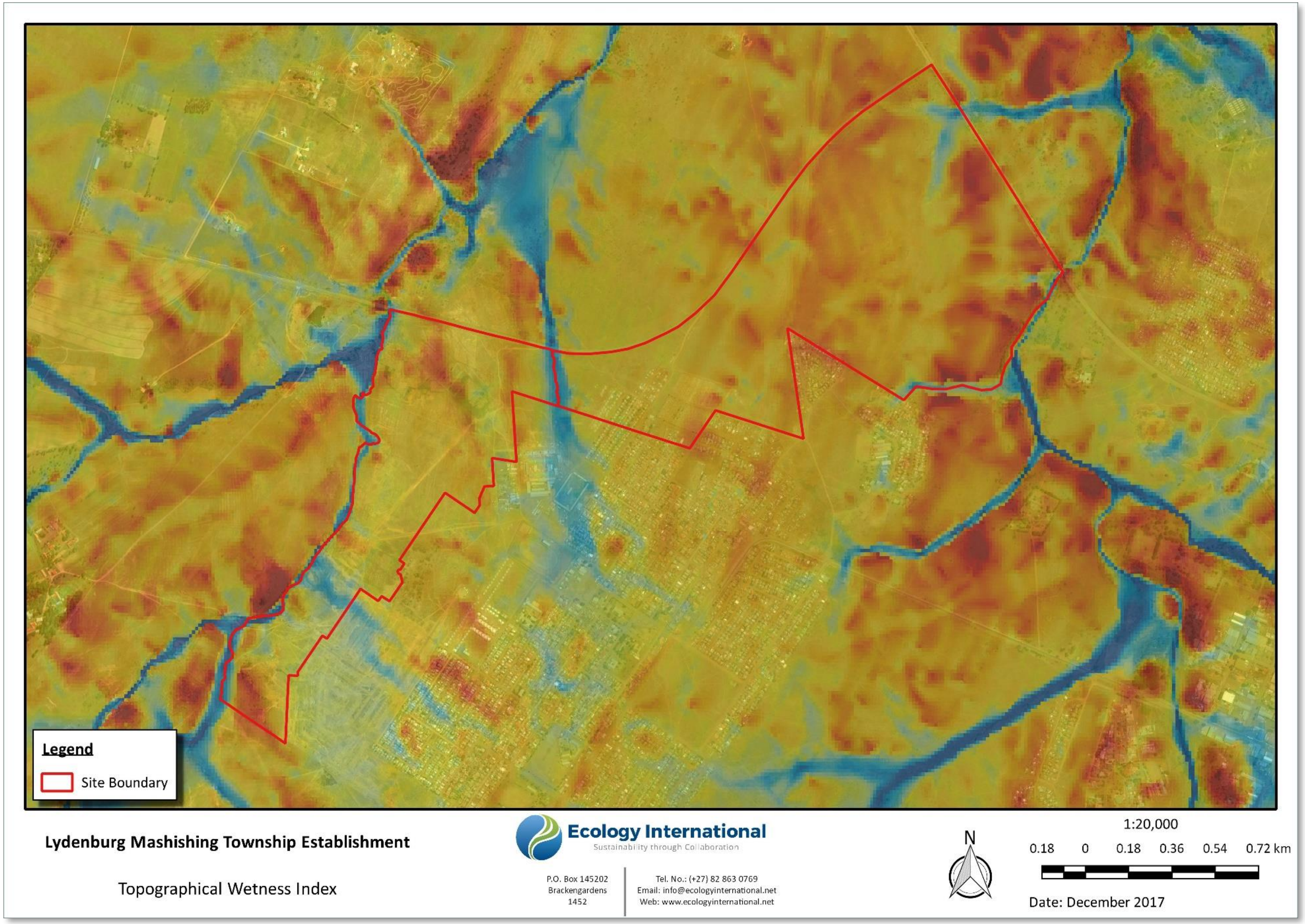


Figure 3: Topographical Wetness Index model developed for the study area based on 5m contour data

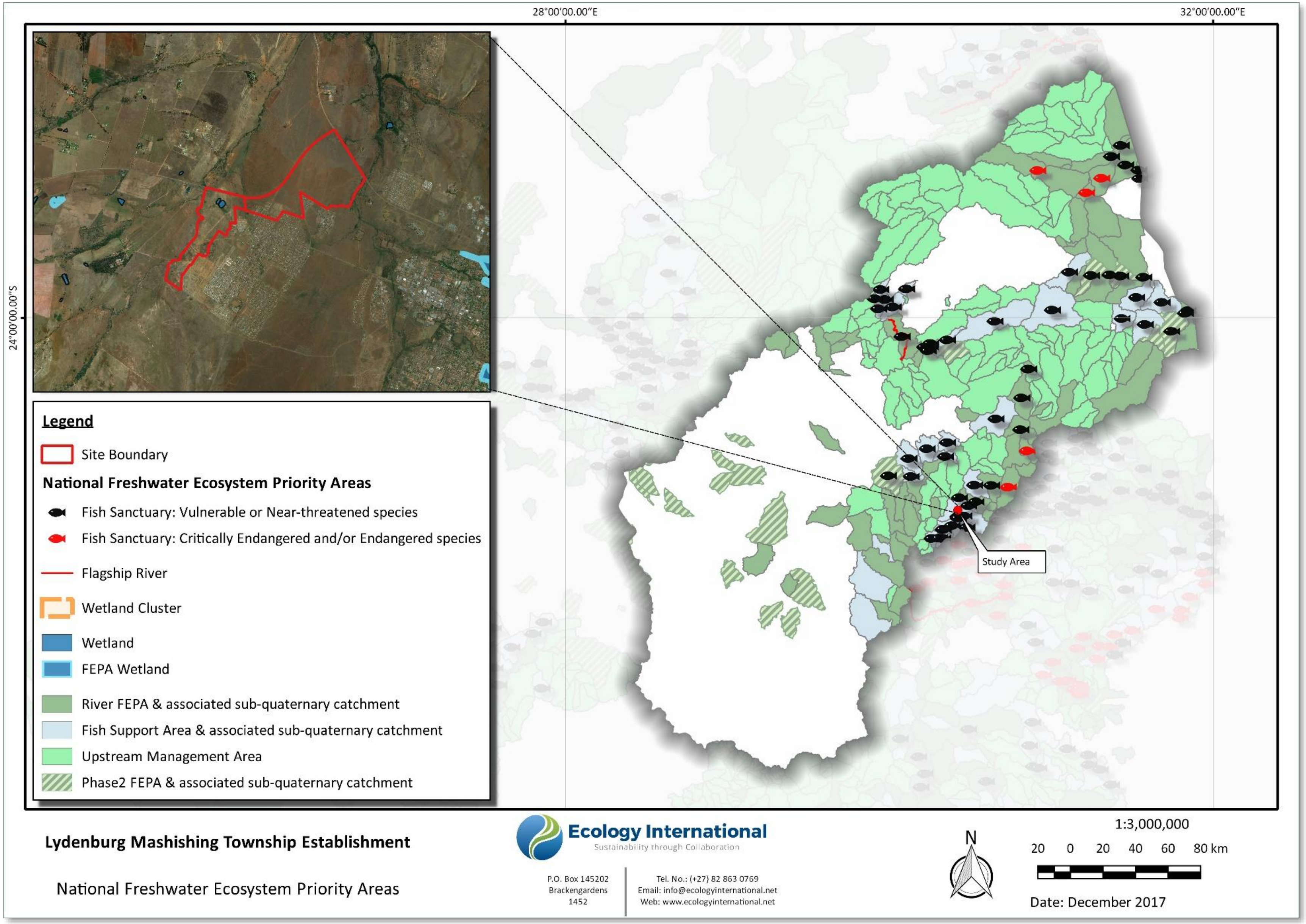


Figure 4: National Freshwater Ecosystem Priority Areas associated with the study area within the Olifants Water Management Area according to Nel et al. (2011)

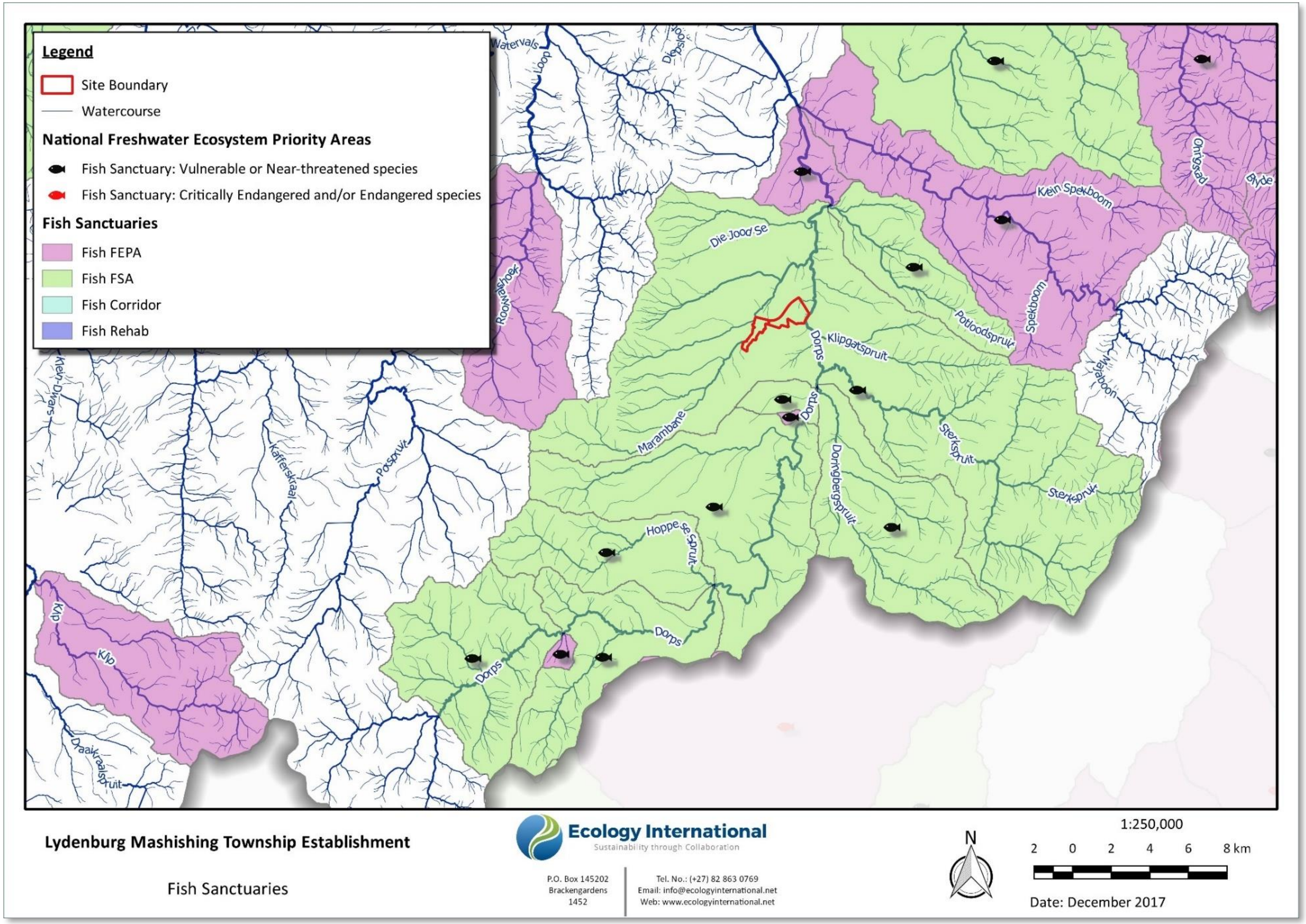


Figure 5: Fish sanctuaries associated with the study area according to Nel et al. (2011)

3. ASSOCIATED AQUATIC ECOSYSTEM

3.1 Selection of Sampling Sites

Sample sites selected for the present assessment were largely based on the extent of the proposed township establishment and possible influencing factors, allowing for a more complete understanding of the associated aquatic ecosystem and the associated impacts. Co-ordinates of the various sampling sites where access was obtainable were determined using a Garmin GPSMAP64 global positioning device and are listed in Table 2, and presented graphically in Figure 6. Photographs of the identified sampling sites are provided in Appendix B.

Table 2: Location and description of sites sampled during the November 2017 field survey

Site	Co-ordinates	Elevation	Description
MTD1	S 25° 5'16.86" E 30°24'20.13"	1,401m	Site located on the Marambane River adjacent to the proposed Mashishing Phase A township area
MTD2	S 25° 4'52.95" E 30°24'39.41"	1,391m	Site located on the Marambane River adjacent to the proposed Mashishing Phase A township area
MTD3	S 25° 3'55.35" E 30°25'14.42"	1,367m	Site located on the Marambane River downstream of the proposed Mashishing Phase A township area
MTD4	S 25° 4'51.96" E 30°26'16.98"	1,360m	Site located on the Dorps River upstream of the proposed Mashishing Phase B township area
MTD5	S 25° 4'30.52" E 30°26'21.25"	1,350m	Site located on the Dorps River immediately downstream of the proposed Mashishing Phase B township area, and below DWS Gauging Weir B4H010
MTD6	S 25° 4'5.28" E 30°26'29.47"	1,339m	Site located on the Dorps River downstream of the proposed Mashishing Phase B township area, and upstream of the Lydenburg WWTW discharge point

3.2 Water Quality

Aquatic communities are influenced by numerous natural and human-induced factors, including physical, chemical and biological factors. The assessment of water quality variables in conjunction with assessment of biological assemblages is therefore important for the interpretation of results obtained during biological investigations. Table 3 provides the *in situ* water quality data obtained at each site assessed during the November 2017 field survey.

During the present study, pH values measured at the sampling sites were noted to represent alkaline conditions, with the highest value observed to be associated with Site MTD1 (Table 3). Further, electrical conductivity values were noted to be comparable between the Marambane River and the Dorps River. A noticeable increase in the electrical conductivity was however observed between sites MTD1 and MTD2 along the Marambane River, and again between sites MTD2 and MTD3. This increase along the reach of the Marambane River assessed was likely attributed to a combination of factors, including catchment runoff from the current developments within the Mashishing Phase A township area, and washing of clothes within the river between sites MTD1 and MTD2 by members of the community, as well as the inflow of raw sewage into the Marambane River between sites MTD2 and MTD3 as a result of failing sewage infrastructure present within the Mashishing Phase A township area (Figure 7).

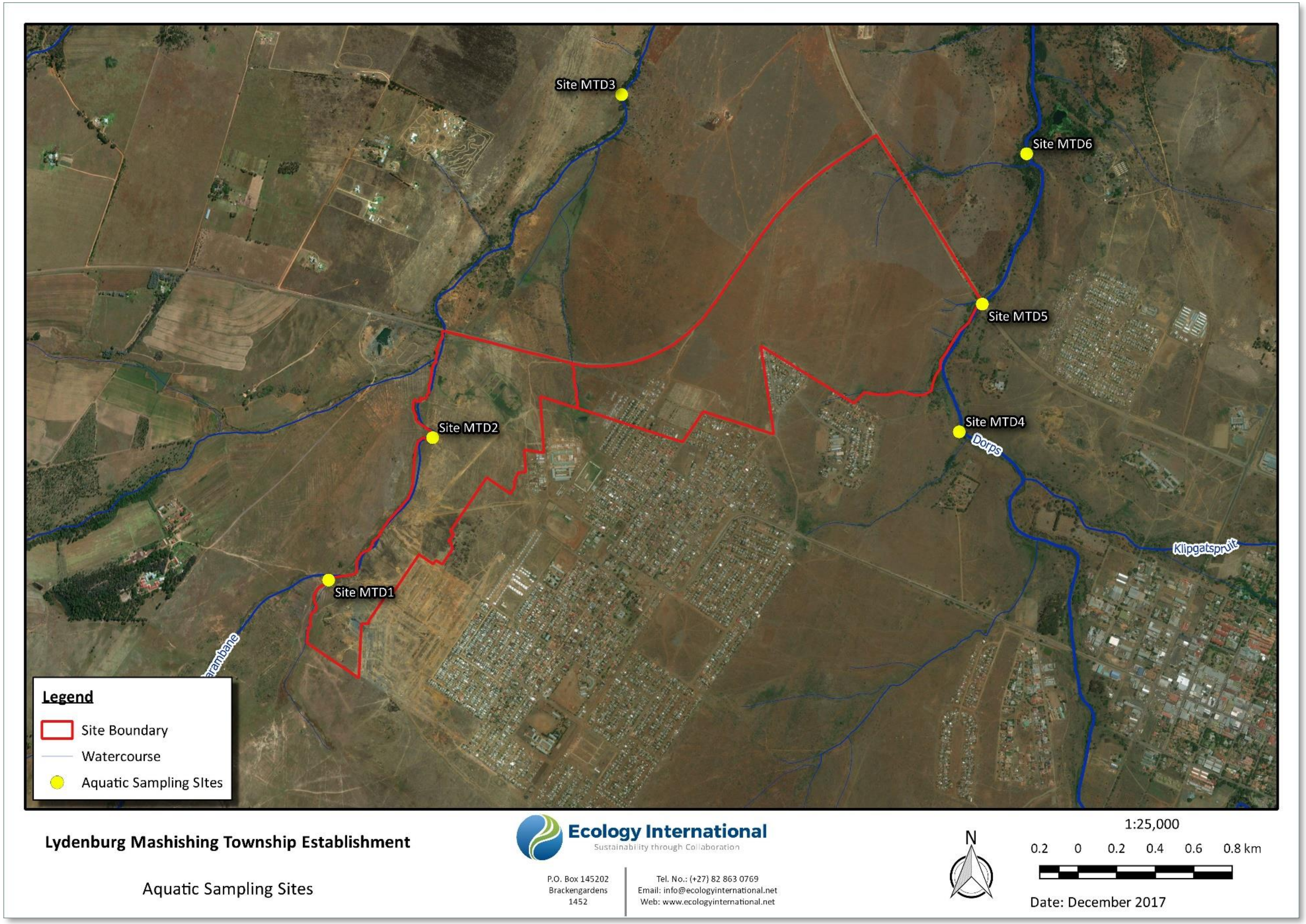


Figure 6: Aquatic sampling sites utilised during the present study

Table 3: *In situ* water quality variables determined at the time of the November 2017 field survey

Site	Temperature (°C)	pH	Electrical conductivity (µS/cm)	Dissolved oxygen	
				(mg/ℓ)	(% sat)
MTD1	25.20	8.43	208.00	7.72	97.10
MTD2	18.70	7.77	241.00	6.01	63.80
MTD3	22.40	7.82	312.00	7.65	88.70
MTD4	20.60	8.15	220.00	8.43	94.50
MTD5	-	-	-	-	-
MTD6	17.60	8.01	226.00	7.82	80.60

Unfortunately, there is very little information available with regards to the salinity tolerances of freshwater organisms in South Africa, although some research is being done by various tertiary institutions in this regard. However, available research does indicate changes in the distribution patterns of individual species or communities can be attributed to changes in salinities. Nevertheless, a number of generalisations can be made based on current research results, including (Dallas & Day, 2004):

- It is often the rate of change rather that the final salinity that is most critical;
- Juvenile stages are often more sensitive to increased salinity concentrations;
- Salinity may act as an antagonist or a synergist in relation to a variety of toxicants; and
- The responses of freshwater organisms to alterations in salinity are likely to be related to the evolutionary origins on the taxon of which they are part.

Figure 7: Raw sewage flowing into Marambane River from the proposed Mashishing Phase A township area downstream of Site MTD2 as a result of failing sewage infrastructure

3.3 Riparian Habitat

Riparian functions have both on-site and off-site effects, some of which may be expressed as goods and services available to society (Table 4). For example, functions related to hydrology and sediment dynamics include storage of surface water and sediment, which reduces damage from floodwaters downstream from the riparian area. Similarly, the function of cycling and accumulating chemical constituents has been measured in a number of studies on nitrogen and phosphorus cycling (National Research Council, 2002). These studies have shown that nutrients are intercepted, to varying degrees, as runoff passes through managed and natural riparian zones. The societal benefit is the buffering effect of pollutant removal, a service that has been a major motivation for protecting and managing riparian areas.

The inclusion of the assessment of riparian elements within the present study should not be considered an exhaustive assessment of the riparian component of the freshwater ecosystem present. Instead, the purpose was to provide a brief overview of the riparian component for the determination of the integrated EcoStatus and riparian delineation. Ideally, the assessment of the riparian elements should to be done using information obtained during the associated ecological assessment. However, the ecological report associated with the proposed township establishment was not available at the time of writing. For a more detailed assessment of the flora associated with the riparian component, the reader is referred to the associated ecological study.

Riparian habitat associated with the Dorps River included graminoids (especially along the marginal zone) such as *Miscanthus junceus, Cyperus sexangularis, Schoenoplectus brachyceras, Pennisetum macrourum* and *Agrostis lachnantha,* whereas woody species included *Combretum erythrophyllum, Searsia spp.* and invasive vegetative species such as *Populus spp*., *Acacia mearnsii*, *Eucalyptus spp*., *Melia azedarach*, *Solanum mauritianum, Sesbania sp., Morus alba,* and *Acacia melanoxylon.* Riparian habitat associated with the Marambane River along the western boundary of the study area was dominated by graminoid species including *Arisitda junciformis, Andropogon appendiculatus, Imperata cylindrica, Pennisetum macrourum, Pennisetum sp., Setaria sphacelate* var*. spachelata, Setaria incrassate* as well as most graminoids mentioned previously.

