ECOLOGICAL ASSESSMENT

WETLANDS AND AQUATIC ECOSYSTEMS ASSOCIATED WITH THE BOIKARABELO COAL MINE IN THE WATERBERG, LIMPOPO.

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EXECUTIVE SUMMARY

The aim and objective of the study was to delineate, classify and map the wetlands at the Boikarabelo Coal mine and demarcate wetland areas to be managed as conservation areas. Additionally, the initiation of an ecological monitoring (biomonitoring) assessment of the local aquatic ecosystem was designed to determine the condition or health of the river system by implementing accredited fresh/surface-water biomonitoring assessment methodologies.

Both the practical field procedure for the identification and delineation of wetlands and riparian areas as well as the corps of engineers' wetland delineation manual were adopted as joint methodologies for this survey. Due to the familiarity and better understanding of the Department of Water Affairs and Forestry guidelines, interpretation of the results will be based predominantly on this methodology. A Level II functional assessment was conducted to identify and categorise the importance of ecological services offered by the wetlands. Additionally the state of the wetland areas was assessed with the application of the Index of Wetland Integrity. An assessment was also conducted to determine the Ecological Importance and Sensitivity (EIS) of the wetland units.

In order to determine to the ecological integrity of the aquatic environment, individual biophysical attributes of the streams were assessed. Methodologies formulated by the River Health Programme and the Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers were adopted for this survey to conduct the aquatic biological assessment of the Limpopo River.

Three hydro-geomorphic types of natural wetland systems that occurred within the area assessed. Numerous ecological services for the wetland units were determined to be of intermediate to moderately high importance. Such services include flood attenuation, biodiversity maintenance and streamflow regulation. The present ecological state of the floodplain was determined to be close to natural. The overall ecological importance and sensitivity of the wetland units were determined to vary from moderate to high.

An aquatic assessment was conducted on two sites, one upstream of the study area and the other site further downstream. All of the assessed water quality parameters were within water quality guidelines with the exception of dissolved oxygen (DO). The low levels of saturation and concentration may be attributed to high rainfall experienced prior to the survey period. This would result in organic matter and pollutants being flushed down into the system where they will be decomposed which would result in a low DO. In light of this, results indicated that the quality of water would not be a limiting factor for biotic diversity. The overall quality of habitat was determined to be moderately modified to good. This is in spite of the extreme high flow conditions and the quality of habitat is expected to improve during natural flow periods. The macroinvertebrate community indicated the system to be in a largely modified state. This may be attributed to the high flow conditions resulting in poor habitat quality and availability. Thus this component of the study may not provide and accurate representation of the state of the system. The fish index indicated the system to be in a largely modified state. No endangered or rare fish

species were sampled during the survey. Taking into consideration the flow velocities, the overall integrity of the system was determined to be largely natural to moderately modified.

In spite of moderate impacts to the biodiversity and water quality of the wetland area, none of the current land use practices affect the underlying hydrology of the units. A 300m buffer zone has been assigned to the floodplain system and a 100m buffer has been assigned to the pans and associated hillslope seepage areas. The size of the buffer areas have been determined as a result of the ecological state of the ecosystems, the functioning of the ecosystems as well as the ecological importance and sensitivity of the associated ecosystems. Focussing on water quality management as a vital ecological service provided for by the wetlands, taking into consideration the proximity of the Limpopo River and the significance thereof, conservation of the wetland area is vital.

The potential causes for the decline in integrity of the local aquatic ecosystem are the result of impacts to water quantity as well as impacts to ecological functioning. Such impacts include abstraction of water from the Limpopo River to water fields and stock large dams. The proposed mining activities will have a significant impact on both the water quality and quantity of the receiving systems if mitigation measures are not adhered to. It may be assumed that impacts to the system as a result of the mining activities may be irreversible or extremely expensive to try and correct. The proposed railway line does not impact directly on any of the wetland systems but is situated on the periphery of a pan and associated hillslope seepage wetland. The severity of this impact is considered to be negligible.

Careful management should be put into place so as to avoid unnecessary impacts to the systems. Adopted management strategies should only be applied if proven to be effective and successful with similar projects in other areas. Due to the ecological importance of the Limpopo River as well as taking into consideration the proximity of the mining activities to the system, an aquatic biomonitoring strategy has been proposed. This programme will determine the status of the assessed aquatic system, the drivers (water quality and habitat) and responses (invertebrates and fish) and detect spatial and temporal trends in the ecological state of aquatic ecosystems as well as identify emerging problems regarding the aquatic ecosystem.

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1 TERMS OF REFERENCE

Digby Wells & Associates (DWA) was appointed by ResGen South Africa (Pty) Ltd as environmental consultants to investigate the environmental and social aspects for the proposed Boikarabelo Coal Mine and associated railway line located within the Waterberg magisterial district of the Limpopo Province. Portions of the study area are situated within the Limpopo floodplain and thus may be impacted on by the proposed mining activities. Environmental study considerations for this study included the wetland areas as well as the surface water ecosystem associated with the Limpopo River. The National Water Act 36 of 1998 is important in that it provides a framework to protect water resources against over exploitation and to ensure that there is water for social and economic development, human needs and to meet the needs of the aquatic environment. The Act recognises both wetlands and rivers as water resources and are both protected under the Act.

In light of this, DWA has been commissioned to undertake a wetland delineation and integrity assessment and establish an aquatic monitoring programme at the proposed Boikarabelo Coal Mine. This assessment incorporates a detailed on site survey of the study area. Information generated from this survey would be used to delineate, classify and map the wetlands associated with the Limpopo floodplain and surrounding wetland areas and demarcate wetland areas to be managed as potential conservation areas. In addition, an initial ecological monitoring (biomonitoring) assessment of the local surface aquatic ecosystems will be undertaken to determine the condition or health of the river system by implementing accredited fresh/surface-water biomonitoring assessment methodologies. This study addresses the following regulations and regulatory procedures of the South Africa Departments of Water Affairs and Forestry and the Department of Environmental Affairs and Tourism:

- Section 19 of the National Water Act (Act 36, 1998);
- Section 21 of the National Water Act (Act 36 of 1998);
- Section 21 of the Environment Conservation Act, 1989;
- Section 24 of the Constitution – Environment (Act 108 of 1996); and
- Section 5 of the National Environmental Management Act (Act 108 of 1998).

2 INTRODUCTION

South Africa has a diverse assortment of natural resources which does not include water (Ashton, 2007). One of the primary reasons for the scarcity of our water resources is that the excessive human population growth and development has resulted in unbalancing the availability of and state of water resources locally and on a global scale (Davies & Day, 1998). Water resources in South Africa are currently considered to be finite which suggests that in South Africa as a result of the excessive use of water resources will result in a water shortage that will progress into a water crisis unless the adequate management actions are taken to address this area of concern (Davies & Day, 1998). There have been some significant changes over the past few years to the priorities and approaches to management of water resources in South Africa (Ashton *et. al*, 2005). Culmination in the promulgation of the Water Services Act (WSA: Republic of South Africa, 1997) and the National Water Act (NWA: Republic of South Africa, 1998) may be attributed to the process of reform of the policy on water resources and water services (Ashton *et. al*, 2005).

According to the National Water Act (Act 36 of 1998), a water resource is not only considered to be the water that can be extracted from a system and utilized but the entire water cycle. This includes evaporation, precipitation and entire aquatic ecosystem including the physical or structural aquatic habitats, the water, the aquatic biota, and the physical, chemical and ecological processes that link water, habitats and biota. The entire ecosystem is acknowledged as a life support system by the National Water Act. According to van Wyk *et al.* (2006) the "resource" is defined to include a water course, surface water, estuary and aquifer, on the understanding that a water course includes rivers and springs, the channels in which the water flows regularly or intermittently, wetlands, lakes and dams into or from which water flows, and where relevant, the banks and bed or the system. Basic human needs, societal well-being and economic growth and development are supported by river ecosystem goods and services. A range of processes which support human well-being are included as ecosystem services such as the maintenance of water quality, waste disposal as well as those services relating to recreational and spiritual needs (van Wyk *et al.*, 2006). The Act requires that sufficient water is to be reserved to maintain as well as sustain the ecological functioning of the country's aquatic ecosystems which include rivers, wetlands, groundwater and estuarine systems. If the country's water resources continue to be abused and deteriorate, this will result in an unavoidable loss of key ecosystem services that support social and economic development (Postel and Richter, 2003; Driver et al., 2005; MEA, 2005; Dudgeon et al., 2006; Dasgupta, 2007).