3.3.1 Present Ecological State

The Present Ecological State of the riparian zone was assessed using the Riparian Vegetation Response Assessment Index (VEGRAI) Level 3 approach (Kleynhans et al., 2007a). The findings of the VEGRAI revealed that riparian habitat associated with the Marambane River within the study area was largely modified (i.e. Ecological Category D), while riparian habit associated with the Dorps River was similarly determined to be largely modified (i.e. Ecological Category D; Table 4). Riparian habitat was typically modified through removal of natural riparian vegetation and replacement by rudimentary and pioneer species as a result in changes to hydrological regimes, overgrazing, as well as cultivation within several sections. Further, basal cover of the riparian zone was completely removed in some sections in order to avoid competition with planted seasonal crops. Several alien invasive plants were observed within the marginal and non-marginal zones of both sections of riparian habitat.

Figure 8: Riparian habitat along the Dorps River

Table 4: Present Ecological State of riparian components of the Marambane River and the Dorps River as determined during the November 2017 assessment following application of the VEGRAI approach (Kleynhans et al., 2007a)

Site	RQO*	VEGRAI Score	Ecological Category
Marambane River	**C**	45.30	**D**
Dorps River	**C**	45.00	**D**

3.4 Aquatic Habitat

3.4.1 Index for Habitat Integrity

The ecological condition of the instream and riparian habitats of the watercourses associated with the proposed Mashishing Township Development was determined through the application of the Index for Habitat Integrity, Version 2 (IHI-96-2; Kleynhans, *pers. comm.*, 2015). While the recently upgraded IHI-96-2 replaces the relatively comprehensive and expensive IHI assessment model developed by Kleynhans (1996), it is important to note that the IHI-96-2 does not replace the IHI model developed by Kleynhans et al. (2008a), which should preferably be applied where sufficient data is available (i.e. intermediate and comprehensive Reserve Determinations). Consequently, the IHI-96-2 model is meant to be used in cases where a relatively large number of river reaches needs to be assessed, budget and time provisions are limited, and/or detailed available information is lacking (i.e. rapid

Reserve Determinations and for River Health Programme purposes). Since time on site was limited at the time of the present study, aerial photography and observations made at each of the assessed sampling points were used to inform the adapted IHI model, which allows for a rapid, field-based, visual assessment of modifications to a number of pre-selected biophysical drivers within a localised portion of the associated hydrogeomorphic unit (Kemper, 1999). Table 5 presents the results obtained following the application of the IHI approach on the watercourses associated with the study area.

Table 5: Index for Habitat Integrity (IHI) values obtained for watercourses associated with the study area during the November 2017 field survey

Reach	RQO*	Component	IHI Score	Ecological Category
Marambane River	**C**	Instream Habitat	61.56	**C**
		Riparian Habitat	39.48	**D/E**
Dorps River	**C**	Instream Habitat	57.84	**D**
		Riparian Habitat	55.47	**D**

* Resource Quality Objectives for Quaternary Catchment (Department of Water and Sanitation, 2016)

During the present study, primary impacts identified within the associated watercourses included the presence of solid waste items in both watercourses, but was more prominent in the Dorps River which was likely a result of adjacent as well as upstream activities. In addition, bed modification within the Marambane River as a result of sediment input and bank erosion was noted, especially within the lower reaches of the study area. Moreover, some inundation of the reach of the Dorps River as a result of DWS Gauging Weir B4H010 located immediately upstream of Site MTD5 was noted. Further, indigenous vegetation removal for the purposes of subsistence agricultural practices by the local community was noted within the riparian component of the Marambane River, while exotic vegetation encroachment was a prominent feature in both watercourses, as was physico-chemical modification as a result of catchment runoff and inflow of raw sewage.

3.4.2 Invertebrate Habitat Assessment Method

The Invertebrate Habitat Assessment System (IHAS, Version 2.2), developed by McMillan (1998), has routinely been used in conjunction with the South African Scoring System (SASS) as a measure for the variability in the amount and quantity of aquatic macroinvertebrate biotopes available for sampling. However, according to a recent study conducted within the Mpumalanga and Western Cape regions, the IHAS method does not produce reliable scores with regard to the suitability of habitat at sampling sites for aquatic macroinvertebrates (Ollis et al., 2006). Furthermore, the performance of the IHAS seems to vary between geomorphologic zones and between biotope groups (Ollis et al., 2006). Therefore, more testing of the IHAS method is required before any final conclusion can be made regarding the accuracy of the index. An adaptation of the IHAS method was, however, retained for the purposes of this assessment, as the basic data remains of value and is suitable for the comparison of sampling efforts across the various sites based on available invertebrate habitat. Results are thus presented relative to an “ideal” aquatic macroinvertebrate sampling habitat, and need to be interpreted with caution taking into consideration the nature of the watercourse surveyed. Results obtained during the November 2017 field survey are presented in Table 6.

Table 6: Adapted IHAS values obtained within the study area during the November 2017 field survey

Site	IHAS Score	Description
MTD1	61.80	**Adequate / Fair**
MTD2	81.82	**Excellent**
MTD3	80.00	**Excellent**
MTD4	67.27	**Good**
MTD5	-	-
MTD6	67.27	**Good**

Based on the scores obtained following the application of the IHAS index, habitat suitability for sampling of aquatic macroinvertebrates was generally considered good to excellent, with the only exception being Site MTD1 which provided limited substrate variability due to the dominance of bedrock, the lack of sufficient stones biotope, and limited contact of water with marginal vegetation due to an incised channel. However, downstream of Site MTD1, habitat regarded as being excellent for sampling of aquatic macroinvertebrates was present, with areas of deposition available where macroinvertebrates associated with gravel and/or sand could be sampled, and the size of the stones present allowed for effective sampling by means of the SASS5 approach. Sedimentation of the riffle habitat as well as the presence of algae was however noticeable at Site MTD3 downstream of the inflow of sewage into the Marambane River, and was expected to impact on the habitat suitability for aquatic macroinvertebrates (Figure 9). In contrast, the reach of the Dorps River assessed was dominated by bedrock-boulder cascades with limited depositional areas, thus limiting the amount of gravel-sand-mud biotope available for sampling. As with the Marambane River, the presence of significant algae on the available substrate was noticeable at all sites assessed along the Dorps River. Nevertheless, invertebrate habitat present within the Dorps River was considered good, with a diversity of hydraulic habitats present at the time of the November 2017 assessment.

3.5 Aquatic Macroinvertebrates

During the November 2017 field survey, a total of 41 aquatic macroinvertebrate taxa ranging from 21 to 30 taxa per site were collected within the study area, while SASS5 scores ranged from 90 to 161, and Average Score Per Taxon (ASPT) values ranged from 4.29 to 5.55 at sites MTD3 and MTD1, respectively (Table 7). A number of taxa regarded as moderately sensitive to water quality impairment were collected during the present study, namely Aeshnidae (Emperor and Hawker Dragonflies), Athericidae (Snipe Flies), Elmidae (Riffle Beetles), Hydracarina (Water Mites), Leptophlebiidae (Prongill Mayflies), Lestidae (Emerald Damselflies), Platycnemidae (Stream Damselflies) and Trichorythidae (Stout Crawler Mayflies). In addition, one taxon regarded as sensitive to water quality impairment was sampled within the Dorps River during the course of the present study, namely Pyralidae (Aquatic Caterpillar), while more than two species of Baetidae were sampled at all but one site (Site MTD5; Appendix C).

Figure 9: Algal growth and sedimentation of stones habitat within the Marambane River at Site MTD3 as a result of catchment runoff and sewage inflow

In general, aquatic macroinvertebrate diversity present within the study area varied, with the highest diversity identified upstream of the sewage inflow into the Marambane River, as well as downstream of the proposed Mashishing Phase B township area on the Dorps River. According to Darwall et al. (2011), approximately 65 species of Odonata (Dragonflies and Damselflies) and 14 species of molluscs have distribution ranges that correlate with the present study area. Further, approximately 64 different aquatic macroinvertebrate families exhibited a potential to occur with the study area based on the ecoregion, longitudinal zone and altitude associated with the study area (Thirion, 2016). Available records for aquatic macroinvertebrates sampled within similar watercourses based on the ecoregion and longitudinal zonation of the watercourses assessed indicate the highest number of taxa collected at a site during a single assessment within the Dorps River in the vicinity of Lydenburg is 38 taxa (Dallas, 2007), suggesting that the diversity observed during the present study was lower than expected. Of particular relevance was the high number of larvae from the genus *Chironomus* (Diptera: Chironomidae) sampled at Site MTD3 during the present study (Appendix C). This genus is generally regarded as being an indicator of organic enrichment, and as such its presence was likely driven primarily by the input of sewage identified between Site MTD2 and Site MTD3.

Table 7: Aquatic macroinvertebrate results obtained from the study area during the November 2017 field survey

Site	SASS5 Score	No. of Taxa	ASPT*
MTD1	161	29	5.55
MTD2	150	29	5.17
MTD3	90	21	4.29
MTD4	108	21	5.14
MTD5	-	-	-
MTD6	153	30	5.10

* Average Score Per Taxon

3.5.1 Present Ecological State

SASS5 data obtained during the present assessment was used in the Macro-Invertebrate Response Assessment Index (MIRAI; Thirion 2008) in order to determine the Present Ecological State according to the most acceptable method. Chutter (1998) developed the SASS protocol as an indicator of water quality. It has since become clear that SASS gives an indication of more than mere water quality, but rather a general indication of the present state of the invertebrate community. Because SASS was developed for application in the broad synoptic assessment required for the River Health Programme (RHP; now the River EcoStatus Monitoring Programme (REMP)), it does not have a particularly strong cause-effect basis. The aim of the MIRAI, on the other hand, is to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community (assemblage) from the reference condition (Thirion, 2008). This does not preclude the calculation of SASS scores should they be required. However, the recent tendency is to use the MIRAI even for River Health Programme purposes, and it is now the preferred approach. Results obtained during the November 2017 field survey are presented in Table 8.

Table 8: Present Ecological State of watercourses assessed during the November 2017 assessment, as determined following application of the MIRAI approach (Thirion, 2008)

Site	RQO*	MIRAI Score	Ecological Category
MTD1	**C**	57.62	**D**
MTD2	**C**	53.42	**D**
MTD3	**C**	35.67	**E**
MTD4	**C**	40.35	**D/E**
MTD5	**C**	-	-
MTD6	**C**	46.49	**D**

* Resource Quality Objectives for Quaternary Catchment (Department of Water and Sanitation, 2016)

Based on the results obtained following the application of the MIRAI approach, it was determined that the reach of the Marambane River upstream of the observed sewage inflow can be regarded as being in a largely impaired state (i.e. Ecological Category D), whereas the reach downstream of the sewage inflow can be regarded as being in a seriously impaired state (Ecological category E; Table 8). Similarly, results obtained for the Dorps River during the present study determined that the reach adjacent to the proposed Mashishing Phase B township area can be regarded as being in a largely/seriously modified state (i.e. Ecological Category D/E), whereas the reach downstream of DWS Gauging Weir B4H010 and upstream of the Lydenburg WWTW effluent release point can be regarded as being in a largely modified state (i.e. Ecological Category D; Table 8). Further, the highest MIRAI score obtained during the present study was obtained at Site MTD1 within the upstream reach of the Marambane River associated with the proposed Mashishing Phase A township area, with the second highest being obtained at Site MTD2. Nevertheless, the ecological categories obtained for all sites were determined to not meet the Resource Quality Objectives for the quaternary catchments within which they were located.

3.6 Ichthyofauna

Based on known distribution ranges, professional judgement, as well as the available habitat noted within the watercourses assessed, a total of eleven (11) indigenous fish species were considered likely to be associated with the assessed reaches of the Marambane River and the Dorps River under natural conditions, of which seven were sampled from the study area during the November 2017 field survey (Table 9). Further, the taxonomy of several species expected to occur within the study area has changed following recent taxonomic studies. The taxonomy as presented within this report is therefore representative of the scientific name valid at the time of writing.

It should be noted that species collected during the present study were identified on the basis of morphological characteristics. However, in the case of *Enteromius cf. anoplus* and *Enteromius sp. 'Ohrigstad'*, an overlap of morphological characteristics exists that make separation between the species difficult from a macroscopic perspective, such that determination by means of genetic analysis will prove more definitive. For the present study, specimens of the Chubbyhead Barb complex (within which both species are located) were tentatively identified as *Enteromius sp. 'Ohrigstad'* based on morphological features as described by da Costa (2012). Although treated as separate species for the present study, the *Enteromius cf. anoplus* and *Enteromius sp. 'Ohrigstad'* species within the catchments associated with the present study area are likely to represent a single undescribed lineage of the Chubbyhead Barb complex, although further detailed taxonomic studies are required to inform this likelihood.

3.6.1 Fish Assemblage and Catch Record

During the November 2017 field survey, a total of 200 individuals comprising seven species were collected within the Marambane and Dorps rivers, with *Enteromius sp. nov. 'South Africa'* noted to dominate the catch with the species contributing to approximately 73% of the total catch during November 2017 (Figure 10). Further *Enteromius. sp. nov. 'South Africa'* was noted to be the dominant species within the Marambane River upstream of the sewage inflow, with the dominance shifting to *Tilapia sparrmanii* downstream of the sewage inflow (Figure 11). However, despite significant sampling effort, a low number of specimens were collected at Site MTD3 (Figure 12), strongly suggesting that the sewage inflow observed is having a marked impact on the fish assemblage within the Marambane River.

Table 9: Indigenous fish species potentially associated with the reaches of the Marambane River and the Dorps River assessed as part of the present study

Scientific Name	Common Name	IUCN Status*	Expected	Confirmed
Amphilius uranoscopus	Stargazer Mountain Catfish	LC	X	
Clarias gariepinus	Sharptooth Catfish	LC	X	X
Enteromius cf. anoplus	Chubbyhead Barb	LC	X	
Enteromius lineomaculatus	Line-spotted Barb	LC	X	
Enteromius paludinosus	Straightfin Barb	LC	X	
Enteromius sp. nov. 'South Africa'	Sidespot Barb	NT	X	X
Enteromius sp. 'Ohrigstad'	Ohrigstad Barb	DD	X	X
Labeobarbus marequensis	Lowveld Largescale Yellowfish	LC	X	X
Labeobarbus polylepis	Bushveld Smallscale Yellowfish	LC	X	X
Pseudocrenilabrus philander	Southern Mouthbrooder	LC	X	X
Tilapia sparrmanii	Banded Tilapia	LC	X	X

* DD – Data Deficient; LC – Least Concern; NT – Near Threatened

Results obtained further indicate a higher diversity of fish species are present within the Dorps River relative to the Marambane River, which is likely attributed to the different sizes of the watercourses assessed and habitat preferences of the individual species. However, analysis of catch-per-unit-effort data suggests that the abundance of fish is lower within the Dorps River relative to the Marambane River particularly those reaches directly adjacent to the proposed Mashishing Phase A and Phase B township areas, despite there being a higher degree of suitable habitat. This was attributed to the impacts present with the Dorps River catchment upstream of the present study area, which is likely to have impacted on the fish assemblage present.

Of interest was the fact that no *Labeobarbus* spp. were collected upstream of DWS Weir B4H010 during the November 2017 assessment, suggesting that the weir is acting as a barrier for movement for fish moving upstream (particularly those species with a requirement for movement between reaches). Although none were collected during the November 2017 assessment, available collection records do however confirm the presence of *Labeobarbus spp.* upstream of the weir. This upstream population of *Labeobarbus spp.* is thus likely to represent a remnant population that have become isolated from downstream populations following the construction of the weir, with genetic flow thus only occurring in a downstream direction.

3.6.2 Present Ecological State

Assessment of the Present Ecological State of the fish assemblage of the watercourses associated with the study are was conducted by means of the Fish Response Assessment Index (or FRAI; Kleynhans, 2008), part of the larger suite of EcoStatus models. The procedure followed to determine the fish Present Ecological State, or Ecological Category, in accordance

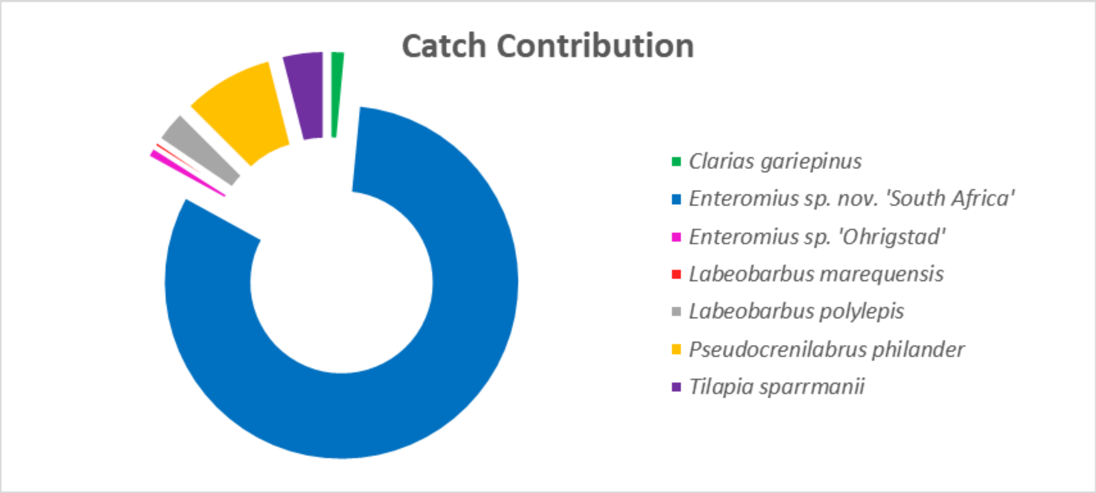


Figure 10: Contribution of species to the total number of fish collected during the November 2017 field survey

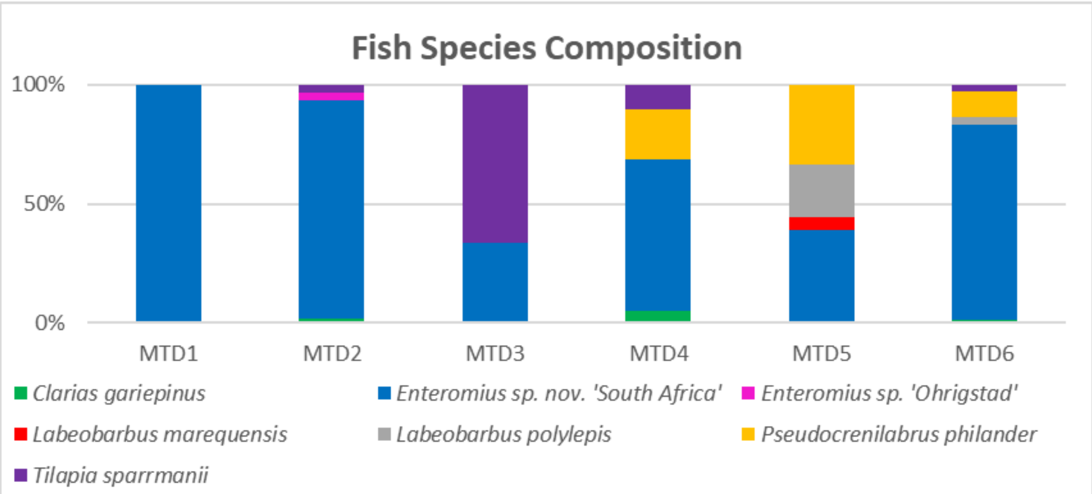


Figure 11: Fish assemblage at each site assessed during the November 2017 field survey

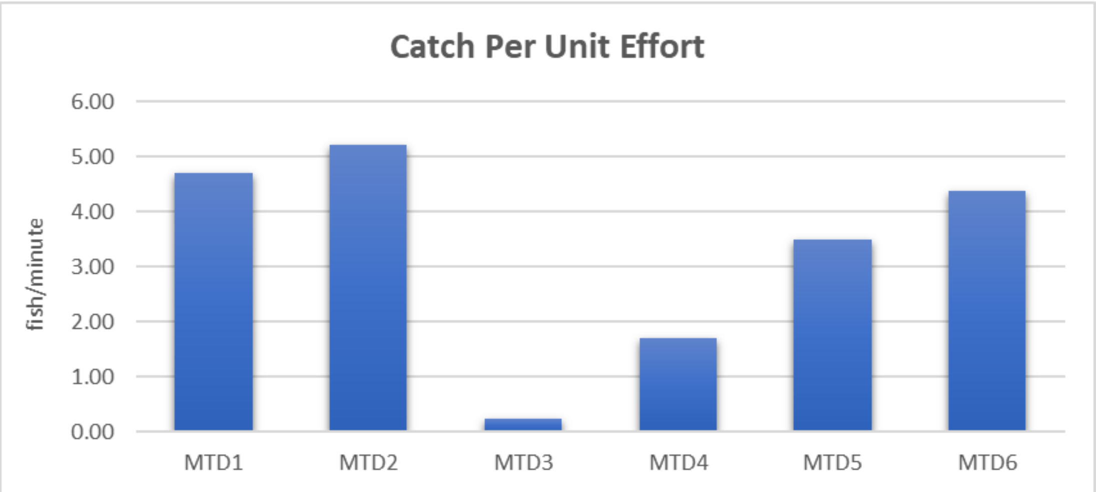


Figure 12: Catch Per Unit Effort (CPUE) for sites assessed during the November 2017 assessment.

with the FRAI methodology is an integration of ecological requirements of fish species in an assemblage and their derived or observed responses to modified habitat conditions. In the case of the present assessment, the observed response was determined by means of fish sampling as well as a consideration of species requirements and driver changes (Kleynhans, 2008).

For the purpose of the present study, the Marambane River was divided into two separate reaches for the application of the FRAI model due to the sewage inflow representing a likely barrier to the upstream movement of fish from the lower reaches. As such, the Marambane River was separated into a reach upstream of the sewage inflow, and a reach downstream of the sewage inflow, thus denoting two fish segments. Similarly, the Dorps River was divided into two separate reaches for the application of the FRAI model, namely a reach upstream of the DWS gauging weir and a reach downstream of the gauging weir. It is however acknowledged that this approach may present a bias towards reaches where more than one site was sampled within the reach.

Based on the results obtained, it was determined that the reach of the Marambane River upstream of the sewage inflow can be regarded as being in a moderately modified state (i.e. Ecological Category C), whereas the ecological state of the Marambane River decreased to a seriously modified state (i.e. Ecological Category E) downstream of the sewage inflow (Table 10). Accordingly, it was determined that the inflow of sewage into the Marambane River is having a significant impact on the state of the fish assemblage present within the lower reaches of the Marambane River, likely preventing the upstream movement of fish species from the mainstem Dorps River.

Similarly, it was determined that the DWS gauging weir present is having an impact on the Dorps River (albeit to a lesser degree than the sewage inflow into the Marambane River), with the upstream reach adjacent to the proposed Mashishing Phase B township area considered to be in a largely modified state (i.e. Ecological Category D), whereas the downstream reach was considered to be in a moderately modified state (i.e. Ecological Category C; Table 10). In both the Marambane River as well as the Dorps River, fish species with an intolerance to no-flow and water quality impairment were lacking from the fish assemblage sampled during the November 2017 assessment.

Table 10: Present Ecological State of watercourses assessed during the November 2017 assessment, as determined following application of the FRAI index (Kleynhans, 2008)

Site	RQO*	FRAI Score	Ecological Category
Marambane River (Adjacent)	**C**	73.00	**C**
Marambane River (Downstream)	**C**	35.10	**E**
Dorps River (Adjacent)	**C**	44.10	**D**
Dorps River (Downstream)	**C**	73.70	**C**

3.7 Species of Conservation Concern

Species of conservation concern are those that are important for South Africa's conservation decision-making processes. For the purposes of this report, species of conservation concern are taken to include those listed as Threatened (Critically Endangered, Endangered or Vulnerable), Extinct in the Wild, Data Deficient, Near Threatened, Critically Rare, Rare and Declining (Raimondo et al., 2009).

Aquatic taxa regarded as being of conservation concern were identified based on confirmed observations and/or on distribution records (known extant and probably extant), while their likelihood of occurrence within the study area was based on the representivity of habitat within the watercourses under study. Conservation categories indicated below are in accordance with those provided by the IUCN based on the assessment of the species on a regional basis (i.e. southern Africa; Darwall et al., 2009). It should however be noted that at the time of writing, the latest Red List assessment for freshwater fish in South Africa was in the process of being collated and finalised by the South African National Biodiversity Institute (SANBI). As such, updated conservation categories have been included for those species where individual species assessments have been finalised and published.

With the exception of Odonata, Mollusca and Crustacea which were assessed by Darwall et al. (2009), the aquatic macroinvertebrate taxa in South Africa have not had their conservation status adequately assessed in terms of the IUCN Red List assessment procedure (James, pers. comm., 2017[1]). Nevertheless, of the aquatic macroinvertebrate taxa that have been assessed by Darwall et al. (2009) and that may occur within the study area, none were determined to be of conservation concern. However, two fish species of conservation concern were confirmed to be present within the study area at the time of the November 2017 field survey, namely:

- *Enteromius sp. nov. 'South Africa'* (Sidespot Barb; currently regarded as Near Threatened; Figure 13). Similar to *Enteromius neefi* Greenwood, 1962 which was described from the Kabompo River in northern Zambia, and identified as *Enteromius sp. 'neefi cf. South Africa'* in Darwall et al. (2009). Populations of the southern *Enteromius cf. neefi* occur in headwater streams of the Limpopo system south to the Phongolo River and south-west into the Vaal River in South Africa and Swaziland. The taxonomic status of the southern *Enteromius cf. neefi* still needs to be determined, but it is likely they are an undescribed species. The recent Red List assessment was based only in the southern *Enteromius cf. neefi* and was referred to as *Enteromius sp. nov. 'South Africa'* (Roux & Hoffman, 2017). Although the geographical distribution is fairly widespread within the Limpopo System in South Africa, many subpopulations are isolated and are severely impacted on by threats. In Swaziland, only a single record was found in over 200 collection sites and it was assessed as regionally Critically Endangered in Swaziland (Bills et al., 2004). The species is experiencing continuous threats such as forestry and associated sedimentation and river crossings preventing

[1] Dr. Helen M. James, Head: Department of Freshwater Invertebrates, Albany Museum. Personal electronic communication, 11 April 2017

fish movement as well as stream regulation and mining with associated pollution. Although, it is known from a large number of locations and is still widespread, the impacts of the multiple threats for the species could lead to its decline and it is thus assessed as Near Threatened within the latest IUCN Red List Assessment, although is it acknowledged that this species should be monitored to assess the impacts of these threats (Roux & Hoffman, 2017); and

- *Enteromius sp. 'Ohrigstad'* (Ohrigstad Barb; currently regarded as Data Deficient; Figure 14). It is recognised that many records currently ascribed to *Enteromius motebensis* and *Enteromius anoplus* in the eastern Lowveld may be synonymous with a new species *Enteromius sp. nov. "Ohrigstad"* proposed by Engelbrecht & Van Der Bank (1996), which was assessed previously as taxonomically Data Deficient by Darwall et al. (2009). Nonetheless, given the taxonomic uncertainty surrounding the 'Ohrigstad' lineage, all records from the Eastern Lowveld catchments were recognised as *Enteromius anoplus* for the purpose of the latest IUCN Red List Assessment, accepting that a taxonomic revision of this group is required (Woodford, 2017). It is however understood that a separate assessment may have been conducted for this lineage during a recent Red List assessment, confirmation of which was still outstanding at the time of writing.

Figure 13: *Enteromius sp. nov. 'South Africa'* (Sidespot Barb; currently regarded as Near Threatened) collected from the Marambane River during the present study, showing colour differences between female (top) and male (bottom) during breeding periods. This species was noted to dominate the catch during the November 2017 assessment

Figure 14: Specimen tentatively identified as *Enteromius sp. 'Ohrigstad'* (Ohrigstad Barb; currently regarded as taxonomically Data Deficient) collected within the Marambane River upstream of the sewage inflow

3.8 Non-native Species

For the purpose of the present study, alien species are defined as those that have been introduced from outside the political boundaries of South Africa, whereas extralimital species are species native to South Africa that have been translocated into areas where they do not naturally occur. Within the context of the present study, non-native species are therefore collectively taken to include both alien and extralimital species.

During the present study, only one non-native species was identified within the study area, namely *Physa acuta* (Physa Snail). Accidentally introduced prior to 1956 (probably in associated with aquatic plants imported through the aquarium trade), this highly invasive species is well distributed throughout most of South Africa, although their impact on indigenous species is unknown (de Moor & Bruton, 1988). According to the unified framework proposed by Blackburn et al. (2011), *Physa acuta* can be classified as fully invasive species, with individuals dispersing, surviving and reproducing at multiple sites across a greater or lesser spectrum of habitats and extent of occurrence.

3.9 Integrated EcoStatus

EcoStatus is defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna, as well as its capacity to provide a variety of goods and services (Iversen et al., 2000). In essence, the EcoStatus represents an ecologically integrated state of a system and represents both the drivers (hydrology, geomorphology and physico-chemical conditions) and the responses (aquatic invertebrates, fish and riparian vegetation) (Kleynhans & Louw, 2008). Results obtained during the present assessment for each site are provided in Table 11.

Following integration of ecological categories obtained for instream and riparian elements during the November 2017 assessment, it was determined that the Marambane River associated with the proposed Mashishing Phase A township area can generally be regarded as being in a largely modified state (i.e. Ecological Category D; Table 11). However, the impact of the inflow of sewage into the Marambane River on the instream components of the watercourse is clearly evident, with the integrated ecological state decreasing to a largely/seriously modified state (i.e. Ecological Category D/E; Table 11).

Table 11: Integrated Present Ecological State of sites assessed during the November 2017 field survey

Response Index	MTD1	MTD2	MTD3	MTD4	MTD6
Aquatic Macroinvertebrates EC	D	D	E	D/E	C
Fish EC	C	C	E	D	D
Instream EC	*C*	*C/D*	*E*	*D*	*C/D*
Riparian Vegetation EC	*D*	*D*	*D*	*D*	-
EcoStatus Category	D	D	D/E	D	C/D

It was similarly determined that the reach of the Dorps River associated with the proposed Mashishing Phase B township area can generally be regarded as being in a largely modified state (i.e. Ecological Category D; Table 11). While the state of riparian component was not determined for the reach of the Dorps River downstream of DWS Gauging Weir B4H010, it was nevertheless determined that the instream component of the watercourse can be regarded as being in a moderately/largely modified state (i.e. Ecological Category C/D; Table 11).

3.10 Ecological Importance and Ecological Sensitivity

Ecological importance refers to biophysical aspects in the sub-quaternary reach that relates to its capacity to function sustainably. In contrast, ecological sensitivity considers the attributes of the sub-quaternary reach that relates to the sensitivity of biophysical components to general environmental changes such as flow, physico-chemical and geomorphic modifications. Essentially, the ecological importance and the ecological sensitivity of the relevant reaches are assessed to obtain an indication of its vulnerability to environmental modification within the context of the Present Ecological State. This would relate to the ability of the sub-quaternary reach to endure, resist, and recover from various forms of human use (Department of Water and Sanitation, 2014).

Following the approach used by the Department of Water and Sanitation (2014), it was determined that the ecological importance of the reach of the Marambane River and the Dorps River associated with the proposed Mashishing Township Establishment can be regarded as high from a riverine biodiversity perspective, with fish rarity relative to the larger secondary catchment regarded as very high, especially considering the assemblage dominance of the Near-Threatened *Enteromius sp. nov. 'South Africa'*, as well as the tentative confirmation of *Enteromius sp. 'Ohrigstad'* within the Marambane River during the present study. Fish representivity was however considered low, while invertebrate representivity and rarity relative to the larger secondary catchment regarded as moderate. Collectively, the Ecological Importance of the Marambane River and the Dorps River associated with the proposed township development was determined to be moderate.

Similarly, ecological sensitivity for can be regarded as high from a riverine biodiversity perspective. This was due to the high sensitivity of fish species and aquatic macroinvertebrate taxa present to altered no-flow conditions (i.e. presence of flow-intolerant species or taxa), as well as the high sensitivity (i.e. moderate intolerance) of fish species and aquatic macroinvertebrate taxa to physico-chemical impairment, including *Enteromius sp. nov. 'South Africa'* and *Enteromius sp. 'Ohrigstad'*. A summary of the Ecological Importance and the Ecological Sensitivity of the associated watercourses is presented in Table 12.

Table 12: Ecological Importance and Ecological Sensitivity of the Marambane River and Dorps River associated with the proposed Mashishing Township Establishment, as determined using results obtained during the November 2017 field survey.

	Ecological Importance	Ecological Sensitivity
Marambane River	**Moderate**	**High**
Dorps River	**Moderate**	**High**

4. ASSOCIATED WETLANDS

4.1 Wetland Soils

According to the Department of Water Affairs and Forestry (DWAF) (2005), the permanent zone of a wetland will always have either Champagne, Katspruit, Willowbrook or Rensburg soil forms present, as defined by the Soil Classification Working Group (1991). The seasonal and temporary zones of the wetlands will have one or more of the following soil forms present (signs of wetness incorporated at the form level): Kroonstad, Longlands, Wasbank, Lamotte, Estcourt, Klapmuts, Vilafontes, Kinkelbos, Cartref, Fernwood, Westleigh, Dresden, Avalon, Glencoe, Pinedene, Bainsvlei, Bloemdal, Witfontein, Sepane, Tukulu, and Montagu. Alternatively, the seasonal and temporary zones will have one or more of the following soil forms present (signs of wetness incorporated at the family level): Inhoek, Tsitsikamma, Houwhoek, Molopo, Kimberley, Jonkersberg, Groenkop, Etosha, Addo, Brandvlei, Glenrosa, and Dundee (Department of Water Affairs and Forestry, 2005).

The traversed catena within the study area resembled a plinthic topo-sequence, especially in the lower lying areas of the study area. Plinthic soils are characterized by their susceptibility to prolonged seasonal wetness due to a fluctuating water table, which creates reducing redox conditions that are expressed as mottles and sometimes Iron and Manganese concretions. Plinthic soils in which the Orthic A horizon grades directly into a plinthic horizon (e.g. Westleigh soil form) were generally not as wet as expected, possibly due to anthropogenic impacts within the catchment. In contrast, soils in which the Orthic A horizon grades indirectly through an E horizon (e.g. Longlands soil form) were relatively wet. Furthermore, presence of an E horizon on plinthic soils such as in the Longlands form generally indicates greater susceptibility to wetness than those soils with a yellow-brown apedal B horizon such as the Pinedene soil form.

However, very few E horizons were sampled during the field survey, with red apedal and red structured soil horizons (Figure 15) dominating within the study area, often within very close proximity of wetland and riparian habitat (e.g. Bloemdal soil form). Poorly drained soils were observed in the wetter section of the hillslope seepage wetlands and comprised mostly of the Katspruit, Rensburg and Willowbrook soil forms. The Katspruit and Willowbrook soil forms identified within the toe of hillslope seepage wetlands present had a G horizon with marked gleyed features indicative of a permanent wetland zone (Figure 16). Terrestrial soil forms identified within the study area included Mispah, Shortlands, Hutton, Augrabies, Lichtenburg, Valsrivier, Oakleaf, Sterkspruit and Witbank soil forms, with such soils within the majority of the wetland catchment being well to very well structured, likely leading to high surface runoff during precipitation events, and may be why very few interflow soils were observed within the study area.

According to the Department of Water Affairs and Forestry (2005), soil wetness indicators (i.e. identification of redoximorphic features) are the most important indicator of wetland occurrence due to the fact that soil wetness indicators remain in wetland soils in most instances, even if they are degraded or desiccated. It is important to note that the presence or absence of redoximorphic features within the upper 500mm of the soil profile alone is sufficient to identify the soil as being hydric (a wetland soil), or non-hydric (non-wetland soil) (Collins, 2005). Several redoximorphic features were present within soil profiles of the delineated wetland areas, including black, orange and red mottles and rhizospheres (Figure 17; Figure 18).

4.2 Wetland Vegetation

According to the Department of Water Affairs and Forestry (2005), vegetation is regarded as a key component to be used in the delineation procedure for wetlands. Vegetation also forms a central part of the wetland definition in the National Water Act, Act 36 of 1998. Using vegetation as a primary wetland indicator however, requires undisturbed conditions (Department of Water Affairs and Forestry, 2005). A cautionary approach must therefore be taken as vegetation alone cannot be used to delineate a wetland, as several species, while common in wetlands, can occur extensively outside of wetlands. When examining plants within a wetland, a distinction between hydrophilic (vegetation adapted to life in saturated conditions) and upland species must be kept in mind. There is typically a well-defined 'wetness' gradient that occurs from the centre of a wetland to its edge that is characterized by a change in species composition between hydrophilic plants that dominate within the wetland to upland species that dominate on the edges of, and outside of the wetland (Department of Water Affairs and Forestry, 2005). It is important to identify the vegetative indicators which determine the three wetness zones (temporary, seasonal and permanent) which characterize wetlands. Each zone is characterized by different plant species which are uniquely suited to the soil wetness within that zone.

The majority of the study area had been disturbed through various historic and current anthropogenic practices. Permanent zonation areas and associated high water tables contained hydrophilic plants such as *Kyllinga melanosperma, Pycreus mundtii, Schoenoplectus brachyceras, Juncus* sp., *Typha capensis*, *Juncus* sp., *Cyperus sexangularis, Phragmites australis,* as well as several invasive species. From a vegetation point of view, the temporary and seasonal zones of the hillslope seepage wetland were not always clearly distinguishable as a result of surface impacts and subsurface hydrological impacts. These have in turn resulted

Figure 15: Erosion donga exposing red structured soils within the study area

Figure 16: Willowbrook exposed soil form indicating melanic soil form (black arrow) and gleyed G horizon (white arrow) within the toe of a hillslope seepage wetland

Figure 17: Augered sample of plinthic horizon with black mottles likely to be manganese

Figure 18: Orange rhizospheres and orange mottles within a gleyed grey reduced matrix sampled within a low-lying area of a hillslope seepage wetland

in successional changes in the vegetation composition, as evident by disturbance indicators such as *Cynodon dactylon, Pennisetum clandestinum, Argemone ochroleuca, Bidens sp.*, *Datura stramonium, Solanum sisymbriifolium* and *Verbena bonariensis*. Several sections contained a mixture of obligatory wetland, facultative wetland and terrestrial species such as *Pennisetum macrourum, Agrostis lachnantha, Miscanthus junceus, Paspalum scrobiculatum*, *Eragrostis curvula, Eragrostis chloromelas, Imperata cylindrica*, *Becium obovatum, Felicia muricate, Hilliardiella oligocephala, Lobelia flaccida*, *Monopsis decipiens*, *Hypoxis spp.* and *Trachyandra spp.* Similarly, David Hoare Consulting (2018) identified various natural and artificial hygrophilous vegetation units within the study area that had characteristics that indicate that it experiences at least seasonally elevated soil moisture conditions in that they are dominated by facultative wetland sedge, grass and forb species. Much of this vegetation was however likely a result of opportunistic establishment as a result of the saturated conditions brought about by failing infrastructure identified within the study area (most notably within the proposed Mashishing Phase A township area)

4.3 Delineated Wetland and Riparian Areas

According to the National Water Act (Act no 36 of 1998) a wetland is defined as, "*land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil*." A piece of land is therefore considered a wetland when the period of saturation is sufficient to allow for the development of hydric soils which under normal circumstances support, or would support, hydrophytic vegetation.

Wetlands typically occur on the interface between aquatic and terrestrial habitats and therefore display a gradient of wetness – from permanent, to seasonal, to temporary zones of wetness - which is represented in their plant species composition, as well as their soil characteristics. It is important to take cognisance of the fact that not all wetlands have visible surface water - an area which has a high water table just below the surface of the soil is as much a wetland as a pan that only contains water for a few weeks during the year.

Hydrophytes and hydric soils are generally used as the two main wetland indicators. The presence of these two indicators is symptomatic of an area that has sufficient saturation to classify the area as a wetland. However, vegetation is quick to react to changes in hydrology, and as a result the presence of hydrophytic vegetation is not always representative of the natural hydrological regime as it would be under normal circumstances that would otherwise present hydric soil indicators. It is due to these challenges that emphasis is placed on identifying wetlands by applying the hydric soils criterion, and the presence of hydric soils are therefore considered suitable for identifying land which "in normal circumstances supports or would support vegetation that is typically adapted to life in saturated soils" as per the definition of the National Water Act (Act 36 of 1998). The presence of hydric soils criterion is therefore seen as the primary criterion for the delineation of wetlands, while hydrological and hydrophytic vegetation are mostly used to confirm the finding of the hydric soils criterion (Collins, 2005). Terrain unit which is another indicator of wetland areas and refers to the land unit in which the wetland is found, although wetlands can occur across all terrain units from the crest to valley bottom.

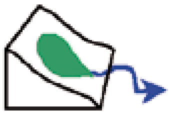
In practice all indicators should be used in any wetland assessment / delineation exercise, the presence of redoximorphic features being most important, with the other indicators being confirmatory. An understanding of the hydrological processes active within the area is also considered important when undertaking a wetland assessment. Indicators should be 'combined' to determine whether an area is a wetland and to delineate the boundary of a wetland. According to the DWAF delineation guidelines, the more wetland indicators that are present the higher the confidence of the delineation. In assessing whether an area is a wetland, the boundary of a wetland or a non-wetland area should be considered to be the point where indicators are no longer present.

In the present study however, the disturbance caused by anthropogenic impacts and resulting vegetation changes made using vegetation indicators complex in various circumstances, especially on the temporary boundaries of wetlands. Therefore, identifying wetland features on-site was primarily done by identifying terrain unit, soil forms and soil wetness features such as the presence of mottling, a gleyed matrix and/or Fe and Mg concretions. It should be noted that various natural and artificial hygrophilous vegetation units occurred throughout the study area (David Hoare Consulting, 2018) due in large part to leaking or failing municipal water and sewage lines but were not included within the delineation of wetland areas within the context of the present study. While these areas did present hydrophytic vegetation that may be attributed to the saturated conditions brought about by the failing infrastructure, it is likely that the period of saturation has been insufficient or of such a nature to not allow for the development of hydric soil indicators such as hydric soil forms and redoximorphic features within the associated soils, as several auger points within these areas presented soil forms reminiscing of terrestrial soil forms. It is however acknowledged that over time, prolonged saturation within these areas would in all likelihood result in the development of hydric soil features that would classify these areas as wetlands. In contrast however, should such failing infrastructure be upgraded or repaired, it is likely that these saturated areas will cease to exist, and it is unlikely such hydric soil features would develop.