The diverse goods and services provided for by aquatic ecosystems is acknowledged by the National Water Act. This ingrains the democratic principles necessary to safeguard equity in access to these resources. The aim is that society should be able to use as well as protect an agreed upon suite of goods and services derived from the river system. The water law provides for an integrated, adaptive process for water resource management. The optimal use of natural resources for sustainable economic activity is essential in developing countries (Howarth and Farber, 2002).Biodiversity is a vital component for maintaining ecological processes and thus in ensuring sustainability of the ecosystem goods and services which is vital for successful water resource management (MacKat *et al.*, 2004)

South Africa's National Biodiversity Strategy and Action Plan (DEAT, 2005) acknowledges that there is cause for significant concern due to the declining status of ecosystems that degradation of ecosystems leads to a reduction in ecosystem services. This may result in a reduced capacity to generate clean water and a loss of food production due to land degradation. The overall framework for environmental governance in South Africa has been created by South Africa's Constitution (Act 108 of 1996) by establishing the right to an environment that is not harmful to health and well-being, by balancing the right to have the environment protected with rights to valid social and economic development and by allocating environmental functions to a wide range of government agencies in all spheres and requiring co-operation between government agencies and spheres of government (DEAT, 2005). National legislation has been promulgated to govern national competencies, one of which is water (National Water Act).

Therefore the approach adopted within South Africa by freshwater surface ecosystem regulators to balance the use of aquatic ecosystems includes ascertaining the current state and or availability of ecosystem resources, allocating ecological, social and or economic values to the resource to enable the sustainable use and or protection of the resources. In this study the surface aquatic ecosystems associated with the proposed Boikarabelo Coal Mine, including the Limpopo River and associated floodplain and wetland areas have been addressed.

Wetlands are highly susceptible to the degradation of quality and a reduction in quantity as a result of anthropogenic resource use activities, (Mitsch and Gosselink, 1993; Brinson, 1993; Bernaldez et al., 1993, Diederichs and Ellery, 2001). land-surface-development (Gibbs, 2000) and landscape-management (Kotze and Breen, 1994; Whitlow, 1992) practices that alter their hydrological regime impacting these systems (Winter and Llamas, 1993). Historically wetlands have been perceived to be wastelands (Maltby, 1986) and this has resulted in the exploitation, alteration and in many cases the complete destruction of these valuable ecosystems, with an accompanying loss of associated ecosystem goods and services (Begg, 1986). It is now acknowledged that these ecosystems perform functions making them invaluable to the management of both water quantity and quality, and as a result wetlands are regarded as integral components of catchment systems (Jewitt and Kotze, 2000; Dickens et al., 2003).

River systems are the primary source of water and supply more than 85% of all the water that is used in South Africa for agricultural, domestic and industrial uses, with groundwater systems providing the remainder (Ashton, 2007). There is cause for concerns as a result of the status of river ecosystems in South Africa (DEAT, 2005). According to the spatial biodiversity assessment of South Africa's 120 river signatures, findings revealed that 82% of these segments are threatened (DEAT, 2005). Additionally, almost half (44%) are critically endangered, while 27% are endangered, 11% are vulnerable and 18% are least threatened. Poor protection is afforded to the river ecosystems in South Africa (DEAT, 2005). All of South Africa's freshwater systems are being heavily utilized and South Africa is already a water-scarce country (DEAT, 2005).

This study addresses two components including a wetland delineation assessment and an ecological state assessment of the local reach of the Limpopo River. These two components will be addressed separately throughout this report.

In particular the aim of the first component is to delineate and assess the associated wetland areas of the study area. The following tasks were identified in order to meet the project objectives:

- Conduct a desktop and field investigation of the wetlands within the study areas;
- Assess, classify, delineate and map the identified wetlands;
- Describe the general functions of the wetlands;
- Determine the Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) of the wetlands on site; and

- Provide a report with maps of wetlands, detailing all the information.

The aim of the second component of the study is to determine the present ecological state of the aquatic ecosystems in the study area, in order to achieve this validated rapid aquatic biomonitoring methodologies were applied. In order to achieve this aim the following objectives have been established:

- Collect and review existing literature pertaining to the study area and the ecological state of aquatic ecosystems in the area;
- Selection of a suitable study area;
- Characterise the current ecological state of the aquatic ecosystem by making use of selected driver indices which address the habitat and *in situ* water quality state;
- Characterise the current ecological state of the aquatic ecosystem by making use of selected responder indices which address macroinvertebrate and ichthyofauna population attributes; and
- Provide a report with plans of sampling sites, detailing all the information.

Digby Wells & Associates was appointed by Ledjadja Coal to undertake a wetland study and initiate a monitoring programme at the Boikarabelo Coal Mine. For the ease of understanding as well as for the interpretation of data for the study, these two components will be addressed separately throughout the report. This report presents the approach adopted, the results of the approach as well as a discussion of the significance and relevance of the determined results. Additionally management options have also been provided to protect and manage ecosystems and areas of ecological importance.

3 STUDY AREA

The proposed Boikarabelo Coal Mine is located in the Limpopo Catchment west of the town of Lephalale. The study area is associated with the Limpopo River quaternary catchment A41E which is situated within the Limpopo Water Management Area (WMA 1). The area assessed included sections of the farm Osorno 700 LQ, Witkopje 238 LQ, Groot-Zwart-Bult 290 LQ and Steenbokpan 295 LQ. The study area is directly adjacent to the Limpopo River which forms the border between South Africa and Botswana and flows next to and through, a number of countries and is regulated by trans-boundary agreements. In addition to this, many water users are dependent on the Limpopo River as a water resource for agricultural and livestock purposes as well as for human consumption. The majority of the area is currently used for game farming as well as hunting activities. A wetland delineation was conducted for the Limpopo River floodplain and associated wetland areas and an ecological assessment of the aquatic ecosystem consisted of an integrity assessment of the Limpopo River.

4 EXPERTISE OF THE SPECIALIST

A curriculum vitae (CV) and declaration of independence is attached in Appendix A.

5 AIMS AND OBJECTIVES

Due to the study being comprised of two specialist components, the aims and objectives for the wetland delineation assessment and an ecological state assessment of the local reach of the Limpopo River are described as follows:

An assessment of the wetland areas associated with the proposed study area will be conducted in order to delineate the respective wetland units and additionally to describe the integrity of these units and associated ecological significance. In order to achieve this aim the following objectives have been formulated:

- Identification, classification and description of wetland units;
- Determine the Present Ecological State (PES) of the wetland units;
- Determine the Ecological Importance and Sensitivity (EIS) of the wetland units; and
- Describe the ecological services provided (function) by wetland units.

An assessment of the surface aquatic ecosystem will be conducted in order to determine the integrity of this system. In order to achieve this aim the following objectives have been formulated:

- Characterisation of ecological driver components;
- Characterisation of ecological response components; and
- Measure, assess and report on the ecological state of aquatic ecosystems.

6 METHODOLOGY

6.1 Wetland delineation

Floodplains are complex due to backwater swamps, ox-bows, relict ox-bows and cut-off meanders. However all of these features are regarded as water resources (Hlongwane, 2009). Backwater swamps normally have wetland features (hydric indicators) and are easier to identify from aerial photos (Hlongwane, 2009). The wetland delineation method described by DWAF (2005) is used to determine the backwater swamps as well as seepage wetlands surrounding the floodplain. Additionally, the riparian delineation method described by DWAF (2005) is used to determine riparian zones associated with the Limpopo River. In spite of wetland and riparian areas being addressed as separate concepts, both habitats were delineated simultaneously as it is likely that wetlands and riparian areas will overlap (DWAF, 2005). Both the practical field procedure for the identification and delineation of wetlands and riparian areas (DWAF, 2005) as well as the Corps of engineers wetland delineation manual (Corps, 1987) were adopted as joint methodologies for this survey. Due to the proposed study area being situated within the Limpopo province of South Africa, the interpretation of the results will be based predominantly on the DWAF (2005) guidelines.

Maps were generated from 1:50 000 topographic maps and satellite imagery, onto which the wetland boundaries were delineated. The identified wetland was classified according to the hydrogeomorphic (HGM) determinants based on modification of the system proposed by Brinson (1993), and modified for use by Marneweck and Batchelor (2002) and subsequently revised by Kotze *et al.* (2004).

A site visit was undertaken in January 2010 for orientation on the farms Osorno 700 LQ and Witkopje 238 LQ. In order to determine the boundaries of wetlands and riparian areas, the methodology described by DWAF (2005) was adopted. This included a desktop delineation by estimating wetland boundaries from aerial photos, making use of topography, the presence of water and different vegetation structure as clues. The wetland delineation procedure was started from the downstream part of the area to be delineated, utilising cues such as the presence of water or obligate hydrophilic vegetation. A soil auger was used to examine the first 0.5m of the soil profile for the presence of soil wetness and/or soil form indicators (DWAF, 2005) In Accordance with Kotze and Marneweck (1999) soil augering was conducted to identify indicators of hydric conditions so as to verify whether or not the areas delineated as wetlands met the criteria for classification as wetlands.

6.1.1 Wetland classification, delineation and mapping

In accordance with DWAF guidelines (2005) the wetland delineation procedure considers four attributes to determine the limitations of the wetland. These attributes are discussed according to the DWAF guidelines in further detail later on in this section. The four attributes are:

- Terrain Unit Indicator – helps to identify those parts of the landscape where wetlands are more likely to occur;
- Soil Form Indicator – identifies the soil forms, which are associated with prolonged and frequent saturation;
- Soil Wetness Indicator – identifies the morphological "signatures" developed in the soil profile as a result of prolonged and frequent saturation; and
- Vegetation Indicator – identifies hydrophilic vegetation associated with frequently saturated soils.

In accordance with the definition of a wetland in the NWA, vegetation is the primary indicator of a wetland, which must be present under normal circumstances. However, the soil wetness indicator tends to be the most important in practices. The remaining three indicators are then used in a confirmatory role. The reason for this is that the response of vegetation to changes in the soil moisture regime or management are relatively quick and may be transformed, whereas the morphological indicators in the soil are significantly more permanent and will hold the indications of frequent and prolonged saturation long after a wetland has been drained (perhaps several centuries) (DWAF, 2005).

For the purpose of this study, wetlands are considered as those ecosystems defined by the National Water Act 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."

Terrain Unit Indicator.

Terrain Unit Indicator (TUI) areas include depressions and channels where water would be most likely to accumulate. These areas are determined with the aid of topographical maps, aerial photographs and engineering and town planning diagrams (these are most often used as they offer the highest degree of detail needed to accurately delineate the various zones of the wetland) (DWAF, 2005).

Soil Form Indicator.

Hydomorphic soils are taken into account for the Soil Form Indicator (SFI) which will display unique characteristics resulting from prolonged and repeated water saturation (DWAF, 2005). The continued saturation of the soils results in the soils becoming anaerobic and thus resulting in a change of the chemical characteristics of the soil. Iron and manganese are two soil components which are insoluble under aerobic conditions and become soluble when the soil becomes anaerobic and thus begin to leach out into the soil profile. Iron is one of the most abundant elements in soils and is responsible for the red and brown colours of many soils. Resulting from the prolonged anaerobic conditions, iron is dissolved out of the soil, and the soil matrix is left a greying, greenish or bluish colour, and is said to be "gleyed". Common in wetlands which are seasonally or temporarily saturated is a fluctuating water table, these results in alternation between aerobic and anaerobic conditions in the soil (DWAF, 2005). Iron will return to an insoluble state in aerobic conditions which will result in deposits in the form of patches or mottles within the soil. Recurrence of this cycle of wetting and drying over many decades concentrates these insoluble iron compounds. Thus, soil that is gleyed and has many mottles may be interpreted as indicating a zone that is seasonally of temporarily saturated (DWAF, 2005).

Soil Wetness Indicator.

In practice, the Soil Wetness Indictor (SWI) is used as the primary indicator (DWAF, 2005). Hydromorphic soils are often identified by the colours of various soil components. The frequency and duration of the soil saturation periods strongly influences the colours of these components. Grey colours become more prominent in the soil matrix the higher the duration and frequency of saturation in a soil profile (DWAF, 2005). A feature of hydromorphic soils are coloured mottles which are usually absent in permanently saturated soils and are most prominent in seasonally saturated soils, and are less abundant in temporarily saturated soils (DWAF, 2005). In order for a soil horizon to qualify as having signs of wetness in the remporary, seasonal or permanent zones, a grey soil matrix and/or mottles must be present.

Vegetation Indicator (VI).

If vegetation was to be used as a primary indicator, undisturbed conditions and expert knowledge are required (DWAF, 2005). Due to this uncertainty, greater emphasis is often placed on the SWI to delineated wetland areas. In this assessment the SWI has been relied upon to delineated wetland areas in addition, the identification of indicator vegetation species and the use of plant community structures has been used to validate these boundaries. As one moves along the wetness gradient from the centre of the wetland to the edge, and into adjacent terrestrial areas plant communities undergo distinct changes in species composition. Valuable information for determining the wetland boundary and wetness zone is derived from the change in species composition. When using vegetation indicators for delineation, emphasis is placed on the group of species that dominate the plant community, rather than on individual indicator species (DWAF, 2005).

6.1.2 Riparian delineation and mapping

In accordance with DWAF guidelines (2005) the riparian delineation procedure considers three attributes to determine the limitations of the riparian zone. These attributes are discussed according to the DWAF guidelines in further detail later on in this section. The three attributes are:

- Topography – indicates the outer edge of the riparian areas by the edge of the macro channel bank;
- Vegetation – identifies the distinctive difference between riparian and terrestrial species and is used as the primary indicator; and
- Alluvial Soils – identifies recent deposits of sand, mud etc set down by flowing water.

For the purpose of this study, riparian habitats are defined by the National Water Act as follows:

"Riparian habitat includes the physical structure and associated vegetation of the area associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas."

Topography

The edge of the macro channel bank is used as an indicator of the outer edge of the riparian area. This is defined as the outer bank of a compound channel and not the active river or stream bank. Alluvial deposits often cover flood benches which may exist between the active channel and the macro channel bank. These benches often have riparian vegetation on them. A dramatic change in the frequency, duration and depth of flooding experienced is often represented by the macro channel bank, leading to a corresponding change in vegetation structure and composition.

Vegetation

The riparian delineation relies primarily on vegetation indicators. Through the use of vegetation, the outer boundary of the riparian area must be adjacent to a watercourse and can be defined as the zone where a distinctive change occurs in species composition as well as physical structure. These differences between riparian and terrestrial vegetation are primarily a result of more water being available to species growing adjacent to watercourses. Thus it is not necessary to identify different species in order to delineate the riparian boundary. All that is required is to compare changes in the species composition and growth forms. (DWAF, 2005).

Alluvial Soils

Allluvial soils are relatively recent deposits of sand, mud etc set down by flowing water. Riparian areas often, but not always, have alluvial soils. The use of alluvial soils cannot always be used as a primary indicator to accurately delineate riparian areas, it can be used to confirm the topographical and vegetative indicators. (DWAF, 2005)

Deposited material can also be used to delineate the areas where bank stabilization, provided by the roots of riparian vegetation, is most important. Such material is deposited adjacent to the macro channel bank during flooding and may include vegetation debris as well as soil deposits. (DWAF, 2005).

6.1.3 Wetland delineation (Corps)

An additional approach available to delineate wetland areas includes a triple application, parameter approach, as defined in CORPS (1987). This methodology involves and assessment of the evaluation of vegetation, soil, and hydrology to determine the presence or absence of wetlands. The routine delineation method was used for the determination of the presence of wetland habitat in this study. Data from wetland and upland plots were recorded to determine the wetland boundaries. In order for an area to be delineated as a wetland area, particular aspects pertaining to the following variables must be considered:

- Wetland Vegetation;
- Hydric Soils;
- Wetland Hydrology.