Areas in the north-eastern portion of the proposed Mashishing Phase B township area similarly supported hydrophytic vegetation but lacked hydric soil features within the upper reaches of the catchment that would otherwise classify these areas as true wetland areas. Further, several A Section channels leading to the Dorps River were identified within the eastern portion of the proposed Mashishing Phase B development area. A Section channels are those headward channels that are situated well above the zone of saturation at its highest level and because the channel bed is never in contact with the zone of saturation, these channels do not carry baseflow. They do however carry storm runoff during fairly extreme rainfall events but the flow is of short duration (Department of Water Affairs and Forestry, 2005). It is important to note that these steep, eroding, headward watercourses do not have a riparian habitat (in terms of the definition in the National Water Act, Act 36 of 1998) because they are too steep to be associated with deposition of alluvial (or hydromorphic) soils and are not flooded with sufficient frequency to support vegetation of a type that is distinct from the adjacent land areas (Department of Water Affairs and Forestry, 2005). As such, A Section channels are not considered to constitute part of the Regulated Area for consideration in Water Use Licence requirements and were thus not delineated during the present study.

Accordingly, one hydro-geomorphic (HGM) type, a hillslope seepage connected to a watercourse, was identified during the present study and classified into four separate HGM units located across the area (Figure 19). Table 13 describes the characteristics that form the basis for the classification of the HGM units identified within the study area. It should also be emphasized that wetlands within the study area were confirmed through field investigations, whereas areas outside the boundaries of the study area were often extrapolated. Confidence for the delineations of extrapolated wetland boundaries were therefore moderate.

Table 13: Wetland hydro-geomorphic types typically supporting inland wetlands in South Africa within the study area (adapted from Kotze et al., 2008))

Hydro-geomorphic types	Description	Source of water maintaining the wetland[1]	
		Surface	**Sub-surface**
Hillslope seepage connected to a watercourse 	Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from sub-surface flow and outflow is usually via a well-defined stream channel connecting the area directly to a stream channel.	*	***

[1] Precipitation is an important water source and evapotranspiration an important output in all of the above settings

Water source: * Contribution usually small

*** Contribution usually large

*/ *** Contribution may be small or important depending on the local circumstances

Wetland

In addition to the wetland units delineated, two sections of riparian habitat were also delineated, one section on the eastern boundary associated with the Dorps River and the other section on the western boundary associated with the Marambane River (Figure 19). According to the Department of Water Affairs and Forestry (2005), riparian zones can be distinguished from adjacent terrestrial areas through their association with the physical structure (banks) of the river or stream, as well as the distinctive structural and compositional vegetation zones between the riparian and upland terrestrial areas. Unlike wetland areas, riparian zones are usually not saturated for a long enough duration for redoximorphic features to develop. Riparian zones instead develop in response to (and are adapted to) the physical disturbances caused by frequent overbank flooding from the associated river or stream channel (Department of Water Affairs and Forestry, 2005).

4.4 Functional and Present Ecological State Assessment

Wetlands within the study area serve to improve habitat within and potentially downstream of the study area through the provision of various ecosystem services. Many of these functional benefits therefore contribute directly or indirectly to increase biodiversity within the transformed study area as well as downstream of the study area through provision and maintenance of appropriate habitat and associated ecological processes (Table 14).

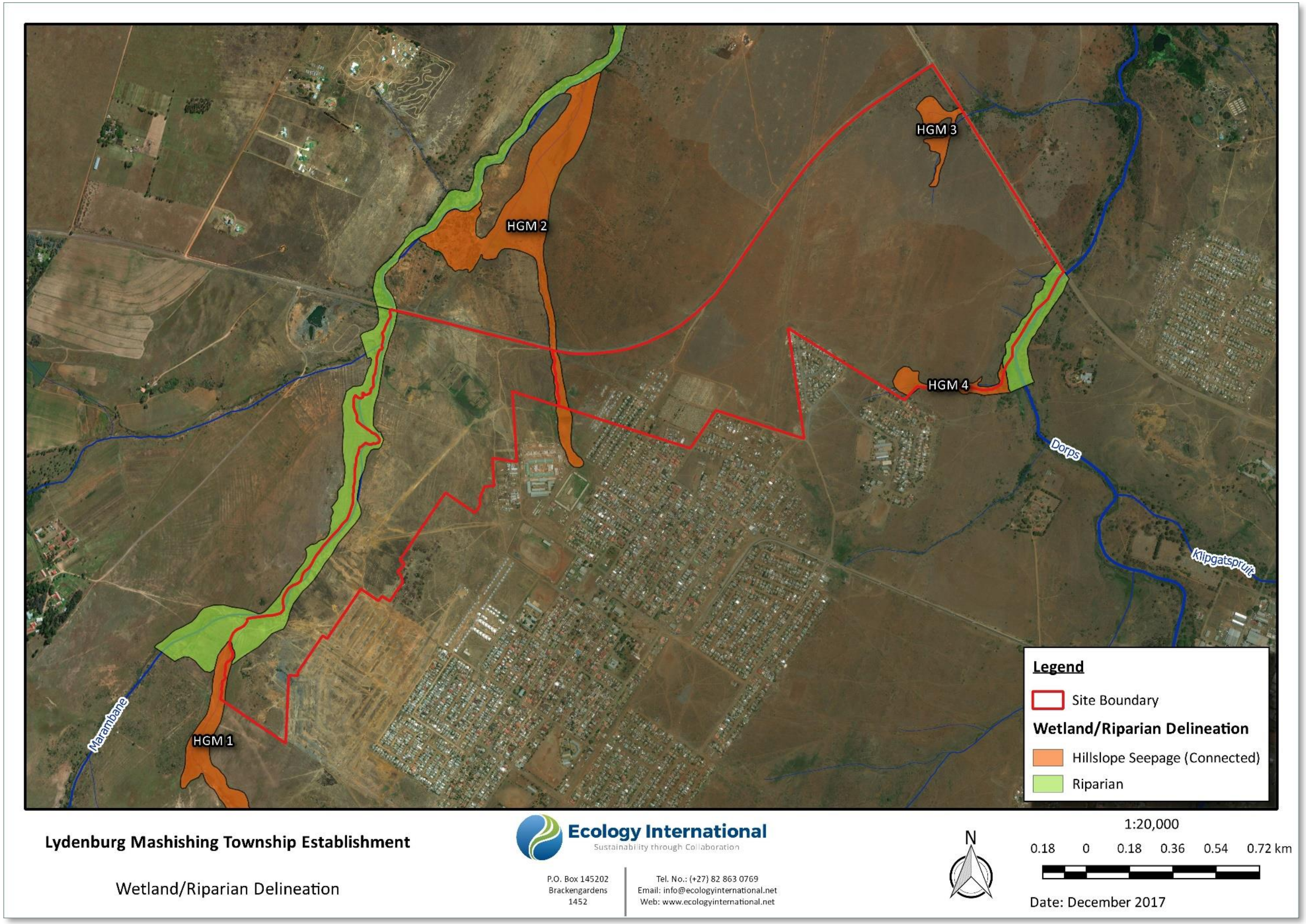


Figure 19: Wetland and riparian delineation for the study area

Table 14: Potential wetland services and functions in study area

Function	Aspect
Water balance	Streamflow regulation
	Flood attenuation
	Groundwater recharge
Water purification	Nitrogen removal
	Phosphate removal
	Toxicant removal
	Water quality
Sediment trapping	Particle assimilation
Harvesting of natural resources	Reeds, Hunting, etc.
Livestock usage	Water for livestock
	Grazing for livestock
Crop farming	Irrigation

Hydro-geomorphic units are inherently associated with hydrological characteristics related to their form, structure and particularly their position in the landscape. This, together with the biotic and abiotic character (or biophysical environment) of wetlands in the study area, means that these wetlands are able to contribute better to some ecosystem services than to others (Kotze et al., 2008).

The highest scoring eco-services attributes for the hillslope seepage wetland within the study area were streamflow regulation, sediment trapping, phosphate trapping, nitrate and toxicant removal (Figure 20; Figure 21; Figure 22; Figure 23). The accumulation of organic matter and fine sediments in the wetland soils results in the wetland slowing down the sub-surface movement of water down the slope. This “plugging effect” increases the storage capacity of the slope above the wetland, and prolongs the contribution of water to the stream system during low flow periods (Kotze et al., 2008). Seepage wetlands are commonly considered to supply a number of water quality enhancement benefits, for example, removing excess nutrients and inorganic pollutants produced by agriculture, industry and domestic waste (Rogers et al., 1985; Gren, 1995; Ewel, 1997; Postel & Carpenter, 1997). Hillslope seepage wetlands generally would be expected to have a relatively high nitrogen removal potential. Nitrogen, and specifically nitrate removal, could be expected as the groundwater emerges through low redox potential zones within the wetland soils, with the wetland plants contributing to the necessary supply of organic carbon. Particularly effective removal of nitrates has been recorded from diffuse sub-surface flow, as characterizes hillslope seepages (Muscutt et al., 1993). Various agricultural and domestic activities taking place within the catchment of the seepage wetlands would likely act as a source of nitrates, toxicants and phosphates. A few shallow water pools are present which would promote sunlight penetration, contributing to the photodegradation of certain toxicants. In addition, the seepage wetlands are expected to contribute to biodiversity through potentially serving as a movement corridor for faunal species as well as through the provision of habitat, albeit to a limited degree. Further, from a natural resource utilisation perspective, seepage wetlands within the study area were observed to be utilised for grazing, stock watering and within HGM 1, planting of crops.

It should be noted that the assessment of eco-services according to the Wet-EcoServices approach determines likely ecosystem services based on inherent features of the wetlands. However, ecosystem service delivery of the wetlands has potentially been reduced as a result of anthropogenic impacts present.

Degradation of wetlands through impacts in catchments or in wetlands themselves is resulting in the reduction and loss of their functional effectiveness and ability to deliver ecosystem services or benefits to humans and the environment (Kotze et al., 2008). The set relationships allow the provision of ecosystem services to be inferred from the determination of wetland health (or Present Ecological State) and presented as healthy wetland hectare equivalents. Wet-Health results obtained for the various hillslope seepage wetlands within the study area are discussed in more detail below. Overall impacts and Present Ecological State scores for HGM 2, HGM 3 and HGM 4 were very similar, and were therefore discussed collectively in order to avoid repetition

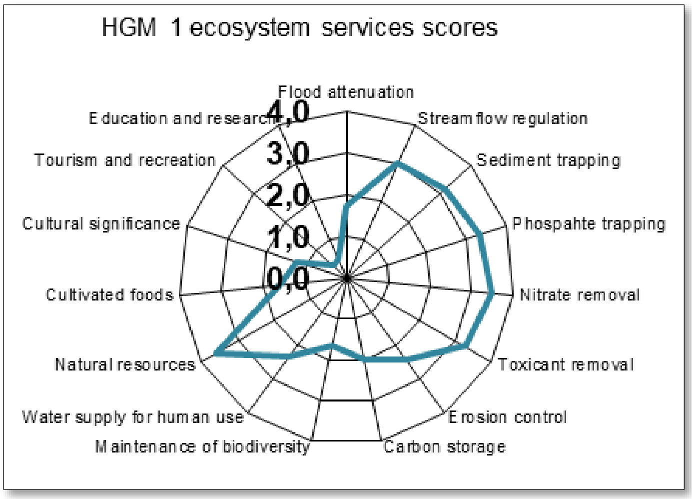


Figure 20: Radar diagram of potential ecosystem services provided by HGM 1

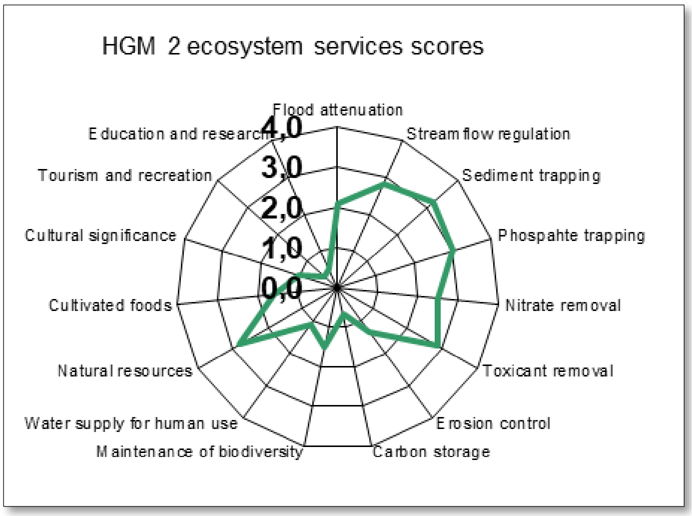


Figure 21: Radar diagram of potential ecosystem services provided by HGM 2

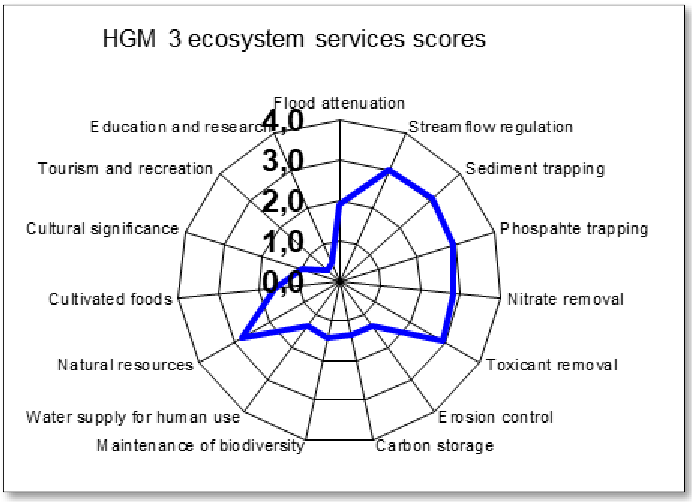


Figure 22: Radar diagram of potential ecosystem services provided by HGM 3

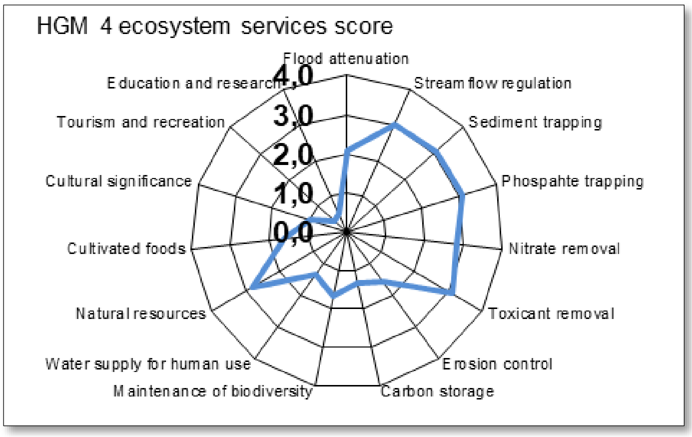


Figure 23: Radar diagram of potential ecosystem services provided by HGM 4

HGM 1

Present Ecological State scores obtained for the hydrology module of HGM 1 indicated that water inputs derived from the wetland's catchment have been moderately modified, and that water retention and distribution patterns within HGM 1 have also been moderately modified. Changes in flow patterns within the catchment of the wetland include some dirt roads, reduced basal cover, drainage channels as well as high density residential and informal settlements in a segment of the wetlands catchment. However, a relatively large section of the catchment is still semi natural in terms of associated flow patterns and regimes.

Nevertheless, distribution and retention patterns of water within the wetland itself has been negatively impacted by cultivation and heavy grazing regimes reducing basal cover. It is especially the lower toe end section of the hillslope seepage where the seepage wetland joins the Marambane River and the gradient relaxes (making the area suitable for cultivation) that the high utilisation and initiation of erosional process has resulted in channel formation within the wetland.

Further, vegetation composition changes of the hillslope seepage wetland were not considered a major factor, as the majority of the hillslope seepage was composed of indigenous graminoid species. However, the more intensely utilised lower-lying toe end contained areas dominated by weeds and rudimentary species or was otherwise dominated by graminoids categorised as Increasers (e.g. *Cynodon dactylon, Eragrostis chloromelas* and *Eragrostis curvula*).

Overall HGM 1 was determined to represent a moderately modified system (i.e. Ecological Category C; Table 15), based on the Wet-Health approach.

Table 15: Wet-Health scores for HGM 1

Wetland size	Hydrology	Geomorphology	Vegetation	Ecological Category	Healthy hectare equivalent
6.9 ha	3.0	1.6	2.6	**C (2.5)**	5.2 ha

HGM 2, HGM 3 and HGM 4

Present Ecological State scores obtained for the hydrology module indicated that water inputs derived from the wetlands catchment's have been severely modified and that water retention and distribution patterns within the wetlands themselves have been moderately to seriously modified. Changes in flow patterns within the catchment of the wetlands include formal and informal road infrastructure, drainage channels, high density residential and informal settlements with associated electricity, sewage and water infrastructure. The removal of natural basal cover and the substantial increase in hardened surface and modified flow paths has increased flood peak delivery to the wetlands. In addition, there were several municipal and sewage leaks within each of the hillslope seepages catchments (Figure 24), substantially increasing the amount of water received by the wetlands.

In addition, distribution and retention patterns of water within the wetlands has been negatively impacted by infilling, excavations, road infrastructure, stormwater infrastructure, as well as several smaller drainage channels and linear infrastructure developments. Typically, where concentrated flows enter the wetlands, small erosion features were present, followed immediately by sediment deposition.

Vegetation composition changes of the hillslope seepage wetland was also a considerable driver of the ecological categories obtained. Due to the nature of historic and current land uses within the catchment, species composition within the wetlands have changed relative to the perceived natural condition or benchmark. Surface roughness within the wetlands have also been reduced as a result of successional changes which caused reduced basal cover in many areas, likely through historic heavy grazing regimes and infrastructure development.

Overall, HGM 2, HGM3 and HGM 4 were determined to represent largely modified systems (i.e. Ecological Category D; Table 16), based on the Wet-Health approach.

Table 16: Wet-Health scores for HGM 2, HGM 3 and HGM 4

HGM Unit	Wetland size	Hydrology	Geomorphology	Vegetation	Ecological Category	Healthy hectare equivalent
HGM 2	20.2 ha	7.5	2.5	6.0	D (5.6)	8.9 ha
HGM 3	4.1 ha	7.0	2.8	5.5	D (5.4)	1.9 ha
HGM 4	2.4 ha	7.2	2.6	5.0	D (5.3)	1.1 ha

Figure 24: Typical sewage leak and dirt road observed within study area during the November 2017 assessment

4.5 Ecological Importance and Sensitivity

All wetlands, rivers, their flood zones and their riparian areas are protected by law and no development is allowed to negatively impact on rivers and river vegetation. The vegetation in and around rivers and drainage lines plays an important role in water catchments, assimilation of phosphates, nitrates and toxins as well as flood attenuation. Quality, quantity and sustainability of water resources are fully dependent on good land management practices within the catchment. All flood lines, riparian zones and wetlands along with corresponding buffer zones must be designated as sensitive.

The Ecological Importance and Sensitivity (EIS) assessment was undertaken to rank water resources in terms of:

- Provision of goods and service or valuable ecosystem functions which benefit people;
- Biodiversity support and ecological value; and
- Reliance of subsistence users (especially basic human needs uses).

Water resources which have high values for one or more of these criteria may thus be prioritised and managed with greater care due to their ecological importance (for instance, due to biodiversity support for endangered species), hydrological functional importance (where water resources provide critical functions upon which people may be dependent, such as water quality improvement) or their role in providing direct human benefits (Rountree et al., 2013). Ecological Importance and Sensitivity results for each of the four HGM units identified to be associated with the study area are listed in Table 17.

Table 17: Ecological Importance and Sensitivity scores for wetland complexes

Wetland Complex	Parameter	Rating (0 -4)	Confidence (1 – 5)
HGM 1 (Hillslope seepage wetland)	**Ecological Importance & Sensitivity**	**Low** (1.9)	2.0
	Hydrological / Functional Importance	**Moderate** (2.4)	2.5
	Direct Human Benefits	**Moderate** (2.3)	2.5
HGM 2 (Hillslope seepage wetland)	**Ecological Importance & Sensitivity**	**Low** (1.7)	2.4
	Hydrological / Functional Importance	**Moderate** (2.3)	2.5
	Direct Human Benefits	**Low** (1.2)	2.5
HGM 3 (Hillslope seepage wetland)	**Ecological Importance & Sensitivity**	**Low** (1.7)	2.4
	Hydrological / Functional Importance	**Moderate** (2.3)	2.5
	Direct Human Benefits	**Very low** (1.2)	2.5
HGM 4 (Hillslope seepage wetland)	**Ecological Importance & Sensitivity**	**Low** (1.7)	2.4
	Hydrological / Functional Importance	**Moderate** (2.3)	2.5
	Direct Human Benefits	**Very low** (1.2)	2.5

The hillslope seepage wetlands were determined to have a low Ecological Importance and Sensitivity, mostly as a result of the lack of species of conservation concern present. However, the potential for species of conservation concern to be present with the seepage wetlands still exists, especially later in the season. Further, the hillslope seepage wetlands were regarded as having a moderate Hydrological and Functional Importance due to the potential ecosystem services they provide, especially in terms of trapping and nitrate removal. In addition, direct human benefits were regarded as moderate within HGM 1 due to the grazing, stock watering and production of cultivated crops within the wetland unit, whereas direct human benefits associated with HGM 2, HGM 3 and HGM 4 were regarded as very low as the hillslope seepages are not noted as being utilised at the time of the November field survey.