Wetland Vegetation

Plant species which have adapted to saturated and/or anaerobic conditions are referred to as hydrophytic plants. These plants are typically found in areas where the frequency and duration of inundation produce permanently or periodically saturated soil conditions. The presence of hydrophytic vegetation is determined through the use of several indicators. The Corps and the U.S. Fish and Wildlife Service (USFWS) have assigned an indicator status to many plant species, based on the estimated probability of the species existing in wetland conditions. The indicator status definitions for plant species is presented in Table 1. Plants with an indicator status of obligate (OBL), facultative-wet (FACW), or facultative (FAC) are considered to be adapted to wetland conditions. The strongest indicator for hydrophytic vegetation is when greater than 50 percent of the dominant plant species have an indicator status of OBL, FACW, or FAC. (CORPS, 1987).

Table 1: Plant indicator status definitions (CORPS, 1987)

Indicator Status Category	Occurrence
Obligate wetland plants (OBL)	Occur in wetlands, under natural conditions, approximately 99 percent of the time.
Facultative wetland plants (FACW)	Occur in wetlands approximately 67 to 99 percent of the time.
Facultative plants (FAC)	Occur in wetlands approximately 34 to 66 percent of the time. Similar likelihood of being found in wetlands or non-wetlands
Facultative upland plants (FACU)	Occur in wetlands approximately 1 to 33 percent of the time.
Upland plants (UPL)	Occur in non-wetlands, under natural conditions, approximately 99 percent of the time.
Plants with no indicator status (NI)	Assumed to be upland

Hydric Soils

Hydric soils have been defined by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) as those soils that are sufficiently wet to support the growth and regeneration of hydrophytic vegetation (CORPS, 1987). As a result of this, not all areas having hydric soils will qualify as wetlands, such as soils that have been drained and no longer support hydrophytic vegetation. Thus the soil may only be referred to as wetland soil only when the hydric soil supports hydrophytic vegetation and the area has indicators of wetland hydrology. Hydric s oils exhibit distinct characteristics that are directly observable as a result of the anaerobic conditions. These characteristics include:

- Presence of organic soils commonly called peat, or muck. These soils have high organic matter content (greater than 50 percent) in the upper 32 inches of soil;
- Sulfidic material is present, giving the soil a rotten-egg odor;
- Water saturation within a specific depth, ranging from 0, 0.5, or 1 ft from the surface (depending on soil drainage class, permeability, and texture) for a duration sufficient to produce anaerobic conditions within the upper 20 inches; and
- Dark soil colors that are quantified using the Munsell Soil Color Chart. Dark colors are defined as those areas where:
  - ❖ The matrix chroma is 1 or less;
  - ❖ The matrix chroma is 2 or less in mottled soils. Mottles are bright spots of color, in a dark soil matrix, indicating a fluctuating water table; and
  - ❖ Blueish or grey color, called “gley”, indicating anaerobic soil conditions.

Wetland Hydrology

Areas where the presence of water has an overriding influence on characteristics of vegetation and soils due to anaerobic conditions caused by water, are considered wetland areas as a result of this evidence of wetland hydrology. These characteristics are typically present in areas that are inundated or have soils that are saturated to the surface for a sufficient duration during the growing season to both develop hydric soils, and support hydrophytic vegetation. Often hydrology is the least exact of the parameters, and indicators of wetland hydrology are sometimes difficult to find in the field (CORPS, 1987). In spite of this, it is important to determine the wetland area is periodically inundated or has saturated soils during the growing season (CORPS, 1987).

6.1.4 Wetland functional assessment

In accordance with the method described by Kotze *et al.* (2007) a Level 2 ecological functional assessment of the associated wetland and riparian areas was undertaken. This methodology provides for a scoring system to establish the services of the wetland ecosystem. The onsite wetlands were grouped according to homogeneity and assessed utilizing the functional assessment technique, WET-EcoServices, developed by Kotze *et al*, (2007) to provide an indication of the benefits and services. As a result of this, scores are not wetland area specific but do however provide an indication of the ecological services offered by the different HGM units as a whole for this study.

6.1.5 The Wetland Index of Habitat Integity for floodplains

According to Rountree *et al.* (2007) the Wetland Index of Habitat Integrity (WETLAND-IHI) is a tool developed for use in the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP). The WETLAND-IHI has been developed to allow the NAEHMP to include floodplain and channeled valley bottom wetland types to be assessed and the monitoring data to be incorporated into the national monitoring programme. For this reason this model was only applied to the floodplain wetland and was not used to determine the integrity of the hillslope seepage areas or the unchanneled valley bottom wetlands. The output scores from the WETLAND-IHI model are presented in the standard DWAF A - F ecological categories (Table 2), and provide a score of the Present Ecological State of the habitat integrity of the wetland system being examined. According to Kleynhans and Louw (2007) EcoClassification is the procedure to determine and categorise the ecological state of various biological and physical attributes compared to the reference state.

Table 2: Interpretation of the ecological categories and descriptions (Kleynhans & Louw, 2007).

Categories	Classes	Ecological Description
A	Natural	Modifications to the natural abiotic template and the characteristics of the biota are undetectable. The characteristics of the resource are completely determined by unmodified natural regimes. Even potential anthropogenic induced changes to the abiotic characteristics and anthropogenic risks to the well-being of biota are not measurable.
A/B, B, B/C	Good	Modifications to the natural abiotic template and the characteristics of the biota may vary from small to moderate. The characteristics of the resource are largely determined by natural regimes while anthropogenic influences tend to play a small to moderate role. There is a small risk that the resource base may be exceeded. Consequently, the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a limited number of localities may be somewhat higher than expected under natural conditions. Temporally and spatially this may result in somewhat lowered abundances and frequency of occurrence of intolerant and moderately intolerant species. However, even in the short, medium and long term the resilience and adaptability of biota are not compromised. The impact of acute disturbances on the biota is effectively mitigated by the presence of sufficient refuge areas.
C, C/D, D	Fair	Modifications to the natural abiotic template and the characteristics of the biota may vary from moderate to large. The characteristics of the resource are partly determined by natural regimes but anthropogenic influences tend to play a major role. There is a moderate to large risk that the resource base may be exceeded. Consequently, the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a significant number of localities may be higher than expected under natural conditions. Temporally and spatially this may result in low abundances and frequency of occurrence of intolerant and moderately intolerant species, as well as a possible increase in the abundances and frequency of occurrence of tolerant species which may reach pest proportions. However, in the medium to long term the resilience and adaptability of biota are not compromised. The impact of local and acute disturbances are to an extent mitigated by some refuge areas.
E,F	Poor	Modifications to the natural abiotic template and the characteristics of the biota may vary from large to completely dominant. The characteristics of the resource are almost completely determined by severe anthropogenic influences. There is a serious to critical risk that the resource base may be exceeded. Consequently, the risk to the well-being and survival of all but the most tolerant biota (depending on the nature of the disturbance) at almost all localities is serious to critical. Temporally and spatially this will result in the absence of intolerant and moderately intolerant species and very low abundances and frequency of occurrence of moderately tolerant species. Tolerant species tend to increase in abundance and frequency of occurrence and can reach pest proportions. On all temporal and spatial scales the resilience and adaptability of biota are compromised. The impact of local and acute disturbances are to an extent mitigated by some refuge areas.

The model is composed of four modules of which hydrology, geomorphology and water quality all assess the existing driving processes responsible for the wetland formation and maintenance. The fourth module is vegetation alteration which provides an indication of the significance of human land use activities on the wetland surface itself and how these may have modified the condition of the wetland (Rountree *et al.*, 2007). The integration of the scores from these four modules provides an overall Present Ecological State (PES) score for the wetland system being examined.