5. FRESHWATER ECOSYSTEM BUFFERS

Buffer zones associated with water resources have been shown to perform a wide range of functions and have been proposed as a standard measure to protect water resources and associated biodiversity on this basis. These functions can include (Macfarlane & Bredin, 2016):

- Maintaining basic aquatic processes;
- Reducing impacts on water resources from upstream activities and adjoining land uses;

- Providing habitat for aquatic and semi-aquatic species;
- Providing habitat for terrestrial species; and
- A range of ancillary societal benefits.

However, despite the range of functions potentially provided by buffer zones, buffer zones are unable to address all water resource-related problems. For example, buffers can do little to address impacts such as hydrological changes caused by stream flow reduction activities or changes in flow brought about by abstractions or upstream impoundments. Buffer zones are also not the appropriate tool for mitigating against point-source discharges (e.g. sewage outflows), which can be more effectively managed by targeting these areas through specific source-directed controls (Macfarlane & Bredin, 2016).

Nevertheless, buffer zones are well suited to perform functions such as sediment trapping and nutrient retention which can significantly reduce the impact of activities taking place adjacent to water resources. Buffer zones are therefore proposed as a standard mitigation measure to reduce impacts linked with diffuse storm water runoff from land-uses / activities planned adjacent to water resources. These must, however, be considered in conjunction with other mitigation measures which may be required to address specific impacts for which buffer zones are not well suited (Macfarlane & Bredin, 2016).

Determination of the preliminary buffer requirements for riverine and wetland features associated with the proposed Mashishing Township Establishment followed the approach of Macfarlane & Bredin (2016), whereby the required buffers were developed based on various factors, including assumed housing densities, slope, annual precipitation, rainfall intensity, channel width, catchment to wetland ratio, etc. Given that the slope in the study area is not consistent, a variable buffer width was applied to the identified watercourses, resulting in preliminary riverine buffers which ranged from 61m to 75m (Figure 25), whereas the preliminary wetland buffers ranged from 52m to 55m (Figure 26). The final integrated watercourse buffer determinations for the watercourses associated with the proposed Mashishing Township Establishment was therefore taken to include the extent of the riparian area, buffer area for riverine components, or the buffer area determined for the wetland components, whichever was greater (Figure 27). However, given the preliminary nature of the information available for the proposed activity, buffers as determined following the approach of Macfarlane & Bredin (2016) should be regarded as preliminary and subject to change based on final proposed design and layout, final proposed housing densities, applicability of mitigation measures, etc.

It should further be noted that the importance of other functions associated with riverine and wetland features such as the provision of habitat necessary for wetland-dependant species needing both aquatic and terrestrial habitats, was not catered for within the present study, as the present study was done in isolation to the ecological assessment. As such, the results obtained for the ecological assessment associated with the proposed activity will need to be incorporated within the final buffer zone requirements of the proposed development (including possible additional management buffers).

5.1 Sensitivity Mapping

A comprehensive sensitivity mapping methodology has been developed by EIMS for use by all specialists in order to standardise the scoring system which allows for a comparative assessment of all impacts. The methodology utilises a revised scoring table as well as including a base score for the entire study area in question (Table 18). This deviated from the past approach where features were scored based on their inherent sensitivity. According to the sensitivity mapping approach applied by EIMS, features/areas should be scored in terms of the proposed project context and not purely on "perceived sensitivity of landscape features". Thus, the specialist should continually be asking themselves the question "how will this feature be affected by the proposed development".

Table 18: Sensitivity ratings and weighting

Sensitivity Rating	Description	Scoring/Weighting	Preference
Least Concern	The inherent feature status and sensitivity is already degraded. The proposed development will not affect the current status and/or may result in a positive impact. These features would be the preferred alternative for mining or infrastructure placement.	-1	Preferable
Low/Poor	The proposed development will not have a significant effect on the inherent feature status and sensitivity.	0	
High	The proposed development will negatively influence the current status of the feature.	+1	
Very High	The proposed development will negatively significantly influence the current status of the feature.	+2	Restricted

Ecological importance and sensitivity of the riverine and wetland features as presented in Section 3.10 and Section 4.5, respectively, were determined through consideration of features associated with each feature. In contrast, the determination of required buffer zones following the approach of Macfarlane & Bredin (2016) is particularly appropriate for determining sensitives by means of the EIMS approach, as the approach specifically takes into consideration the proposed land use and the impact thereof on the associated water resources based on various factors which may influence the degree of impact on the water resource. Given the preliminary nature of the determined buffer zones and the proposed functionality for which the buffer zone was determined (based on the associated proposed land use) and the purpose of limiting impacts on the associated watercourses, the sensitivity of the buffer zones should be regarded as very high according to the approach of EIMS, pending the provision of additional information pertaining to the proposed activity (Figure 28).

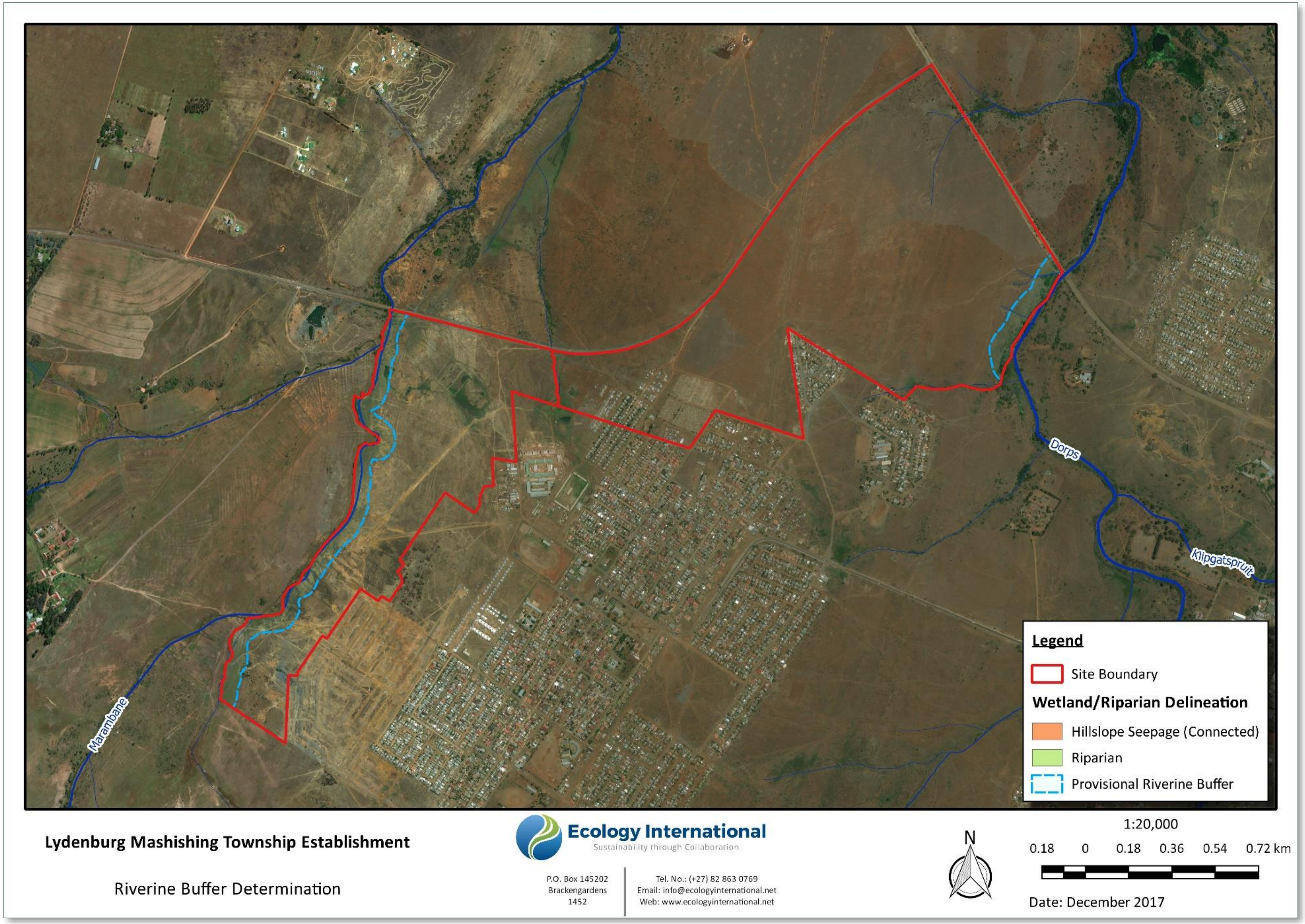


Figure 25: Buffers determined for the riverine component according to the approach of Macfarlane & Bredin (2016)

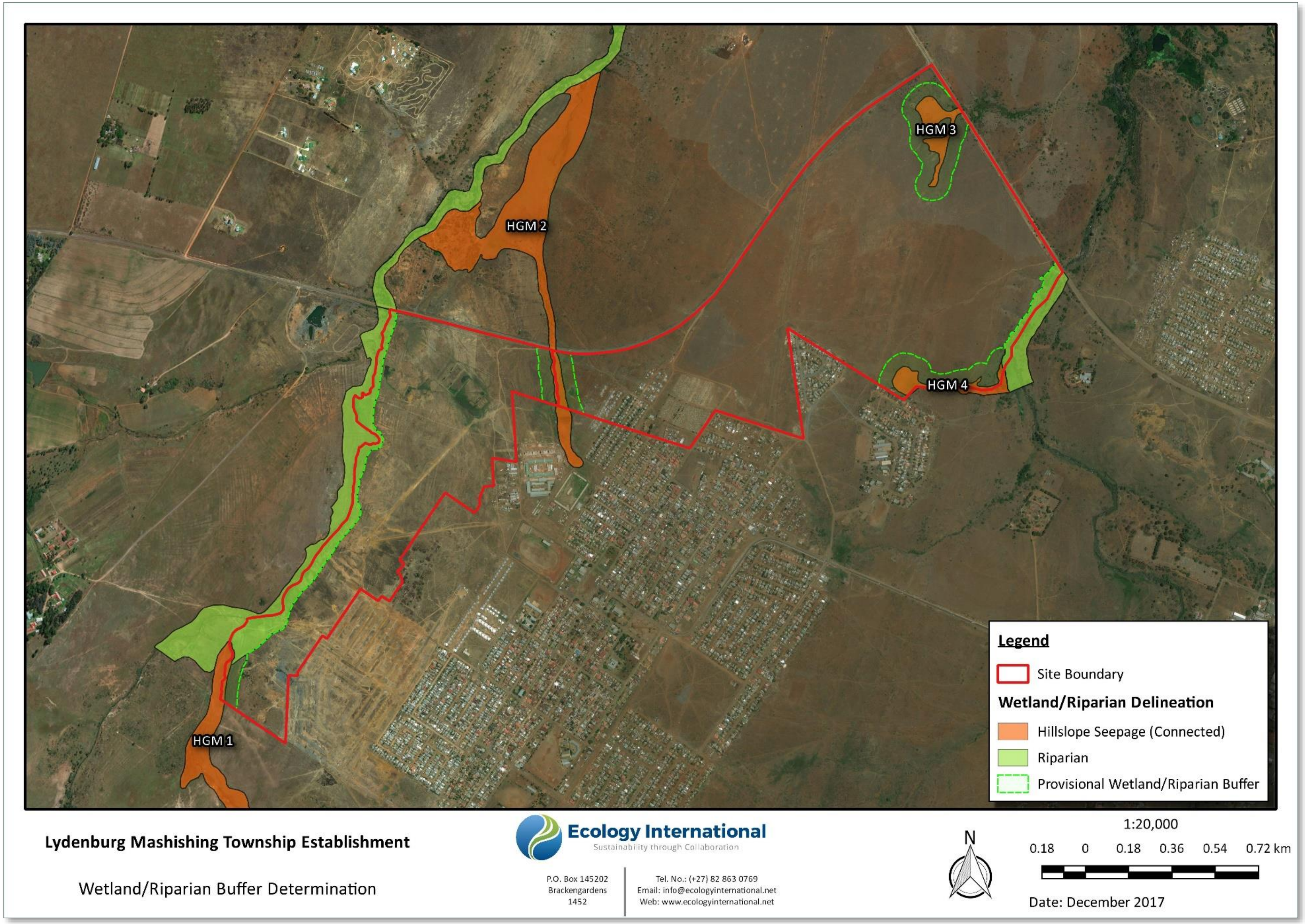


Figure 26: Buffers determined for the wetland and riparian component according to the approach of Macfarlane & Bredin (2016)

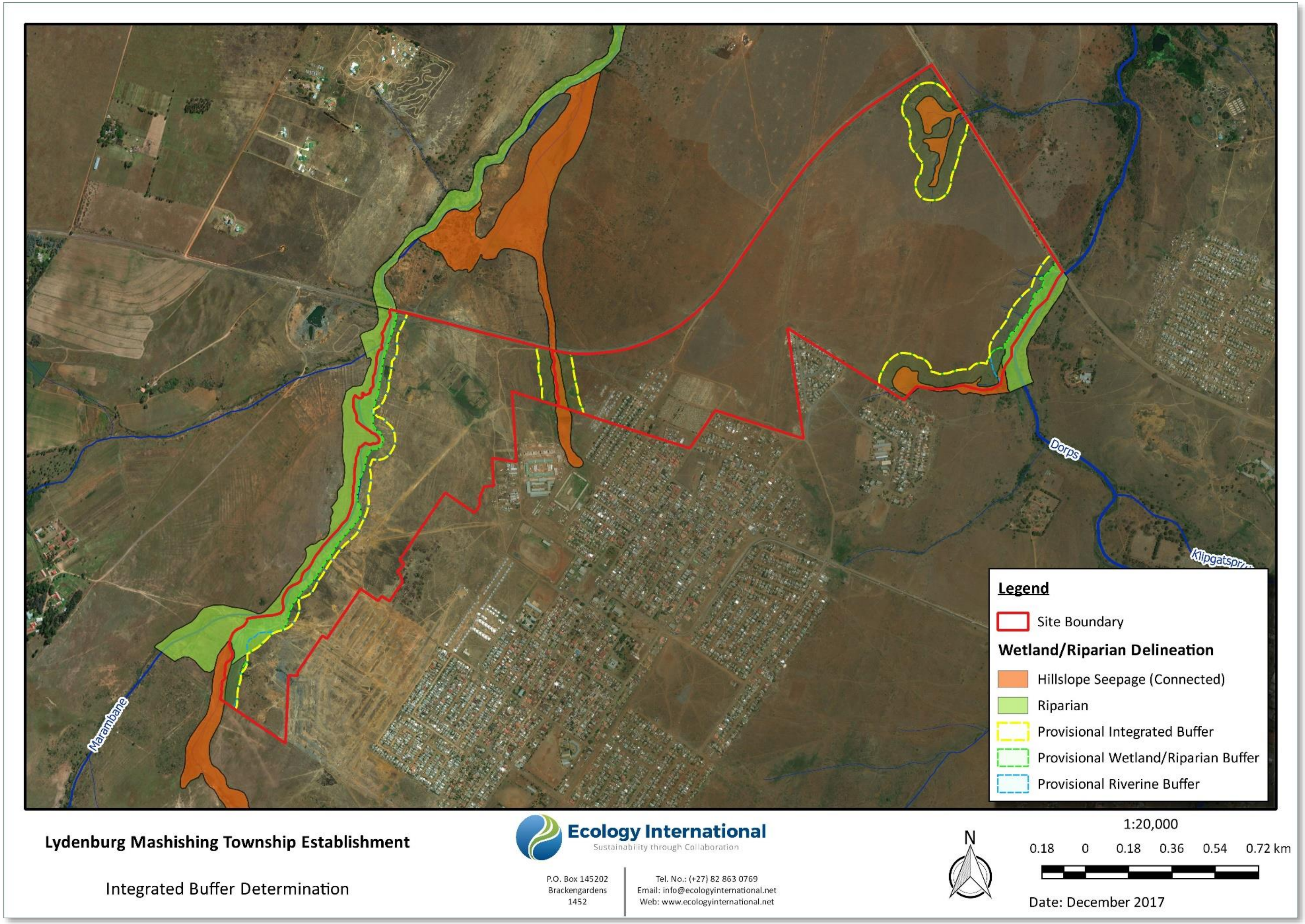


Figure 27: Integrated buffers determined for the freshwater ecosystem associated with the proposed Mashishing Phase A and Phase B township areas according to the approach of Macfarlane & Bredin (2016)

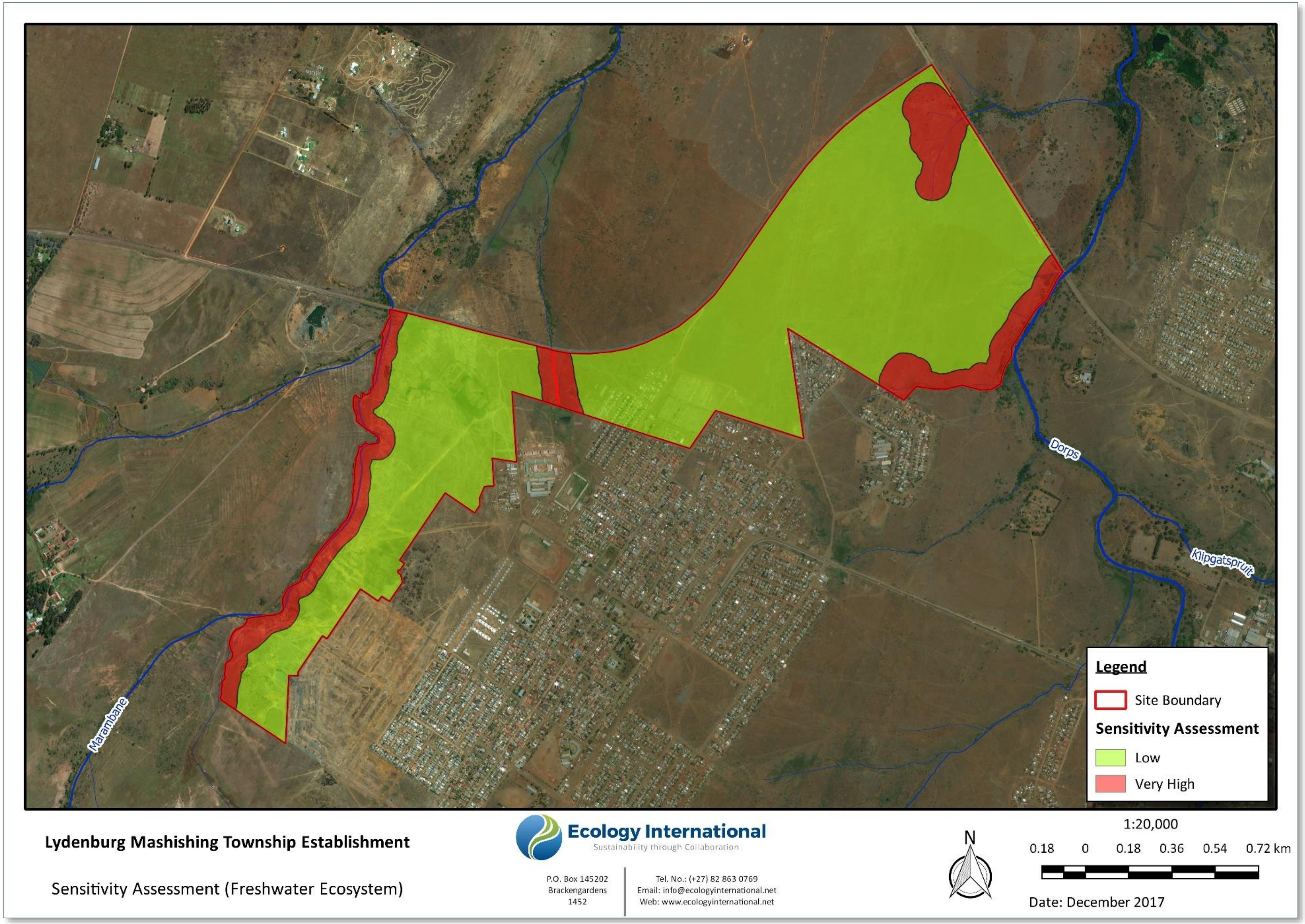


Figure 28: Assessment of sensitivity for the freshwater ecosystems associated with the proposed Mashishing Phase A and Phase B township areas

6. PRELIMINARY IMPACT ASSESSMENT

6.1 Assessment of Impacts associated with Planning and Design

No impacts on the associated aquatic ecosystems are foreseen during the planning and design component of the present study. However, final layout and design must take into consideration proposed integrated buffer requirements and subsequent sensitivities for riverine and wetland ecosystems within the development. Additional consideration for Sustainable Drainage Systems (SuDS) within the layout planning and design is strongly recommended.

6.2 Assessment of Impacts associated with Construction

6.2.1 Sedimentation

The clearing of natural vegetation and the stripping of topsoil for the preparation of the site for construction may result in the increased runoff of sediment from the site and associated stockpiles into associated watercourses. Various impacts have been attributed to sedimentation of aquatic ecosystems, including reduction of light penetration (resulting in reduction in photosynthesis and subsequently, productivity), alteration of foraging dynamics of both carnivores and herbivores, impacting on predator and prey relationships, clogging of gills, rendering the watercourse unfit for various aquatic organisms, truncating and shifting the trophic pyramid, absorption of nutrients onto suspended particles, rendering them unavailable and thereby reducing the productivity of the river, filling of interstitial spaces, thereby destroying habitat for macro invertebrates and vertebrates owing to sedimentation, etc.

Impact Name	**Sedimentation**				
Alternative	**N/A**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	3	1
Extent	3	2	Reversibility	2	2
Duration	1	1	Probability	5	3
Environmental Risk (Pre-mitigation)					-11.25
Mitigation Measures					
• Delineated integrated buffer zones are to be clearly demarcated, and no access of construction equipment or stockpiling of any items is allowed within this area;' • Construction period is to be limited to periods of low rainfall (i.e. winter) in order to limit runoff from the construction area; • The installation of silt/sediment curtains on the downslope side of the areas to be stripped is recommended for the duration of the construction period; • Weekly inspections on the silt curtains should be carried out to determine the efficiency of the structures and to ensure maintenance is carried out in a timely manner; • Where topsoil it stockpiled, ensure that topsoil is at no time buried, mixed with excavated subsoil, rubble or building material, or subjected to compaction or contamination by vehicles, machinery or contaminated surface water runoff; • Stockpile any topsoil or any overburden material separately for later rehabilitation;					

• Where stockpiling of soil is required for whatever reason, position the such stockpiles upslope of any activities to prevent contaminated surface water coming into contact with topsoil; • Do not stockpile topsoil in heaps exceeding 3m in height; • Protect topsoil stockpiles from erosion by creating flow diversion berms upslope of the topsoil stockpile, and silt/sediment curtains downslope of the stockpile; • Remove exotic / invasive plants and weeds that emerge on topsoil stockpiles; • Re-vegetate the stockpiles with indigenous legumes and/or grasses that are indigenous to the area; • Develop soil management measures for the entire surface area of the construction footprint that will prevent runoff of sediment into the associated watercourses; and • Any additional topsoil stockpile areas required by the contractor must be approved by the Environmental Control Officer in the form of an amended EMP indicating the position and extent of thereof.	
Environmental Risk (Post-mitigation)	-4.50
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Public Response	1
Low: Issue not raised in public responses	
Cumulative Impacts	1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	3
High: Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).	
Prioritisation Factor	1.33
Final Significance	-6.00

6.2.2 Erosion of Wetlands

The removal of surface vegetation will cause exposed soil conditions where rainfall and high winds can cause mechanical erosion. High rainfall, inadequate drainage systems, hardened surfaces and bare areas are likely to increase surface run off velocities and peak flows received by wetlands during both the construction and operational phases of the proposed activity.

Impact Name	**Erosion of wetlands**				
Alternative	**N/A**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	2	1
Extent	2	2	Reversibility	3	2
Duration	1	1	Probability	3	1
Environmental Risk (Pre-mitigation)					-6.00
Mitigation Measures					
• Make use of existing roads and tracks where feasible, rather than creating new routes through vegetated areas; • Vegetation and soil must be retained in position for as long as possible, and removed immediately ahead of construction / earthworks in that area • An ecologically-sound stormwater management plan must be implemented at the onset of the construction phase, and should include the use of Sustainable Urban Design Systems (SuDS).					

• Stormwater should not be allowed to discharge directly into wetlands or watercourses or within their designated buffer zones. In this regard, the use of flow spreaders and flow dissipaters must be considered to allow stormwater to enter the buffer zones in a diffuse manner; • Where watercourse crossings are required, crossings are to be designed using box culverts that facilitate dispersed water flow; • Where such watercourse crossings are required, they should traverse the wetlands at an angle perpendicular to the flow of the watercourse, and their base should not be lower than the current level of the watercourse; • Erosion features must not be allowed to develop on a large scale before effecting repairs. Where erosion features do manifest, rehabilitation interventions are to be developed by a civil engineer with experience pertaining to wetland rehabilitation, with input from a suitably-qualified wetland specialist.	
Environmental Risk (Post-mitigation)	-1.50
Degree of confidence in impact prediction:	Low
Impact Prioritisation	
Public Response	1
Low: Issue not raised in public responses	
Cumulative Impacts	1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	3
High: Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).	
Prioritisation Factor	1.33
Final Significance	-2.00

6.2.3 Decreased Water Quality

Hydrocarbon-based fuels or lubricants spilled from construction vehicles, construction materials that are not properly stored, and litter deposited by construction workers may be washed into the surface water bodies. Should appropriate toilet facilities not be provided for construction workers at the construction crew camps, the potential exists for surface water resources and surrounds to be further contaminated by raw sewage. While it is acknowledged that the impacts associated with the proposed activities will be negligible, every effort should still be taken limit additional contributions.

Impact Name	**Decreased water quality**				
Alternative	**N/A**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	1	1
Extent	3	2	Reversibility	2	2
Duration	1	1	Probability	4	1
Environmental Risk (Pre-mitigation)					-7.00
Mitigation Measures					
• Construction vehicles are to be maintained in good working order, to reduce the probability of leakage of fuels and lubricants; • A walled concrete platform, dedicated store with adequate flooring or bermed area should be used to accommodate chemicals such as fuel, oil, paint, herbicide and insecticides, as appropriate, in well-ventilated areas;					

• Storage of potentially hazardous materials should be above any 100-year flood line, or as agreed with the ECO. These materials include fuel, oil, cement, bitumen etc.; • Sufficient care must be taken when handling these materials to prevent pollution; • Surface water draining off contaminated areas containing oil and petrol would need to be channelled towards a sump which will separate these chemicals and oils; • Oil residue shall be treated with oil absorbent such as Drizit or similar and this material removed to an approved waste site; • Concrete, if used, is to be mixed on mixing trays only, not on exposed soil; • Concrete and tar shall be mixed only in areas which have been specially demarcated for this purpose; • All concrete and tar that is spilled outside these areas shall be promptly removed by the Contractor and taken to an approved dumpsite; • After all the concrete / tar mixing is complete all waste concrete / tar shall be removed from the batching area and disposed of at an approved dumpsite; • Storm water shall not be allowed to flow through the batching area. Cement sediment shall be removed from time to time and disposed of in a manner as instructed by the Consulting Engineer; • All construction materials liable to spillage are to be stored in appropriate structures with impermeable flooring; • Portable septic toilets are to be provided and maintained for construction crews. Maintenance must include their removal without sewage spillage; • Portable septic toilets are to be located outside of the 1-100year floodline as well as the designated buffer; • Under no circumstances may ablutions occur outside of the provided facilities; • At all times care should be taken not to contaminate surface water resources; • No uncontrolled discharges from the construction crew camps to any surface water resources shall be permitted. Any discharge points need to be approved by the relevant authority; • In the case of pollution of any surface or groundwater, the Regional Representative of the Department of Water Affairs (DWA) must be informed immediately; • Where construction in close proximity to sewer lines is unavoidable then excavations must be done by hand while at all times ensuring that the soil beneath the sewer lines is not destabilised; • Store all litter carefully so it cannot be washed or blown into any of the water courses within the study area; • Provide bins for construction workers and staff at appropriate locations, particularly where food is consumed; • The construction site should be cleaned daily and litter removed; • Conduct on-going staff awareness programs so as to reinforce the need to avoid littering; • Backfill must be compacted to form a stabilised and durable blanket; and the current load above the sewer lines must at no time be exceeded; and • An adaptive management approach should be taken with regards to the assessment of impacts during the construction phase. In this regard, water quality both upstream and downstream of the proposed bridge expansion should be conducted on a monthly basis.	
Environmental Risk (Post-mitigation)	-1.50
Degree of confidence in impact prediction:	Low
Impact Prioritisation	
Public Response	1
Low: Issue not raised in public responses	
Cumulative Impacts	1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	3

High: Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).	
Prioritisation Factor	1.33
Final Significance	-2.00

6.3 Assessment of Impacts associated with Operation

6.3.1 Altered Riverine Hydrology

One of the primary impacts associated with urbanisation is the impact of stormwater generated on site during times of rainfall. Increased impermeable surfaces within the study area as a result of the proposed township development will decrease catchment infiltration and increase stormwater runoff from the site, resulting in the increase in the periodicity and magnitude of flood events (e.g. increased flood peaks) within the associated watercourses, thus resulting in an altered hydrological regime. This has particular relevance to the potential impact on instream biota which include a Near-Threatened fish species.

Impact Name	**Altered hydrology**				
Alternative	**N/A**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	4	2
Extent	3	3	Reversibility	4	3
Duration	5	5	Probability	5	3
Environmental Risk (Pre-mitigation)					-20.00
Mitigation Measures					
• Hydrological stormwater modelling of various layout designs should be conducted in order to better determine the magnitude of impact associated with the proposed development on the receiving riverine hydrology, and should include evaluation of potential seasonal differences; • Stormwater should as far as possible me managed on-site, and not be allowed to discharge directly into wetlands or watercourses or within their designated buffer zones. In this regard, the use of flow spreaders and flow dissipaters must be considered to allow stormwater to enter the buffer zones in a diffuse manner; • An ecologically-sound stormwater management plan must be implemented at the onset of the construction phase and carried through the to the operational phase, and must include the use of Sustainable Urban Design Systems (SuDS) as well as Water Sensitive Urban Design (WSUD) within the final township design (e.g. permeable pavements, alignment/orientation of roads, etc.). See further Armitage et al. (2013, 2014).					
Environmental Risk (Post-mitigation)					-9.75
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Medium: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					3
High: Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).					
Prioritisation Factor					1.50
Final Significance					-14.63

6.3.2 Erosion of Wetlands

In addition to altering hydrology within the associated riverine environment, poor township planning and resulting increased catchment runoff will increase the potential for wetland erosion to occur during the operational phase of the project. Although addressed separately, management/mitigation measures proposed for management of impacts associated with stormwater for the associated riverine ecosystem (Section 6.3.1) remain applicable for associated wetlands.

Impact Name	**Erosion of wetlands**				
Alternative	**N/A**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	4	2
Extent	1	2	Reversibility	3	2
Duration	5	5	Probability	4	3
Environmental Risk (Pre-mitigation)					-13.00
Mitigation Measures					
• Stormwater should not be allowed to discharge directly into wetlands or watercourses or within their designated buffer zones. In this regard, the use of flow spreaders and flow dissipaters must be considered to allow stormwater to enter the buffer zones in a diffuse manner; • An ecologically-sound stormwater management plan must be implemented at the onset of the construction phase and carried through the to the operational phase, and must include the use of Sustainable Urban Design Systems (SuDS) as well as Water Sensitive Urban Design (WSUD) within the final township design (e.g. permeable pavements, alignment/orientation of roads, etc.). See further Armitage et al. (2013, 2014).Where erosion features do manifest, rehabilitation interventions are to be developed by a civil engineer with experience pertaining to wetland rehabilitation, with input from a suitably-qualified wetland specialist.					
Environmental Risk (Post-mitigation)					-8.25
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					3
High: Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).					
Prioritisation Factor					1.33
Final Significance					-11.00

6.3.3 Nutrient Enrichment

Increased development within the study area is likely to increase the demands on existing sewage infrastructure both within the immediate study area as well as the treatment thereof at the Lydenburg Wastewater Treatment Works (WWTW). With no formal infrastructure supporting the inhabitants currently present within the study area, raw sewerage is currently discharging into the Marambane River. Given that the associated watercourses support populations of a Near-Threatened fish species and that nutrient input into the Marambane River has already resulted in a localised reduction in the abundance of this species, additional input of raw sewage into the Marambane River and/or the Dorps River as a result of insufficient capacity of existing infrastructure and/or inability of the Lydenburg WWTW to adequately treat the resulting increase in inflow as a result of the proposed township is raised as a concern.

Impact Name	**Nutrient Enrichment**				
Alternative	**N/A**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	4	2
Extent	3	3	Reversibility	4	3
Duration	5	5	Probability	5	3
Environmental Risk (Pre-mitigation)					-22.50
Mitigation Measures					
• Ensure that the sewage infrastructure proposed for the development has the capacity to deal with the demands of the proposed housing densities within the study area; • Ensure that the Lydenburg WWTW (or any other treatment works that will be treating the resulting raw sewage) has the capacity to adequately treat the sewage originating from the proposed development;					
Environmental Risk (Post-mitigation)					-9.75
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					3
High: Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).					
Prioritisation Factor					1.33
Final Significance					-14.63

6.4 Assessment of Impacts associated with Decommissioning

Given that decommissioning is not foreseen for the proposed activity, no impacts on the associated watercourses are perceived.

6.5 Assessment of Impacts associated with Rehabilitation and Closure

Given that rehabilitation and closure is not foreseen for the proposed activity, no impacts on the associated watercourses are perceived.

7. CONCLUSION AND RECOMMENDATIONS

Based on results obtained during the present study, it was determined that the diversity of aquatic biota associated with the reaches of the Marambane River and Dorps River associated with the proposed Mashishing Phase A and Phase B township areas was lower than that expected, which was strongly influenced by the nature of upstream and adjacent impacts (including the inflow of sewage as a result of failing infrastructure). Moreover, results obtained further indicate that a higher diversity of fish species are present within the Dorps River relative to the Marambane River, which is likely attributed to the different sizes of the watercourses assessed and habitat preferences of the individual species. However, data obtained during the present study suggested that the abundance of fish is lower within the Dorps River relative to the reaches of the Marambane River directly adjacent to the proposed Mashishing Phase A and Phase B township areas, despite there being a higher degree of suitable habitat within the Dorps River. This was attributed to the impacts presentin with the Dorps River catchment upstream of the present study area, which is likely to have impacted on the fish assemblage present.

Nevertheless, the integrated ecological state of the Marambane River was generally considered to be largely modified (i.e. Ecological Category D), with the inflow of sewage within the lower reaches determined to have a significant impact on the instream biota. The reach of the Dorps River associated with the proposed township establishment was similarly considered to be in a largely modified state, with the instream component downstream of the proposed township being in a better state due to the presence of a Department of Water and Sanitation (DWS) gauging weir that presents a movement barrier to fish attempting to access the upper reaches of the Dorps River. Nevertheless, Ecological Importance for both watercourses was determined to be moderate, whereas the Ecological Sensitivity was determined to be high.

In addition, two fish species of conservation concern were confirmed within the reaches of watercourses assessed during the present study. Of particular relevance is the fact that the designation of the associated catchment as a Fish Support Area (i.e. fish sanctuary in an ecological class lower than an A or B) was originally established based on the potential support for *Enteromius sp. 'Ohrigstad'*, for which there is taxonomic uncertainty, and thus uncertainty regarding the conservation status. However, given the dominance of *Enteromius sp. nov. 'South Africa'* within the study area and in consideration of the recent conservation assessment which assessed the species as Near-Threatened, as well as the EcoStatus results obtained during the present study, the retention of the catchment associated with the proposed township establishment as a Fish Support Area (i.e. fish sanctuary in an ecological class lower than an A or B) is supported.

Further, one hydro-geomorphic (HGM) type, a hillslope seepage connected to a watercourse was delineated during the present study, and classified into four separate HGM units. In addition to the wetland units delineated, two sections of riparian habitat were also delineated, one section on the eastern boundary associated with the Dorps River and the other section on the western boundary associated with the Marambane River. Results indicated that wetlands within the study area have been largely altered as a result of changes in water inputs (derived from its catchment) and water retention and distribution patterns within the wetland unit itself, as well as vegetation changes due to several historic and current anthropogenic impacts. The identified wetlands are therefore considered to be in a largely modified state (i.e. Ecological Category D), and thus reflective of the riverine ecosystem.

The hillslope seepage wetlands present within the study area were assigned a low Ecological Importance and Sensitivity, mostly due to the lack of species of conservation concern present. The hillslope seepage wetlands were further regarded as having a moderate Hydrological and Functional Importance due to the potential ecosystem services they provide, especially in terms of phosphate trapping and nitrate removal. In addition, direct human benefits were regarded as moderate within HGM 1 due to the grazing, stock watering and production of cultivated crops within the wetland unit, whereas direct human benefits associated with HGM 2, HGM 3 and HGM 4 were regarded as very low due to the hillslope seepage wetlands not being fully utilised at present.

Determination of the preliminary buffer requirements for riverine and wetland features associated with the proposed Mashishing Township Establishment followed the approach of Macfarlane & Bredin (2016), whereby the required buffers were developed based on various factors, including assumed housing densities, slope, annual precipitation, rainfall intensity, channel width, catchment to wetland ratio, etc. Given that the slope in the study area is not consistent, a variable buffer width was applied to the identified watercourses, resulting in preliminary riverine buffers which ranged from 61m to 75m, whereas the preliminary wetland buffers ranged from 52m to 55m. The final integrated watercourse buffer determinations for the watercourses associated with the proposed Mashishing Township Establishment was therefore taken to include the extent of the riparian area, buffer area for riverine components, or the buffer area determined for the wetland components, whichever was greater. Subsequently, the sensitivity of the buffer zones should be regarded as very high (pending the provision of additional information pertaining to the proposed activity) given proposed functionality for which the buffer zone was determined and the purpose of limiting impacts on the associated watercourses.

8. BIBLIOGRAPHY

Armitage, N., Fisher-Jeffes, L., Carden, K., Winter, K., Naidoo, V., Spiegel, A., Mauck, B. & Coulson, D. (2014). Water Sensitive Urban Design (WSUD) for South Africa: Framework and Guidelines.: 1–58

Armitage, N., Vice, M., Fisher-Jeffes, L., Winter, K., Spiegel, A. & Dun. (2013). *Alternative Technology for Stormwater Management South African Guidelines for Sustainable Drainage Systems*. TT 558/13. Water Research Commission, Pretoria, South Africa

Bills, I.R., Boycott, R.C., Fakudze, M., Khumalo, N., Msibi, J., Scott, L.E.P., Terry, S. & Tweddle, D. (2004). *Fish and Fisheries of Swaziland (2002-2003): Final Report*. SAIAB Investigational Report. South African Institute for Aquatic Biodiversity (SAIAB), Grahamstown

Blackburn, T.M., Pyšek, P., Bacher, S., Carlton, J.T., Duncan, R.P., Jarošík, V., Wilson, J.R.U. & Richardson, D.M. (2011). A proposed unified framework for biological invasions. *Trends in Ecology and Evolution* 26: 333–339

Chutter, F.M. (1998). *Research on the rapid biological assessment of water quality impacts in streams and rivers (SASS)*. WRC Report No. 422/1/98. Water Research Commission, Pretoria, South Africa

Collins, N.B. (2005). *Wetlands: The basics and some more*. Free State Department of Tourism, Environment and Economic Affairs

da Costa, L.D.M. (2012). Systematic studies on the Chubbyhead Barbs Species Complex (Osteichthyes, Cyprinidae) from southern Africa Systematic studies on the Chubbyhead Barbs Species Complex (Osteichthyes, Cyprinidae) from southern Africa. University of Lisbon, Portugal

Dallas, H.F. (1997). A preliminary evaluation of aspects of SASS (South African Scoring System) for the rapid bioassessment of water quality in rivers, with particular reference to the incorporation of SASS in a national biomonitoring programme. *South African Journal of Aquatic Science* 23: 79–94

Dallas, H.F. (2005). *River Health Programme: Site Characterisation Field-Manual and Field-Data Sheets*. River Health Programme Report Series No. 18. Department of Water Affairs - Resource Quality Services, Pretoria, South Africa

Dallas, H.F. (2007). *River Health Programme: South African Scoring System (SASS) Data interpretation Guidelines*. Report prepared for the Institute of Natural Resources and Department of Water Affairs and Forestry, Pretoria, South Africa

Dallas, H.F. & Day, J.A. (2004). *The effect of water quality variables on aquatic ecosystems: a review*. WRC Report No. TT 224/04. Water Research Commission, Pretoria

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. & Brooks, E.G.E. (2011). The diversity of life in African freshwaters: underwater, under threat: an analysis of the status and distribution of freshwater species throughout mainland Africa. *The diversity of life in African freshwaters: underwater, under threat. An analysis of the status and distribution of freshwater species throughout mainland Africa*: xiii+347+4pp cover

Darwall, W.R.T., Smith, K.G., Tweddle, D. & Skelton, P. (2009). *The status and distribution of* *freshwater biodiversity in Southern Africa*. Gland, Switzerland: IUCN and Grahamstown, South Africa: SAIAB

Davies, B.R. & Day, J.A. (1998). *Vanishing Waters*. University of Cape Town Press, Cape Town

Department of Water Affairs and Forestry. (2005). *A practical field procedure for identification and delineation of wetlands and riparian areas*. Department of Water Affairs and Forestry, Pretoria, South Africa

Department of Water and Sanitation. (2016). *Classes and Resource Quality Objectives of Water Resources for the Olifants River catchment*. Government Gazette No. 39943, Pretoria, South Africa

Dickens, C.W.S. & Graham, P.M. (2002). The South African Scoring System (SASS) Version 5 rapid bioassessment method for rivers. *African Journal of Aquatic Science* 27: 1–10

Engelbrecht, J.S. & Van Der Bank, F.H. (1996). Genetic relationships between seven species within the chubbyhead and goldie barb groups of minnows (Pisces, Cyprinidae). *Journal of African Zoology* 110: 381–396

Ewel, C. (1997). Water quality improvement by wetlands. In: Daily G (ed), *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, D. C.