6.1.6 Determining the Present Ecological State (PES) for the pan systems

A present ecological status analysis was conducted in order to establish baseline integrity (health) for the associated wetlands. The scoring system applied in the procedure for the determination of Resource Directed Measures for wetland ecosystems (DWAF, 1999) was applied. The criteria were selected on the assumption that anthropogenic modification of the criteria and attributes listed under each criterion can generally be regarded as the primary causes of degradation of the ecological integrity of a wetland. The study criteria study components and associated weighting and scoring as well as the PES categories are presented in Appendix B. The selected criteria consisted of:

- Hydrologic;
- Water quality;
- Hydraulic/Geomorphic; and
- Biota.

6.1.7 Determining the Ecological Importance and Sensitivity (EIS) for the wetlands

An ecological importance and sensitivity analysis was conducted for the associated wetland areas. For the purpose of this assessment, the scoring system applied in the procedure for the determination of Resource Directed Measures for wetland ecosystems (DWAF, 1999) was applied. The categories used were modified from Kleynhans (1999). In order to ascribe the individual category scores used in the assessment, air photo analysis, an assessment of the key drivers and a field sampling survey were used. The categories used to determine the EIS is presented in Table 3.

Table 3: Ecological importance and sensitivity categories. Interpretation of median scores for biotic and habitat determinants (Kleynhans, 1999).

Class	Description	Score
A	Floodplains that are considered ecologically important and sensitive on a national or even international level. The biodiversity of these floodplains is usually very sensitive to flow and habitat modifications. They play a major role in moderating the quantity and quality of water of major rivers.	>3 AND <=4
B	Floodplains that are considered to be ecologically important and sensitive. The biodiversity of these floodplains may be sensitive to flow and habitat modifications. They play a role in moderating the quantity and quality of water of major rivers.	>2 AND <=3
C	Floodplains that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these floodplains is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of water of major rivers.	>1 AND <=2
D	Floodplains that are not ecologically important and sensitive at any scale. The biodiversity of these floodplains is ubiquitous and not sensitive to flow and habitat modifications. The play an insignificant role in moderating the quantity and quality of water of major rivers.	0 AND <=1

6.2 Aquatic assessment

In order to determine the ecological integrity of the aquatic environment, individual biophysical components of the streams in the study area were assessed. These biophysical attributes were considered by implementing selected biophysical tools or indices that refer to selected drivers and biological responses of an aquatic ecosystem. Methodologies formulated by the River Health Programme (RHP, 2001) and the Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers (USEPA, 2006) have been adopted for this survey to conduct the aquatic biological assessment of the Limpopo River. These methodologies were developed for lotic systems (rivers and streams) and are not applicable to lentic ecosystems (dams, lakes, pans etc.). The selected drivers and biological responses include:

Drivers

- *In situ* water quality
- Habitat Indicators

Response Indicators

- Aquatic Macroinvertebrates
- Ichthyofauna

According to Kleynhans and Louw (2007) the directional change in the attributes of the drivers and biota is referred to as trend. Generally, an assessment may be approached from a driver perspective (Kleynhans & Louw, 2007). The driver components will be considered in order to determine the degree of contribution towards the current state of the biological communities. The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux (Kleynhans & Louw, 2007).

6.2.1 Water quality

The quality of water is important in order to ensure that the water resource can maintain a healthy biodiversity (DWAF, 1996). This, in conjunction with the social and economic importance of water, can thus be regarded as one of the most important factors to be considered when it comes to conservation and sustainability of this valuable resource. According to Palmer *et al.* (1996), water quality can be defined as the combined effects of the physical attributes and the chemical constituents of an aquatic ecosystem.

The physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses, and for the protection of the health and integrity of aquatic ecosystems refers to the quality of water (DWAF, 1996). Many of these properties are controlled or influenced by components that are either dissolved or suspended in water as a result of either natural or anthropogenic input, or both. The various water quality parameters were all taken *in situ*. These parameters include pH, oxygen content and oxygen saturation, temperature and total dissolved salts (TDS) using calibrated water quality meters (Orion 5 Star). In spite of the fact that these measurements only provide a “snapshot” of the conditions present at the precise time of sampling, they can however provide valuable insight into the characteristics of a specific sample site. It is important to note the influence of the water quality findings on the response components (invertebrate communities) for the biomonitoring assessment. The management of the quality of the water is imperative to ensure the sustainable use of water as a resource, and the biodiversity which relies on this resource. The South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) was applied to this study as the primary source of reference information. The South African Water Quality Guidelines contains information similar to that which is available in the international literature, however, the information provided is specifically formulated for South African aquatic ecosystems and water users (DWAF, 1996).

6.2.2 Habitat quality

The assessment of the composition of the surrounding physical habitat which influences the quality of the water resource and the condition of the resident aquatic community is referred to as a habitat assessment (Barbour et al., 1996). An important factor which determines the survival of a species in an ecosystem is the state of the available habitat. As a result of habitat loss, alteration and degradation the number of species have declined (Karr, 1981). According to Karr (1981) the diversity of biota dependant on the habitat will decrease if the habitat integrity decreases. Types of river habitats which are found include pools, rapids, sandbanks, stones on the riverbed, runs, riffles, as well as marginal and aquatic vegetation (RHP, 2001). The physical habitat of an aquatic ecosystem is a large component which affects the ecological integrity of an aquatic ecosystem and as a result of this, an assessment of the physical habitat should be included in all bioassessments to assist in interpreting the results (Uys *et al.*, 1996; McMillan, 1999; Dickens and Graham, 2002; Vos *et al.*, 2002). If no assessment of the physical habitat was carried out, it would be impossible to determine whether a change in the biological community is a result of either changes in water quality or habitat (Rosenberg and Resh, 1993; Barbour *et al.*, 1999).

6.2.2.1 Index of Habitat Integrity (IHI)

The quality and diversity of the available habitat was assessed by means of the Index of Habitat Integrity (IHI) (Kleynhans, 1996). The IHI was applied on a site basis. The IHI integrity classes and a description of each class are presented in Table 4. This index assesses the number and severity of anthropogenic perturbations and the damage they potentially inflict on the habitat integrity. Criteria used in the assessment of habitat integrity are listed in Table 5. The descriptive classes for the assessment of modifications to habitat integrity protocol are listed in Table 6. Table 7 lists the criteria and weights used for the assessment of intermediate habitat integrity.

Table 4: The IHI integrity classes and short descriptions of each class (Kleynhans, 1999).

Integrity Calss	Description	IHI Score (%)
A	Natural	> 90
B	Largely natural	80 - 90
C	Moderately modified	60 - 79
D	Largely modified	40 - 59
E	Seriously modified	20 - 39
F	Critically modified	0 - 19

Table 5: Criteria used in the assessment of habitat integrity

CRITERION	RELEVANCE
Water abstraction	Direct impact on 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 hab
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,
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 point 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 c
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.
Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependant upon the species involved and scale of infestation.
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.
Indigenous 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 riverbank 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

Table 6: Descriptive classes for the assessment of modifications to habitat integrity

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

Table 7: Criteria and weights used for the assessment of intermediate habitat integrity

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	14	Water abstraction	13
Inundation	10	Inundation	11
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid Waste Disposal	6		
TOTAL	100	TOTAL	100

6.2.2.2 Invertebrate Habitat Assessment System

The Integrated Habitat Assessment System (IHAS) was specifically designed to be used in conjunction with the South African Scoring System, Version 5 (SASS5), benthic macro-invertebrate assessments. The Invertebrate Habitat Assessment System (IHAS) assesses the availability of the biotopes at each site and expresses the availability & suitability of habitat for macroinvertebrates, this is determined as a percentage, where 100% represents "ideal" habitat availability. It is presently thought that a total score of over 65% represents good habitat conditions, whereas a score of 55%-64% represents a moderately suitable habitat for macro-invertebrates (McMillan, 2002).

6.2.2.3 Habitat Assessment for High and Low Gradient Streams

According to the United Stated Environmental Protection Agency (USEPA, 2006) an evaluation of habitat quality is critical to any assessment of ecological integrity and should be performed at each site at the time of the biological sampling. The rapid bioassessment protocol for use in streams and wadeable rivers assumes that habitat incorporates all aspects of physical and chemical constituents along with the biotic interactions (USEPA, 2006). For this study, habitat is narrowed down to the instream and riparian habitat that influences the structure and function of the aquatic community in a stream. According to Karr *et al.* (1986) one of the major stressors on aquatic systems is the presence of an altered habitat structure. This habitat assessment includes a general description of the site, a physical characterization and water quality assessment, and a visual assessment of instream and riparian habitat quality.