Gerber, A. & Gabriel, M.J.M. (2002). *Aquatic Invertebrates of South African Rivers: Field Guide. Institute for Water Quality Studies*. Department of Water Affairs and Forestry, Pretoria, South Africa

Gren, I. (1995). The value of investing in wetlands for nitrogen abatement. *European Review of Agricultural Economics* 22: 157–172

David Hoare Consulting (2018). Ecological Scoping Report: Mashshing Township Development, Mashshing, Mpumalanga.

Iversen, T.M., Madsen, B.L. & Bogestrand, J. (2000). River conservation in the European Community, including Scandinavia. In: P.J. Boon BRD and GEP (ed), *Global Perspectives on River Conservation: Science Policy and Practice*. John Wiley & Sons Ltd

Kemper, N. (1999). Intermediate Habitat Integrity Assessment. In: *Resource Directed Measures for Protection of Water Resources, Volume 3: River Ecosystems, Version 1.0*. Department of Water Affairs and Forestry, Pretoria, South Africa

Kleynhans, C., Mackenzie, J. & Louw, M. (2007a). *River Ecoclassification: Manual for Ecostatus Determination (Version 2). Module F: Riparian Vegetation Response Assessment Index (VEGRAI)*. WRC Report TT 333/08. Water Research Commission, Pretoria, South Africa

Kleynhans, C.J. (1996). A qualitative procedure for the assessment of the habitat integrity status of Luvuvhu River (Limpopo system, South Africa). *Journal of Aquatic Health* 5: 41–54

Kleynhans, C.J. (1999). The development of a fish index to assess the biological integrity of South African rivers. *Water SA* 25: 265–278

Kleynhans, C.J. (2008). *River Ecoclassification: Manual for Ecostatus Determination (Version 2). Module D: Volume 1 – Fish Response Assessment Index (FRAI)*. WRC Report No. TT 330/08. Water Research Commission, Pretoria, South Africa

Kleynhans, C.J. & Louw, M.D. (2008). *River EcoClassification Manual for EcoStatus Determination (Version 2) - Module A: EcoClassification and EcoStatus Determination*. WRC Report No. TT 329/08. Water Research Commission, Pretoria, South Africa

Kleynhans, C.J., Louw, M.D. & Graham, M. (2008a). *River Ecoclassification: Manual for Ecostatus Determination (Version 2). Module G: Index of Habitat Integrity. Section 1: Technical Manual.* WRC Report No. TT 377/08. Water Research Commission, Pretoria, South Africa

Kleynhans, C.J., Louw, M.D. & Moolman, J. (2008b). *River Ecoclassification: Manual for Ecostatus Determination (Version 2). Module D: Volume 2 - Reference frequency of occurrence of fish species in South Africa*. WRC Report No. TT 331/08. Water Research Commission, Pretoria, South Africa

Kleynhans, C.J., Thirion, C.A., Moolman, J. & Gaulana, L. (2007b). *A Level II River Ecoregion classification System for South Africa, Lesotho and Swaziland*. Report No. N/0000/00/REQ0104. Department of Water Affairs and Forestry - Resource Quality Services, Pretoria, South Africa

Kotze, D.C., Marneweck, G.C., Batchelor, A.L., Lindley, D.S. & Collins, N.B. (2008). *WET-EcoServices: A technique for rapidly assessing ecosystem services supplied by wetlands. WRC Report No TT 339/08*. WRC Report No. 339/08. Water Research Commission, Pretoria, South Africa

Macfarlane, D.M. & Bredin, I.P. (2016). *Buffer zone guidelines for rivers, wetlands and estuaries. Part 1: Technical Manual*. WRC Report No. TT 715/1/17. Water Research Commission, Pretoria, South Africa

Macfarlane, D.M., Kotze, D.C., Ellery, W.N., Walters, D., Koopman, V., Goodman, P. & Goge, C. (2008). *WET-Health: A technique for rapidly assessing wetland health*. WRC Report No. TT340/09. Water Research Commission

McMillan, P.H. (1998). *An Integrated Habitat Assessment System (IHAS v2) for the Rapid Biological Assessment of Rivers and Streams*. CSIR Research Report No. ENV-P-I 98132. Water Resources Management Programme, Council for Scientific and Industrial Research, Pretoria, South Africa

de Moor, I.J. & Bruton, M.N. (1988). *Atlas of alien and translocated indigenous aquatic animals in Southern Africa*. South African National Scientific Programmes Report No. 144. CSIR, Pretoria

Muscutt, A.D., G.L., H., Bailey, S.W. & Davies, D.B. (1993). Buffer zones to improve water quality: a review of their potential use in UK agriculture. *Agriculture, Ecosystems and Environment* 45: 59–77

National Research Council. (2002). *Riparian Areas: Functions and Strategies for Management*. The National Academies Press, Washington, D.C.

Nel, J.L., Driver, A., Strydom, N.A., Maherry, A.M., Peterson, C., Hill, L., Roux, D.J., Nienaber, S., van Deventer, H., Swartz, E.R. & Smith-Adao, L.B. (2011). *Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources.* WRC Report No. TT 500/11. Water Research Commission, Pretoria, South Africa

Nel, J.L., Maree, G., Roux, D., Moolman, J., Kleynhans, C.J., Sieberbauer, M. & Driver, A. (2004).

South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 2: River Component. CSIR Report Number ENV-S-I-2004-063. Council for Scientific and Industrial Research, Stellenbosch

Ollis, D.J., Boucher, C., Dallas, H.F. & Esler, K.J. (2006). Preliminary testing of the Integrated Habitat Assessment System (IHAS) for aquatic macroinvertebrates. *African Journal of Aquatic Science* 31: 1–14

Postel, S. & Carpenter, S. (1997). Freshwater ecosystem services. In: Daily G (ed), *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, D. C.

Raimondo, D., Van Staden, L., Foden, W., Victor, J.E., Helme, N.A., Turner, R.C., Kamundi, D.A. & Manyama, P.A. (2009). *Red list of South African plants 2009*. *Strelitzia No. 25*

Rogers, F.E., Rogers, K.H. & Buzer, J.S. (1985). *Wetlands for wastewater treatment: with special reference to municipal wastewaters*. WITS University Press, Johannesburg, South Africa

Rountree, M.W., Malan, H.L. & Weston, B.C. (2013). *Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Vers.2.0).* WRC Report No. 1788/1/12. Water Research Commission, Pretoria, South Africa

Roux, F. & Hoffman, A. (2017). Enteromius sp. nov. 'south africa'. http://www.iucnredlist.org/details/full/109192069/0#threats. Accessed 12/12/2017

Scott, L. (2013). Freshwater Ecoregions of the World: Southern Temperate Highveld. http://www.feow.org/ecoregions/details/575. Accessed 05/06/2017

Soil Classification Working Group. (1991). *Soil classification. A taxonomic system for South Africa*. Department of Agricultural Development, Pretoria, 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. Water Research Commission, Pretoria, South Africa

Thirion, C.A. (2016). Marco-Invertebrate Response Assessment Index (MIRAI). Version 2. Department of Water and Sanitation - Resource Quality Information Services

Thirion, C.A., Mocke, A. & Woest, R. (1995). *Biological monitoring of streams and rivers using SASS4 - A User's Manual.* Internal Report No. N 000/00REQ/1195. Department of Water Affairs and Forestry - Resource Quality Services, Pretoria, South Africa

Woodford, D. (2017). *Enteromius anoplus*. The IUCN Red List of Threatened Species 2017

APPENDIX A – Methodology

***In situ* Water Quality**

During the various field surveys, *in situ* water quality variables were measured at each site using a ExTech EC500 combination meter for measurement of temperature, pH, electrical conductivity, and Total Dissolved Solids, as well as a ExTech DO600 Portable Dissolved Oxygen Meter.

Riparian Assessment

The Present Ecological State of the riparian zone was assessed using the Riparian Vegetation Response Assessment Index (VEGRAI) Level 3 approach (Kleynhans et al., 2007a). Riparian vegetation areas were divided into two sub-zones which included marginal and non-marginal zones. Recognition of the different zones are important given that riparian vegetation distribution and species composition varies in different sub-zones, which has implications for flow-related impacts. Since all VEGRAI assessments are relative to the natural unmodified conditions (reference state) it is necessary and important to define and describe the reference state for the study area (Kleynhans et al., 2007a). This was done (in part) before going into the field, using historic aerial imagery, present and historic species distributions, general vegetation descriptions of the study area, knowledge of the area and comparison of the study area characteristics to other comparable sections of the stream that might be in a better state. According to Kleynhans et al. (2007a), the reference (and present state) is quantified on site; the assessor reconstructs and quantifies the reference state from the present state by understanding how visible impacts have caused the vegetation to change and respond.

Impacts on riparian vegetation at the site are then described and rated. Kleynhans et al. (2007a) further states that it is important to distinguish between a visible / known impact (such as flow manipulation) and the response of riparian vegetation to other impacts such as erosion and sedimentation, alien invasive species and pollution. If there is no response to riparian vegetation, the impact is noted but not rated since it has no visible / known effect. These impacts are then rated as per a scale from 0 (No Impact) to 5 (Critical Impact). Once the riparian zone and sub- zones have been delineated, the reference and present states have been described and quantified (basal cover is used) and species description for the study area has been compiled, the VEGRAI metrics were rated and qualified. The riparian ecological integrity was assessed using the spreadsheet tool that is composed of a series of metrics and metric groups, each of which was rated in the field with the guidance of data collection sheets. The metrics in VEGRAI describe the following attributes associated with both the woody and non-woody components of the lower and upper zones of the riparian area:

- Removal of the riparian vegetation;
- Invasion by alien invasive species;
- Flow modification; and
- Impacts on water quality.

Results from the lower and upper zones of the riparian vegetation were then combined and weighted with a value that reflects the perceived importance of that criterion in determining habitat integrity, allowing this to be numerically expressed in relation to the perceived benchmark. The score is then placed into one of six classes (Table 19).

Table 19: Allocation protocol for the determination of the Present Ecological State (or Ecological Category) for riparian habitat following the VEGRAI application (Kleynhans et al., 2007a)

Score (% of Total)	Category	Description
90 - 100	A	Unmodified, natural.
80 - 89	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
60-79	C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
40-59	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
20-39	E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 - 19	F	Critically modified. Modifications have reached a critical level and there has been an almost complete loss of natural habitat and biota. In the worst instances, the basic ecosystem functions have been destroyed and the changes are irreversible.

Index of Habitat Integrity, Version 2 (IHI-96-2)

The Index of Habitat Integrity (IHI, Version 2; Kleynhans, *pers. comm.*, 2015) aims to assess the number and severity of anthropogenic perturbations along a river/stream/wetland and the potential inflictions of damage toward the habitat integrity of the system (Dallas, 2005). Various abiotic (e.g. water abstraction, weirs, dams, pollution, dumping of rubble, etc.) and biotic (e.g. presence of alien plants and aquatic animals, etc.) factors are assessed, which represent some of the most important and easily quantifiable, anthropogenic impacts upon the system (Table 20).

In accordance with the original IHI approach (Kleynhans, 1996), the instream and riparian components were each analysed separately to yield two separate ecological conditions (i.e. Instream and Riparian components). However, it should be noted that the data for the riparian area is primarily interpreted in terms of the potential impact upon the instream component and as a result, may be skewed by a potentially deteriorated instream condition.

Table 20: Descriptions of criteria used in the assessment of habitat integrity (Kleynhans, 1996; cited from Dallas, 2005)

Criterion	Relevance
Water abstraction	Direct impact upon habitat type, abundance and size. Also impacted in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in the temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment. Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included
Water quality modification	Originates from point and diffuse sources. Measured directly, or agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments.
Alien/Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependent upon the species involved and scale of infestation.
Alien/Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also a general indication of the misuse and mismanagement of the river.
Vegetation removal	Impairment of the buffer the vegetation forms to the movement of sediment and other catchment runoff products into the river. Refers to physical removal for farming, firewood and overgrazing.
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the river bank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

In accordance with the level of the impact created by the abovementioned criterion, the assessment of the severity of impact of the modifications is based on six descriptive categories with ratings ranging from 0 (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact; Table 21). It should be noted that a confidence level (high, medium, low) was also assigned to each of the scored metrics, based on available knowledge of the site and/or adjacent catchment.

Table 21: Descriptive of scoring guidelines for the assessment of modifications to habitat integrity (Kleynhans 1996; cited from Dallas, 2005)

Impact Category	Description	Score
None	No discernible impact or the factor is located in such a way that it has no impact on habitat quality diversity, size and variability.	0
Small	The modification is limited to a very few localities and the impact on habitat quality, diversity, size and variability is also very small.	1 - 5
Moderate	The modification is present at a small number of localities and the impact on habitat quality, diversity, size and variability is also limited.	6 - 10
Large	The modification is generally present with a clearly detrimental impact on quality habitat quality, diversity, size and variability. Large areas are, however, not influenced	11 - 15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability almost the whole of the defined section are affected. Only small areas are not influenced.	16 - 20
Critical	The modification is present overall with a high intensity; the habitat quality, diversity, size and variability in almost the whole of the defined section are detrimentally influenced.	21 - 25

Each of the allocated scores are then moderated by a weighting system (Table 22), which is based on the relative threat of the impact to the habitat integrity of the riverine system. The total score for each impact is equal to the assigned score multiplied by the weight of that impact. The estimated impacts (assigned score / maximum score [25] X allocated weighting) of all criteria are then summed together, expressed as a percentage and then subtracted from 100 to determine the Present Ecological State score (or Ecological Category) for the instream and riparian components, respectively.

Table 22: Criteria and weights used for the assessment of habitat integrity (Kleynhans, 1996; cited from Dallas, 2005)

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality modification	14	Water abstraction	13
Inundation	10	Inundation	11
Alien/Exotic macrophytes	9	Flow modification	12
Alien/Exotic aquatic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	**100**	**TOTAL**	**100**

However, in cases where selected instream component criteria (i.e. water abstraction, flow, bed and channel modification, water quality and inundation) and/or any of the riparian component criteria exceeded ratings of large, serious or critical, an additional negative weight was applied. The aim of this is to accommodate the possible cumulative effect (and integrated) negative effects of such impacts (Kemper, 1999). The following rules were applied in this respect:

- Impact = Large, lower the integrity status by 33% of the weight for each criterion with such a rating.
- Impact = Serious, lower the integrity status by 67% of the weight for each criterion with such a rating.
- Impact = Critical, lower the integrity status by 100% of the weight for each criterion with such a rating.

Subsequently, the negative weights were added for both the instream and riparian facets of the assessment and the total additional negative weight subtracted from the provisionally determined integrity to arrive at a final habitat integrity estimate (Kemper, 1999). The eventual total scores for the instream and riparian zone components are then used to place the habitat integrity in a specific habitat integrity ecological category (Table 23).

Table 23: Ecological Categories for the habitat integrity scores (Kleynhans, 1999; cited from Dallas, 2005)

Score (% of Total)	Category	Description
90 - 100	A	Unmodified, natural.
80 - 89	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
60-79	C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
40-59	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
20-39	E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 - 19	F	Critically modified. Modifications have reached a critical level and there has been an almost complete loss of natural habitat and biota. In the worst instances, the basic ecosystem functions have been destroyed and the changes are irreversible.

Invertebrate Habitat Assessment System (IHAS), Version 2.2

Assessment of the available habitat for aquatic macroinvertebrate colonization at each of the sampling sites during rapid biomonitoring practices are vital to the correct interpretation of results obtained following biological assessments. It should be noted that the available methods for determining habitat quality are not specific to rapid biomonitoring assessments and are inherently too variable in their approach to achieve consistency amongst users.

Nevertheless, the Invertebrate Habitat Assessment System (IHAS) has routinely been used in conjunction with the South African Scoring System (SASS) as a measure of the variability of aquatic macroinvertebrate biotopes available during sampling (McMillan, 1998). The scoring system was traditionally split into two sections, namely the sampling habitat (comprising 55%

of the total score) and the general stream characteristics (comprising 45% of the total score), which were summed together to provide a percentage and then categorized according to the values in Table 24.

Table 24: Adapted IHAS Scores and associated description of available macroinvertebrate habitat

IHAS Score (%)	Description
>75	Excellent
65-74	Good
55-64	Adequate / Fair
<55	Poor

However, the lack of reliability and evidence of notable variability within the application of the IHAS method has prompted further field validation and testing, which implies a cautious interpretation of results obtained until these studies have been conducted (Ollis et al., 2006). In the interim and for the purpose of this assessment, the IHAS method was adapted by excluding the assessment of the general stream characteristics, which resulted in the calculation of a percentage score out of 55 that was then categorised by the aforementioned Table 12. Consequently, the assessment index describes the quantity, quality and diversity of available macroinvertebrate habitat relative to an "ideal" diversity of available habitat.

Aquatic Macroinvertebrates

Rapid biological monitoring (or biomonitoring) protocols have become important tools in the investigation of water quality and the determination of the overall ecosystem health (or integrity). This has largely been evident in the ability of standardized bio-assessment methods being able to assess the cumulative effect of water quality on biological systems over a period of time rather than only a snap-shot at the precise time of collection, as previously provided through routine chemical analysis of water.

While there are a number of indicator organisms that are used within these assessment indices, there is a general consensus that benthic macroinvertebrates are amongst the most sensitive components of the aquatic ecosystem. This was further supported by their largely non-mobile (or limited mobility) within reaches of associated watercourses, which also allows for the spatial analysis of disturbances potentially present within the adjacent catchment area. However, it should also be noted that their heterogeneous distribution within the water resource is a major limitation, as this results in both spatial and temporal variability within the collected macroinvertebrate assemblages (Dallas & Day, 2004).

The South African Scoring System, Version 5 (SASS5) is essentially a biological assessment index which determines the health of a river based on the aquatic macroinvertebrates collected on-site, whereby each taxon is allocated a score based on its perceived sensitivity/tolerance to environmental perturbations (Dallas, 1997). However, the method relies on a standardised sampling technique using a handheld net (300 mm x 300 mm, 1000 micron mesh size) within each of the various habitats available for standardised sampling times and/or areas. Niche habitats (or biotopes) sampled during SASS5 application include:

- Stones (both in-current and out-of-current);

- Vegetation (both aquatic and marginal); and
- Gravel, sand and mud.

Once collection is complete, aquatic macroinvertebrates are identified to family level and a number of assemblage-specific parameters are calculated including the total SASS5 score, the number of taxa collected, and the Average Score per Taxa, which is the SASS score divided by the total number of taxa identified (Thirion et al., 1995; Davies & Day, 1998; Dickens & Graham, 2002; Gerber & Gabriel, 2002). The SASS bio-assessment index has been proven to be an effective and efficient means to assess water quality impairment and general river health (Dallas, 1997; Chutter, 1998).

In order to determine the Present Ecological State (PES; or Ecological Category) of the aquatic macroinvertebrates collected within the study area, the Macroinvertebrate Response Assessment Index (MIRAI) was applied. This biological index integrates the ecological requirements of the macroinvertebrate taxa in a community (or assemblage) and their response to flow modification, habitat change, water quality impairment and/or seasonality (Thirion, 2008). The presence and abundance of the aquatic macroinvertebrates collected are compared to a derived list of families/taxa expected to be present under natural, un-impacted (or reference) conditions. Consequently, the three (or four) metric groups utilised during the application of the MIRAI were combined within the model to derive the ecological condition of the site in terms of aquatic macroinvertebrates (Table 25).

Ichthyofauna

Fish were collected by means of electro-narcosis, whereby an anode and a cathode are immersed in the water to temporarily stun fish in the near vicinity. Thereafter, the fish are easily scooped out by means of a hand net. A photographic record of fish collected was taken. All fish were identified in the field and released back into the river where possible.

Assessment of the Present Ecological State of the fish assemblage of the watercourses downstream of the present study was conducted by means of the Fish Response Assessment Index (FRAI; Kleynhans 2008). The procedure followed to determine the fish Present Ecological State, or Ecological Category, is an integration of ecological requirements of fish species in an assemblage and their derived or observed responses to modified habitat conditions. In the case of the present assessment, the observed response was determined by means of fish sampling as well as a consideration of species requirements and driver changes (Kleynhans 2008). The expected fish species assemblage within the study area was derived from Kleynhans et al. (2008) and aquatic habitat sampled.

Table 25: Allocation protocol for the determination of the Present Ecological State (or Ecological Category) for aquatic macroinvertebrates following the MIRAI application

MIRAI Percentage	Category	Description
>89	A	Excellent Unimpaired; community structures and functions comparable to the best situation to be expected. Optimum community structure for stream size and habitat quality.
80-89	B	Very Good – Minimally impaired; largely natural with few modifications. A slight change in community structure may have taken place but ecosystem functions are essentially unchanged.
60-79	C	Good – Moderately impaired; community structure and function less than the reference condition. Community composition lower than expected due to loss of some sensitive forms. Basic ecosystem functions are still predominantly unchanged.
40-59	D	Fair – Largely impaired; fewer families present than expected, due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
20-39	E	Poor – Seriously impaired; few aquatic families present, due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
<20	F	Very poor – Critically impaired; few aquatic families present. If high densities of organisms, then dominated by a few taxa. Only tolerant organisms present.

It should be emphasised that although the FRAI uses essentially the same information as the Fish Assemblage Integrity Index (FAII), it does not follow the same procedure. The FAII was developed for application in the broad synoptic assessment required for the River Health Programme, and subsequently does not offer a particularly strong cause-and-effect basis. The purpose of the FRAI, on the other hand, is to provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the perceived reference condition (Kleynhans, 2008).

The FRAI is based on the assessment of metrics within metric groups. These metrics are assessed in terms of:

- Habitat changes that are observed or derived;
- The impact of such habitat changes on species with particular preferences and tolerances; and
- The relationship between the drivers used in the FRAI and the various fish response metric groups are indicated in Figure 29. Table 26 provides the steps and procedures required for the calculation of the FRAI.

Interpretation of the FRAI score follows a descriptive procedure in which the FRAI score is classified into a particular Present Ecological State Class or Ecological Category based on the integrity classes of (Kleynhans, 1999). Each class gives a description of generally expected conditions for a specific range of FRAI scores (Table 27).

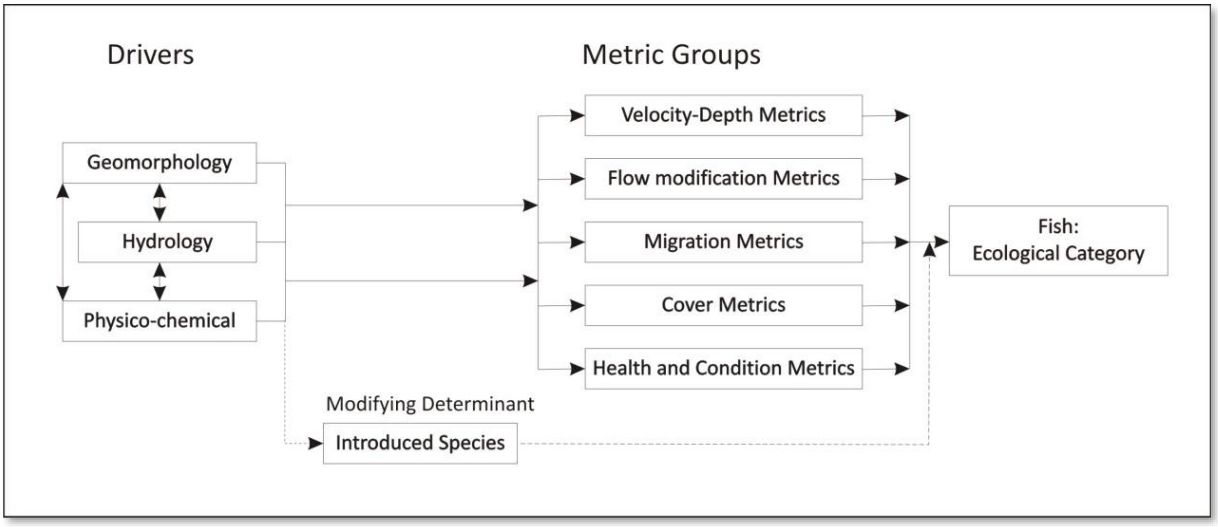


Figure 29: Relationship between drivers and fish metric groups

Table 26: Main steps and procedures in calculating the Fish Response Assessment Index

Step	Procedure
River section earmarked for assessment	As for study requirements and design
Determine reference fish assemblage: species and frequency of occurrence	• Use historical data & expert knowledge • Model: use ecoregional and other environmental information • Use expert fish reference frequency of occurrence database if available
Determine present state for drivers	• Hydrology • Physico-chemical • Geomorphology; or • Index of habitat integrity
Select representative sampling sites	Field survey in combination with other survey activities
Determine fish habitat condition at site	• Assess fish habitat potential Assess fish habitat condition
Representative fish sampling at site or in river section	• Sample all velocity depth classes per site if feasible • Sample at least three stream sections per site
Collate and analyze fish sampling data per site	Transform fish sampling data to frequency of occurrence ratings
Execute FRAI model	• Rate the FRAI metrics in each metric group • Enter species reference frequency of occurrence data • Enter species observed frequency of occurrence data • Determine weights for the metric groups • Obtain FRAI value and category • Present both modelled FRAI & adjusted FRAI.

Table 27: Allocation protocol for the determination of the Present Ecological State/Ecological Category for fish following application of the FRAI

FRAI Percentage	Category	Description
90-100	**A**	Unmodified and natural. Community structures and functions comparable to the best situation to be expected. Optimum community structure for stream size and habitat quality.
80-89	**B**	Largely natural with few modifications. A small change in community structure may have taken place but ecosystem functions are essentially unchanged.
60-79	**C**	Moderately modified. Community structure and function less than the reference condition. Community composition lower than expected due to loss of some sensitive forms. Basic ecosystem functions are still predominantly unchanged.
40-59	**D**	Largely modified. Fewer species present then expected due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
20-39	**E**	Seriously modified. Few species present due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
0-19	**F**	Critically modified. Few species present. Only tolerant species present, if any.

<u>EcoStatus Determination</u>

The EcoStatus is defined as: *The totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services.* In essence, the EcoStatus represents an ecologically integrated state representing the drivers (hydrology, geomorphology, physico-chemical) and responses (fish, aquatic invertebrates and riparian vegetation) (Kleynhans & Louw, 2008).

For the purpose of the present assessment, the latest ECOSTATUS4 1.01 model was used, which is an upgraded and refined version of the original ECOSTATUS4 model of Kleynhans & Louw (2008). The results obtained from the fish and aquatic macroinvertebrate response indices (i.e. FRAI and MIRAI) are to be integrated within the model to determine an Instream Ecological Category, whereas the riparian elements from the IHI-96-2 model can be used as a surrogate for the Riparian Ecological Category in the following manner (Dr. C.J. Kleynhans, *pers. comm.*, 2015):

*Riparian Vegetation EC = 100-((IHI 'Vegetation removal')+(IHI 'Exotic vegetation encroachment'))/50*100)*

<u>Wetland Delineation</u>

The report incorporated a desktop study, as well as field surveys, with site visits conducted during November 2017. Additional data sources that were incorporated into the investigation for further reliability included:

- Google Earth images;
- 1:50 000 cadastral maps;
- ortho-rectified aerial photographs;
- Historic imagery from NGI; and

- 5m contour data.

A pre-survey wetland delineation was performed in order to assist the field survey. Identified wetland areas during the field survey were marked digitally using GIS (changes in vegetation composition within wetlands as compared to surrounding non-wetland vegetation show up as a different hue on the orthophotos, thus allowing the identification of wetland areas). These potential wetland areas were confirmed or dismissed and delineation lines and boundaries were imposed accordingly after the field surveys.

The wetland delineation was based on the legislatively required methodology as described by Department of Water Affairs and Forestry (2005). The DWAF delineation guide uses four field indicators to confirm the presence of wetlands, namely:

- terrain unit indicator (i.e. an area in the landscape where water is likely to collect and a wetland to be present);
- soil form indicator (i.e. the soils of South Africa have been grouped into classes / forms according to characteristic diagnostic soil horizons and soil structure);
- soil wetness indicator (i.e. characteristics such as gleying or mottles resulting from prolonged saturation); and
- vegetation indicator (i.e. presence of plants adapted to or tolerant of saturated soils).

The wetland delineation guide makes use of indirect indicators of prolonged saturation by water, namely wetland plants (hydrophytes) and (hydromorphic) soils. The presence of these two indicators is indicative of an area that has sufficient saturation to classify the area as a wetland. Hydrophytes were recorded during the site visit and hydromorphic soils in the top 0.5 m of the profile were identified by taking cored soil samples with a bucket soil auger and Dutch clay auger (photographs of the soils were taken). Each auger point was marked with a handheld Global Positioning System (GPS) device (Figure 30).

Wetland Functionality

The methodology "Wet-EcoServices" (Kotze et al., 2008) was adapted and used to assess the different benefit values of the wetland units. A level two assessment, including a desktop study and a field assessment were performed to determine the wetland functional benefits between the different hydro-geomorphological types within the study area. Other documents and guidelines used are referenced accordingly. During the field survey, all possible wetlands and drainage lines identified from maps and aerial photos were visited on foot. Where feasible, cross sections were taken to determine the state and boundaries of the wetlands. Following the field survey, the data was submitted to a GIS program for compilation of the map sets. Subsequently the field survey and desktop survey data were combined within a project report.

In order to gauge the Present Ecological State of various wetlands within the study area, a Level 2 Wet-Health assessment was applied in order to assign ecological categories to certain wetlands. Wet-Health (Macfarlane et al., 2008) is a tool which guides the rapid assessment of a wetland's environmental condition based on a site visit. This involves scoring a number of attributes connected to the geomorphology, hydrology and vegetation, and devising an overall score which gives a rating of environmental condition.

Wet-Health is useful when making decisions regarding wetland rehabilitation, as it identifies whether the wetland is beyond repair, whether rehabilitation would be beneficial, or whether intervention is unnecessary, as the wetland's functionality is still intact. Through this method, the cause of any wetland degradation is also identified, and this facilitates effective remediation of wetland damage. There is wide scope for the application of Wet-Health as it can also be used in assessing the Present Ecological State of wetlands and thereby assist in determining the Ecological Reserve as laid out under the National Water Act (Act 36 of 1998). Wet-Health offers two levels of assessment, one more rapid than the other.

For the assessments, an impact and indicator system was used. The wetland is first categorized into the different hydrogeomorphic (HGM) units and their associated catchments, and these are then assessed individually in terms of their hydrological, geomorphologic and vegetation health by examining the extent, intensity and magnitude of impacts, of activities such as grazing or draining. The extent of the impact is measured by estimating the proportion the wetland that is affected. The intensity of the impact is determined by looking at the amount of alteration that occurs in the wetland due to various activities. The magnitude is then calculated as the combination of the intensity and the extent of the impact and is translated into an impact score. This is rated on a scale of 1 to 10, which can be translated into six health classes (A to F – compatible with the EcoStatus categories used by DWAF, Table 28). Threats to the wetland and its overall vulnerability can also be assessed and expressed as a likely Trajectory of Change.

Determination of Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity was determined by utilising a rapid scoring system. The system has been developed to provide a scoring approach for assessing the Ecological, Hydrological Functions; and Direct Human Benefits of importance and sensitivity of wetlands. These scoring assessments for these three aspects of wetland importance and sensitivity have been based on the requirements of the NWA, the original Ecological Importance and Sensitivity assessments developed for riverine assessments, and the work conducted by Kotze et al. (2008) on the assessment of wetland ecological goods and services from the WET-EcoServices tool (Rountree et al., 2013). An example of the scoring sheet is attached as Table 29. The scores are then placed into a category of very low, low, moderate, high and very high as shown in Table 30.

Table 28: Interpretation of scores for determining present ecological status (Kleynhans 1999)

Rating of Present Ecological State (Ecological Category)
CATEGORY A Score: 0-0.9; Unmodified, or approximates natural condition.
CATEGORY B Score: 1-1.9; Largely natural with few modifications, but with some loss of natural habitats.
CATEGORY C Score: 2 – 3.9; Moderately modified, but with some loss of natural habitats.
CATEGORY D Score: 4 – 5.9; Largely modified. A large loss of natural habitats and basic ecosystem functions has occurred.
OUTSIDE GENERAL ACCEPTABLE RANGE
CATEGORY E Score: 6 -7.9; Seriously modified. The losses of natural habitats and basic ecosystem functions are extensive.
CATEGORY F Score: 8 - 10; Critically modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat.

* If any of the attributes are rated <2, then the lowest rating for the attribute should be taken as indicative of the PES category and not the mean

Table 29: Example of scoring sheet for Ecological Importance and sensitivity

Ecological Importance	**Score (0-4)**	***Confidence (1-5)***	Motivation
Biodiversity support			
Presence of Red Data species			
Populations of unique species			
Migration/breeding/feeding sites			
Landscape scale			
Protection status of the wetland			
Protection status of the vegetation type			
Regional context of the ecological integrity			
Size and rarity of the wetland type/s present			
Diversity of habitat types			
Sensitivity of the wetland			
Sensitivity to changes in floods			
Sensitivity to changes in low flows/dry season			
Sensitivity to changes in water quality			
ECOLOGICAL IMPORTANCE & SENSITIVITY			

Table 30: Category of score for the Ecological Importance and Sensitivity

Rating	Explanation
Very low (0-1)	Rarely sensitive to changes in water quality/hydrological regime.
Low (1-2)	One or a few elements sensitive to changes in water quality/hydrological regime.
Moderate (2-3)	Some elements sensitive to changes in water quality/hydrological regime.
High (3-3.5)	Many elements sensitive to changes in water quality/ hydrological regime.
Very high (+3.5)	Very many elements sensitive to changes in water quality/ hydrological regime.

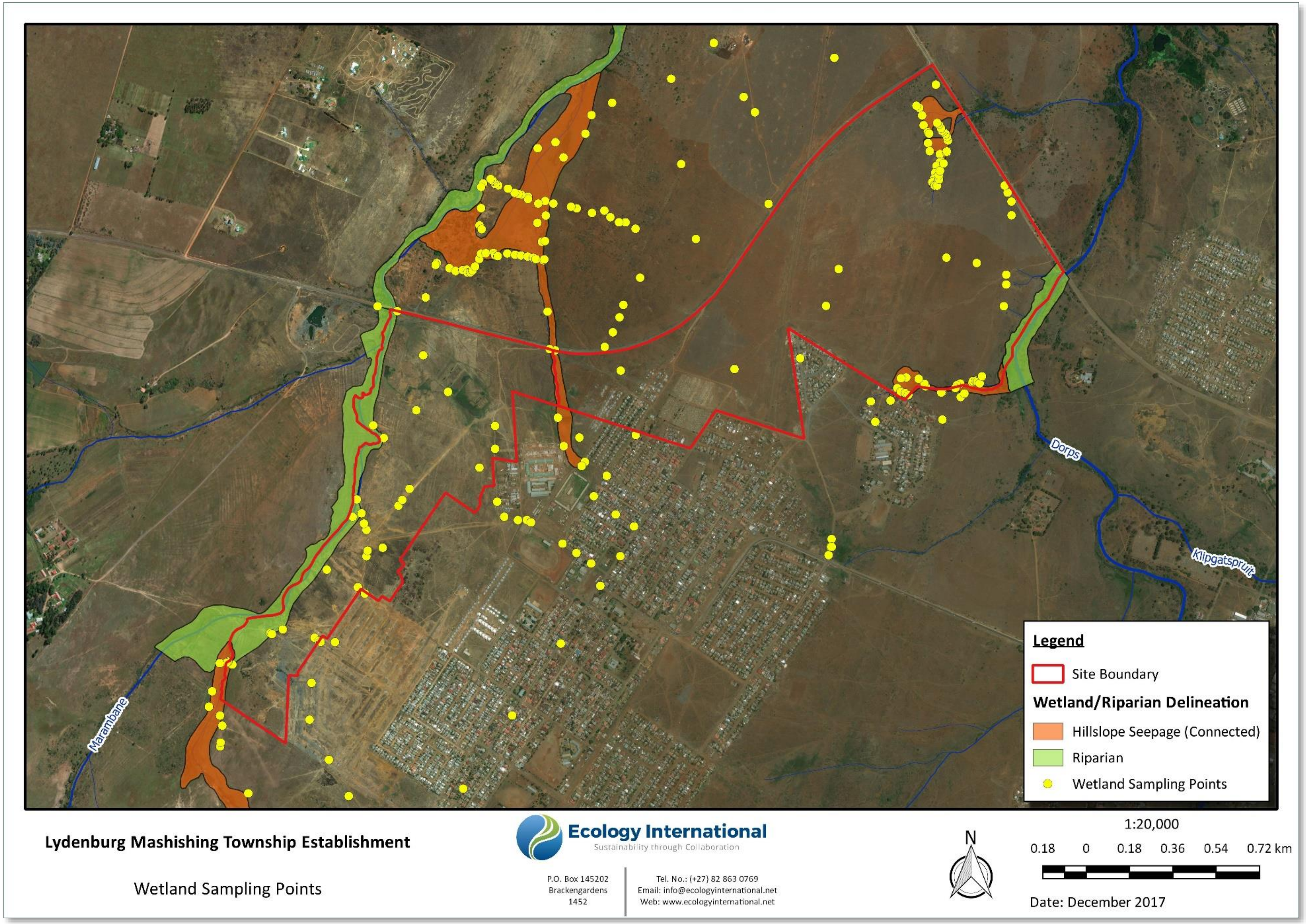


Figure 30: Sampling points assessed during the wetland assessment

APPENDIX B – Site Photographs

Site MTD1

Site MTD2

Site MTD3

Site MTD4

Site MTD5

Site MTD6

APPENDIX C – Aquatic Macroinvertebrates

Relative abundances (Dickens & Graham, 2002):

1 = 1 individual

A = 2 – 10 individuals

B = 11 – 100 individuals

C = 101 – 1000 individuals

D = >1000 individuals

Taxon	Perceived Reference Abundance	Site MTD1	Site MTD2	Site MTD3	Site MTD4	Site MTD5	Site MTD6
Porifera	**P**				P		P
Turbellaria	**B**	A	B	A	B		B
Oligochaeta	**B**	A	A	B	B		B
Hirudinea	**A**		1	A	1		
Potamonautidae	**A**	1	1				A
Atyidae	**A**						
Hydracarina	**A**	A			A		A
Notonemouridae	**1**						
Perlidae	**A**						
Baetidae >2spp	**B**	B	C	B	C		B
Caenidae	**B**	B	B		B		B
Heptageniidae	**B**						
Leptophlebiidae	**B**	B	B	A	B		C
Prosopistomatidae	**1**						
Trichorythidae	**A**				1		A
Calopterygidae	**1**						
Chlorocyphidae	**A**						
Chlorolestidae	**1**						
Coenagrionidae	**B**	B	B	A	A		A
Lestidae	**A**	B		A			
Platycnemidae	**A**	A	A				
Protoneuridae	**1**						
Aeshnidae	**A**	A	1				
Corduliidae	**A**						
Gomphidae	**A**	A	A				
Libellulidae	**A**	A		1			1
Pyralidae	**1**						1
Belostomatidae	**A**						
Corixidae	**B**	B	B	A			A
Gerridae	**A**	A	A	A			A
Hydrometridae	**1**						
Naucoridae	**A**	A					
Nepidae	**A**			A			
Notonectidae	**A**		A				A
Pleidae	**A**						
Veliidae	**A**	A	1		1		A
Ecnomidae	**A**						

Hydropsychidae 1sp		A					
Hydropsychidae 2spp			A		B		B
Hydropsychidae >2spp	**B**						
Philopotamidae	**A**						
Psychomyiidae	**1**						
Hydroptilidae	**A**						
Leptoceridae	**B**						
Dytiscidae	**A**	A	A	A			
Elmidae	**B**	A	1				A
Gyrinidae	**B**	A	B	B	A		A
Haliplidae	**1**						
Helodidae	**1**						
Hydraenidae	**A**						
Hydrophilidae	**B**	A	A	A			1
Psephenidae	**A**						
Athericidae	**A**	1	A				
Ceratopogonidae	**A**	A	A	B	A		1
Chironomidae	**B**	B	B	D	B		A
Culicidae	**A**	1	1	1			
Dixidae	**A**						
Muscidae	**A**			B	1		1
Simuliidae	**A**		A	D	B		A
Tabanidae	**A**						1
Tipulidae	**A**	A	A				1
Ancylidae	**B**	A	A		A		B
Lymnaeidae	**A**		A	1			
Physidae				A	A		A
Planorbinae	**B**				B		B
Thiaridae	**A**						
Sphaeridae	**A**	A	A		A		A
SASS5 Score		161	150	90	108	-	153
No of taxa		29	29	21	21	-	30
ASPT		5.55	5.17	4.29	5.14	-	5.10

APPENDIX D – Ichthyofauna

	Scientific Name	Common Name	IUCN Regional Status (Darwall et al., 2009)*	Endemic to Southern African region (Darwall et al., 2009)	MTD1	MTD2	MTD3	MTD4	MTD5	MTD6
Order	**Cypriniformes**									
Family	Cyprinidae									
	Enteromius anoplus	Chubbyhead Barb	LC	Endemic						
	Enteromius lineomaculatus	Line-spotted Barb	LC							
	Enteromius paludinosus	Straightfin Barb	LC							
	Enteromius sp. nov. 'South Africa'	Sidespot Barb	NT**	Endemic	36	53	1	12	7	54
	Enteromius sp. 'Ohrigstad'	Ohrigstad Barb	DD	Endemic		2				
	Labeobarbus marequensis	Lowveld Largescale Yellowfish	LC	Endemic					1	
	Labeobarbus polylepis	Bushveld Smallscale Yellowfish	LC	Endemic					4	2
Order	**Perciformes**									
Family	Cichlidae									
	Pseudocrenilabrus philander	Southern Mouthbrooder	LC					4	6	7
	Tilapia sparrmanii	Banded Tilapia	LC			2	2	2		2
Order	**Siluriformes**									
Family	Amphiliidae									
	Amphilius uranoscopus	Stargazer Mountain Catfish	LC							
Family	Clariidae									
	Clarias gariepinus	Sharptooth Catfish	LC			1		1		1
Number of species					**1**	**4**	**2**	**4**	**4**	**5**
Number of fish					**36**	**58**	**3**	**19**	**18**	**66**
Effort (seconds)					460	667	791	674	310	903
CPUE					4.70	5.22	0.23	1.69	3.48	4.39

* DD = Data Deficient; LC = Least Concern; NT = Near-Threatened

** Roux & Hoffman (2017)