In order to accomplish the habitat quality assessment selected physicochemical parameters are characterized in conjunction with a systematic assessment of physical structure. This allows for key features to be rated or scored providing a useful assessment of habitat quality. Habitat evaluations are first made on instream habitat, followed by channel morphology, bank structural features, and riparian vegetation. According to the USEPA (2006) methodology the actual habitat assessment process involves rating the parameters as optimal, suboptimal, marginal, or poor based on the criteria included. All of the assessed parameters are rated on a numerical scale of 0 to 20 (highest) for each reached sampled. The range of scores for each parameter is summarized in Table 8. The ratings are then totaled and compared to a reference condition to provide a final habitat ranking. According to Barbour and Stribling (1991) reference conditions are used to scale the assessment to the "best attainable" situation. A percent comparability measure is determined for the ratio between the score for the reach assessed and the score for the reference condition. From the percentage score it is possible to place the site into a general quality class based on the habitat condition parameters (van Staden, 2003). The score percentages for the various quality classes are presented in Table 9. The reach assessed is then classified on the basis of its similarity to expected conditions (reference condition), and its apparent potential to support an acceptable level of biological health. This is determined in accordance with criteria formulated by the Mid-Atlantic Coastal Stream Workgroup (1996).

Table 8: Habitat parameter scoring ranges; (L) left and (R) right bank while looking downstream

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
Epifaunal substrate/Available cover	20 to 16	15 to 11	10 to 6	5 to 0
Pool substrate characterisation	20 to 16	15 to 11	10 to 6	5 to 0
Pool variability	20 to 16	15 to 11	10 to 6	5 to 0
Sediment deposition	20 to 16	15 to 11	10 to 6	5 to 0
Channel flow status	20 to 16	15 to 11	10 to 6	5 to 0
Channel alteration	20 to 16	15 to 11	10 to 6	5 to 0
Channel sinuosity	20 to 16	15 to 11	10 to 6	5 to 0
Bank stability (L) & (R)	10 to 9	8 to 6	5 to 3	2 to 0
Vegetative protection (L) & (R)	10 to 9	8 to 6	5 to 3	2 to 0
Riparian vegetative zone width (L) & (R)	10 to 9	8 to 6	5 to 3	2 to 0

Note: (L) & (R) – Each bank is scored individually

Table 9: The score percentages allocated to the various quality classes for the habitat.

Percentage	Class
78-100 %	Excellent
51-77 %	Good
25-50 %	Fair
0-24 %	Poor

6.2.3 Aquatic invertebrate assessment

Macroinvertebrate assemblages are good indicators of localized conditions because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well-suited for assessing site-specific impacts (upstreamdownstream studies) (USEPA, 2006). Macroinvertebrates respond to a combination of short term environmental variables. Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects (USEPA, 2006). According to Hellawell, (1977) field sampling is easy and since the communities are heterogeneous and several phyla are usually represented, response to environmental impacts is normally detectable in terms of the community as a whole. Sampling is relatively easy, requires few people and inexpensive gear, and has minimal detrimental effect on the resident biota. The assessment and monitoring of benthic macroinvertebrates forms an integral part of the monitoring of the health of an aquatic ecosystems

6.2.3.1 South African Scoring System version 5 (SASS5)

The South African Scoring System version 5 (SASS5) is the current index being used to assess the status of riverine macro invertebrates in South Africa. According to Dickens and Graham (2002), the index is based on the presence of aquatic invertebrate families and the perceived sensitivity to water quality changes of these families. Different families show different sensitivities to pollution, these sensitivities range from highly tolerant families (e.g. Muscidae and Psychodidae) to highly sensitive families (e.g. Oligoneuridae). SASS results are expressed both as an index score (SASS score) and the average score per recorded taxon (ASPT value).

Various macro-invertebrates are sampled from a variety of biotopes within the river using standard DWAF-approved methods. These biotopes and their sampling protocols are described in detail by Dickens and Graham (2002). The standardized sampling methods allow comparisons between studies and sites. Macroinvertebrate sampling is done using a standard SASS net (mesh size 1000 µm, and a frame of 30 cm x 30 cm).. All of the invertebrates collected from different habitats are identified down to family level. This information is then utilised within the South African Scoring System for aquatic macro-invertebrates (version 5) (SASS5) in order to determine the present ecological state of the river segment where macro-invertebrates are concerned (Dickens & Graham, 2002).

The sensitivity scales were derived from the tolerances to pollution as used in the South African Scoring System 5 (Dickens & Graham, 2002). According to van der Merwe (2003) a broad explanation of the sensitivity scales will be as follows:

- 1 – 5 Highly tolerant to pollution (i.e. Family Baetidae, score: 4)
- 6 – 10 Moderately tolerant to pollution (i.e. Family Ecnomidae, score : 8)
- 11 – 15 Very low tolerances to pollution (i.e. Family Heptageniidae, score : 13)

All SASS5 and ASPT scores are compared with the SASS5 Data Interpretation Guidelines (Dallas, 2007) for the relevant ecoregion, namely the Limpopo Plain. This method seeks to develop biological bands depicting the various ecological states and is derived from data contained within the Rivers Database and supplemented with other data not yet in the database. Caution should be noted that ASPT becomes an unreliable indicator of river health at very low SASS5 Scores, since a single taxon with a medium or high sensitivity weighting can increase the ASPT considerably. Caution should be applied when using the biological bands in such instances.

SASS5 was designed as a rapid bioassessment protocol for the evaluation of South African lothic systems therefore, SASS5 could not be applied to the dams and ox-bow lakes. Sampled invertebrates were then identified using the Aquatic Invertebrates of South African Rivers Illustrations book, by Gerber and Gabriel (2002). Identification of organisms was made to family level (Thirion *et al*., 1995; Dickens & Graham, 2002; Gerber & Gabriel,2002).

6.2.3.2 Benthic Macroinvertebrates (USEPA)

The seasonality for benthic collections (adapted from Gibson et al. 1996) suggests the ideal sampling procedure is to survey the biological communities with each change of season, then select the appropriate sampling periods that accommodate seasonal variation. This was not possible for this survey so a single summer season survey was conducted. Many programs have found that a single index period provides a strong database that allows all of their management objectives to be addressed (USEPA, 2006).

The benthic macroinvertebrate sampling methods employ direct sampling of natural substrates. Artificial substrates are eliminated from consideration due to time required for both placement and retrieval, and the amount of exposure time required for colonization (USEPA, 2006). Owing to the nature of the system survey, natural substrate samples were collected. The SASS5 sampling methodology was also used to assist with sample collection. The multi-habitat approach according to the USEPA (2006) methodology was adopted for this study. As a result of the low gradient nature of the system surveyed, a method suitable to sampling a variety of habitat types is desired in this case. The adopted method is based on Mid-Atlantic Coastal Streams Workgroup recommendations designed for use in streams with variable habitat structure (MACS, 1996). This method focuses on a multi-habitat scheme designed to sample major habitats in proportional representation within a sampling reach. Benthic macroinvertebrates are collected systematically from all available instream habitats and are identified to family level.

6.2.4 Fish assessment

There are various reasons why fish are good indicators of ecological integrity:

- Fish are long-lived and can therefore be a good indicator of long-term exposure.
- As a result of being mobile, fish occupy a wide range of habitats
- Fish communities comprise of a range of species from different trophic levels and thus integrate environmental changes
- Indicate that lower food chain levels should be in good health, if fish, mostly top of the food chain, are in good health (DWAF, 1999).

Fish can be sampled through an array of techniques, these may include electro-narcosis (with hand-held electroshocking apparatus), seine nets, fyke nets and any other DWAF-approved sampling methods (where applicable) in order to determine the actual occurrences of certain fish species within the various habitats per site. These methodologies are also applied to the current River Health Programme. This information is then used in an index known as the Fish Assemblages Integrity Index (FAII) (Kleynhans, 1999), with the information gained being an indication of the present ecological state of the river based on the fish assemblage structures observed. All fish were identified in the field and released at the point of capture. Fish species were identified using the guide Freshwater fishes of Southern Africa (Skelton, 2001).

6.2.4.1 Fish Assessment Integrity Index (FAII)

According to Kleynhans (1999) the FAII is based on the fish species expected to be present in biological (fish habitat) segments which are sections of river with relatively homogeneous fish habitat. Within this framework fish are then categorised according to an intolerance index. The intolerance index takes into account trophic preferences and specialisation, habitat preferences and specialisation, requirement for flowing water during different life-stages and association with habitats with unmodified water quality (Kleynhans, 1999). This intolerance index, the expected frequency of occurrence and expected health of fish species in a particular fish habitat segment is used to formulate an index for the situation expected under minimally impaired conditions which was used as the comparative basis for the observed (sampled) situation (Kleynhans, 1999). According to Kleynhans (1999) the observed situation is then expressed as a fraction of the expected situation to arrive at a relative FAII index value which is then grouped into one of six descriptive fish assemblage integrity index classes. The classification system for the fish community integrity is presented in Table 10.

Table 10: The FAII integrity classes and short descriptions of each class (Kleynhans, 1999).

Integrity Class	Description of general expected conditions for each integrity class	FAII Score (%)
A	Unmodified, or approximates natural condictions closely	90 to 100
B	Largely natural with few modification. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modification	80 to 89
C	Moderately modofied. A lower than expected species richness and presence of most intolerant species. Some impairment of health may be evident at the lower end of the scale.	60 to 79
D	Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Impairment of health may become more evident at the lower end of this class.	40 to 59
E	Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become evident.	20 to 39
F	Critically modified. An extremely lowered species richness and an absence of intolerant and maderately intolerant species. Only tolerant species may be present with a complete loss of species at the lower end of the class. Impairment of health generally evident	0 to 19

6.2.4.2 Index of Biotic Integrity (IBI)

The Rapid Bioassessment Protocol (RBP) for fish described by USEPA (2006) consists of the principal evaluation mechanism utilized by the technical framework of the Index of Biotic Integrity (IBI). According to USEPA (2006) the IBI incorporates the zoogeographic, ecosystem, community and population aspects of the fish assemblage into a single ecologically-based index. The IBI typically comprises of a total of 12 community attributes (metrics) that are compared to values expected for a relatively unperturbed stream of the same size in the same ecological region (Plafkin et al., 1989). According to Fausch *et al.* (1990) metrics are scored, representing conditions that deviate slightly, moderately or strongly from situations at reference sites. Kleynhans (1999) states that in spite of the ecological principles on which the IBI is based are sound, the application of the IBI in both its original and modified versions, present a number of problems when considered for use in South African situations. Such problems are according to Kleynhans (1999) are:

- Detailed historical and ecological information that is often not available;

- A very large investment in equipment, financial resources and in a sufficiently large and trained workforce;
- The north-eastern parts of the country represent environmental conditions which often make it dangerous to do intensive sampling; and
- Complications due to the high variability of certain fish species with regard to environmental conditions associated with the variability and unpredictability of rainfall and runoff within seasons and between years.

As a result of the described problems above and the potential difficulties expected of effectively applying the IBI in South Africa, this index was not considered for an assessment of the fish community for this study.

6.3 Ecological description

Ecological classification refers to the determination and categorisation of the integrity of the various selected biophysical attributes of ecosystems compared to the natural or close to natural reference conditions (Kleynhans and Louw, 2007). The ecological evaluation in terms of expected reference conditions, followed by integration of these components and assessed in terms of biological responses, represents the Ecological Status or EcoStatus of a system (Kleynhans and Louw, 2007). According to Iversen *et al.* (2000) EcoStatus may be defined as the totality of the features and characteristics of the system that bear upon its ability to support an appropriate natural flora and fauna. For the purpose of this study ecological classifications have been determined for biophysical attributes for both the wetland areas as well as the Limpopo River. Descriptions of the ecological classification for various biophysical attributes will be done in accordance with Kleynhans and Louw (2007).

According to Kleynhans and Louw (2007) the A to F scale represents a continuum, and that the boundaries between categories are notional, artificially-defined points along the continuum. As a result of this there may be uncertainty regarding which category a particular entity belongs to. This situation falls within the concept of a fuzzy boundary, where a particular entity may potentially have membership of both classes (Robertson *et al*. 2004). For practical purposes these situations are referred to as boundary categories and are denoted as B/C, C/D, and so on. An illustration of the distribution of the ecological categories on a continuum (Kleynhans & Louw, 2007) is presented in Figure 1.

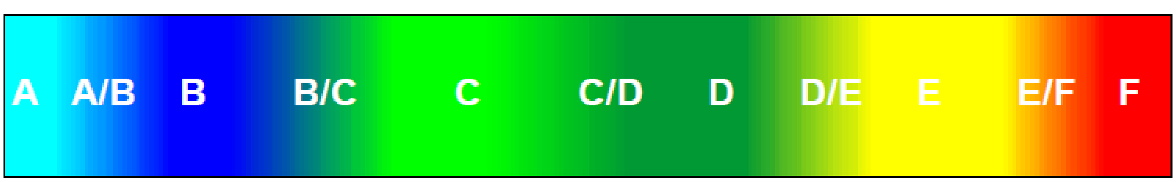

Figure 1: An illustration of the distribution of the ecological categories on a continuum

7 KNOWLEDGE GAPS

Owing to the allocated time frame for the study, a Level 2 RHP assessment was conducted and as such the confidence of the study should be compared to a RHP study of this level (Kleynhans & Louw, 2007). Additionally, as a result of the extreme high flow conditions experienced during the survey due to 70mm of rain falling the night prior to the survey, not all of the aquatic assessment indices could be applied effectively. Only a single survey was carried out and it is suggested that an additional low flow survey be conducted as the results from this study may not provide an accurate representation of the current ecological integrity of the aquatic ecosystems surveyed, which can vary during seasons, and thus confidence in the results would be low. According to Dickens and Graham (2002) SASS5 as an aquatic assessment study component has been designed for low/moderate flow hydrology. The flood-like conditions may not provide a true representation of the macroinvertebrate community structure of the system. Furthermore, SASS5 should only be performed after a period of sustained flow (Thirion et al, 1995). Aquatic invertebrates require at least a few weeks to re-colonise a stream after flow commences. It is recommended that an aquatic assessment be conducted during a low/moderate flow hydrology period in the near future.

8 FINDINGS

The largest wetland unit classified for the survey was a floodplain. According to Marneweck and Batchelor (2002) floodplains can be defined as low-gradient land onto which a river regularly overflows its banks, usually seasonally or during periods of high rainfall in the catchment with a relatively level alluvial (sand or gravel) area lying adjacent to the river channel, which has been constructed by the present river in its existing regime. A total of three wetland areas were assessed for this project. Information pertaining to these three areas is provided in the subsequent sections.

8.1 Wetland delineation

The wetlands in the study area are linked to both perched groundwater and surface water. Three Hydro-geomorphic (HGM) types of natural wetlands occurring within the area assessed and are:

- A floodplain;
- Pans; and
- Hillslope seepage wetland connected to pans

The distribution of the floodplain occurring in the study area as well as the location of the assessed pans in relation to the railways line is presented in Appendix B. The description based on the setting in the landscape and hydrologic components is presented in Table 11.

Table 11: The definition of the wetland units occurring in the study area [based on the system first described by Brinson (1993) and modified by Marneweck and Batchelor (2002), and further developed by Kotze *et al.* (2004)].

WETLAND TYPE	TOPOGRAPHIC SETTING	DESCRIPTION	HYDROLOGIC COMPONENTS		
			Inputs	**Throughputs**	**Outputs**
Floodplain	In depressions and basins, often at drainage divides on top of the hills	Valley bottom areas without a stream channel, gently sloped and characterized by floodplain features such as oxbow depressions and natural levees and the alluvial transport and deposition of sediment, usually leading to a net accumulation of sediment.	From main channel (when channel banks over spill) and from adjacent slopes.	Interflow and diffuse surface flow.	Variable but predominantly stream flow.
Pans	In depressions and basins, often at drainage divides on top of the hills	A basin shaped area with a closed elevation contour that allows for the non-permanent (seasonal or temporary) accumulation of surface water. An outlet is usually absent.	Runoff from the surrounding catchment area and lateral seepage from adjacent hillslope seepage wetlands.	None.	Evapo-transpiration and groundwater discharge from leakage.
Hillslope seepage wetlands connected to pans	Along the slopes of pan basins	Occur adjacent to pans on the concave or convex slopes associated with the pan basin and are characterized by the colluvial (transported by gravity) movement of materials. Generally always associated with sandy soil forms.	Predominantly groundwater from perched aquifers and interflow.	Interflow and diffuse surface flow.	Variable but predominantly restricted to interflow and diffuse surface flow

8.2 A description of wetland types

8.2.1 A floodplain

The floodplain surface usually slopes away from the channel margins due to As a result of preferential sediment deposition along the channel edges and areas closest to the channel the floodplain surface usually slopes away from the channel margins which can then result in the formation of backwater swamps at the edges of the floodplain margins (DWAF, 2007). According to Kotze *et al.* (2007) floodplains usually receive most of their water during high flow events when waters overtop the stream banks. According to McCartney (2000) flood attenuation is likely to be high early in the season until the floodplain soils are saturated and the oxbows and other depressions are filled. Additionally, the flood attenuation capacity is drastically reduced in the late season. It is unlikely that floodplains contribute significantly to stream flow regulation (Kotze *et al.,* 2007). The contribution of water from floodplains to stream flow and groundwater recharge is limited as a result of the clayey floodplain soils which retain water (Kotze *et al.*, 2007). Generally the inundation period of floodplains is short but in the oxbow depression portions of the floodplain inundation is more prolonged. Floodplains also assist with the enhancement of water quality but this is limited due to short residence times during flood events and due to the limited sub-surface water movement within the wetland.

8.2.2 A pan

Pans receive water both from surface and groundwater flows, which then accumulates in the depression owing to a generally impervious underlying layer which prevents the water draining away (Goudie and Thomas, 1985; Marshall and Harmse, 1992). According to Kotze et al. (2007) pans are usually isolated from streams and because of there position in the landscape the opportunity for attenuating flows is limited. However, because of their inward draining nature they do capture runoff and as a result they reduce the volume of surface water that would otherwise reach the stream during stormflow conditions. According to Goudie and Thomas (1985) and Marshall and Harmse (1992) pans are not considered locations for the trapping of sediment, as many pans originate from the removal of sediment by wind, thus creating what are referred to as deflation basins.

8.2.3 A hillslope seepage wetland

According to Kotze et al. (2007) these wetlands are usually associated with groundwater discharges, although flows through them may be supplemented by surface water contributors. These wetlands are expected to contribute to some surface flow attenuation early in the season until the soils are saturated, after which their contribution to flood attenuation will be limited (WRP, 1993; McCartney, 2000 and McCartney et al., 1998). The characteristic soil forms of the hillslope seepage wetlands which occur in the study area are sandy. It is common for these soils to remain saturated for periods during the summer months (wet season). Hillslope seepage wetlands connected to pans are seepage systems situated on the slopes of pan basins which are connected to the pan and contribute to the hydrodynamics of the pan.

8.3 Functional assessment of wetlands

Extensive literature searches have revealed that very few practitioners have quantified the benefits of wetland functionality. In addition to this, it appears likely that the functions of the wetlands are variable depending on the characteristics of the wetlands and landscape. It was not possible to perform the types of investigations necessary for determining functionality (such as, for example, nutrient balance studies or flood attenuation quantifications) for this study. As a result it is extremely difficult to contemplate the specific functions performed by the wetland identified for this study. In spite of these limitations, some general discussion is possible based on generalised functions that the types of wetlands detected in the area may perform.

8.3.1 A floodplain

According to Kotze *et al.* (2007) floodplains are considered to be important for flood attenuation because of the nature of the vegetation and the topographic setting that they occupy. The velocity of flow decreases laterally as the flood overtops the river banks, thus allowing for the deposition of particles within the floodplain landscape (Kotze *et al*, (2007). According to Hemond and Benoit (1998) phosphorous and other toxicants bound to trapped sediment are likely to be retained on the floodplains and this is a vital mechanism through which wetlands trap phosphates. According to Kotze *et al.* (2007) nitrogen removal via nitrification/denitrification is likely but also limited due to the short flooding periods. Additionally, due to the dilution effects the concentration of nutrients in flood waters entering the floodplain is often low (Kotze *et al.*, 2007).

8.3.2 A pan

According to Kotze et al. (2007) the ability for attenuating floods is limited by the position of the pans in the landscape, which are generally isolated from stream channels. As a result of their inward draining nature, pans do catch runoff, and thus reduce the volume of water which would otherwise reach the stream system during stormflow conditions (Kotze et al., 2007). According to Goudie and Thomas (1985) and Marshal and Harmse (1992) pans are not considered important locations for sediment trapping as many pans originate from the removal of sediment by wind, creating what is referred to as deflation basins.

Precipitation of minerals is carried out by temporary pans, including phosphate minerals due to the concentrating effects of evaporation (Kotze et al., 2007). In addition to this, nitrogen cycling is likely to be important with some losses due to denitrification and volatilization in the case of high pH's. According to Allan et al. (1995) the pedology, geology and local climate influence the water quality in pans. These factors in turn also influence the response of these systems to nutrient inputs (Kotze et al., 2007). According to Kotze et al. (2007) accumulated salts and nutrients in non-perennial pans can be transported out of the system by wind and be deposited on the surrounding slopes. That which is remaining may then dissolve again when water enters the system as the pan fills after rainfall events.

8.3.3 A hillslope seepage wetland

According to Kotze at al. (2007) it is recognizable that evapotranspiration in the wetland may result in a considerable reduction in the volume of water which would otherwise potentially reach the stream system. The wetlands offer a service in that they accumulate organic matter and fine sediments in the wetland soils, this results in the wetland slowing down the sub-surface movement of water down the slope. This “plugging effect” thus 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., 2007). According to Rogers, Rogers and Buzer (1985), Gren (1995), Ewel (1997) and Postel and Carpenter (1997) these wetlands remove excess nutrients and inorganic pollutants produced by agriculture, industry and domestic waste. These wetland types have a relatively high removal potential for nitrogen in particular. There is an increase in erosion as the gradient of the slope increases and hillslope seepage wetlands tends not to be very important from an erosion control point of view, provided that the vegetation remains intact (Kotze et al., 2007).

8.4 WET-EcoServices Functional Assessment

The general features of the wetland units were assessed in terms of functioning and the overall importance of the hydrogeomorphic unit was then determined at a landscape level. The level of functioning supplied by the hydrogeomorphic unit for various ecological services is presented in Table 12. The results from the “WET-EcoServices” tool for the respective wetland units are presented below in Figure 2, Figure 3 and Figure 4.

Table 12: A listing and scoring of ecological services offered by the wetlands.

Ecological Services	Floodplains	Pans	Hillslope seepages
	Overall Score	Overall Score	Overall Score
Flood attenuation	3.1	1.3	0.6
Streamflow regulation	2.8	1.4	0.8
Sediment trapping	2.5	1.7	1.3
Phospahte trapping	2.0	1.1	1.3
Nitrate removal	2.1	1.3	1.2
Toxicant removal	2.1	1.2	1.1
Erosion control	2.4	0.7	1.4
Carbon storage	2.3	1.3	1.1
Maintenance of biodiversity	3.3	2.5	1.8
Water supply for human use	2.3	0.3	0.3
Natural resources	1.4	2.8	2.2
Cultivated foods	0.2	0.3	0.3
Cultural significance	0.0	0.4	0.3
Tourism and recreation	3.3	2.4	1.9
Education and research	2.3	0.3	0.3

Note: The ecoservices supplied by the wetland systems are scored according to the following:

0 – Low; 1 - Moderately Low; 2 – Intermediate; 3 - Moderately High; 4 - High

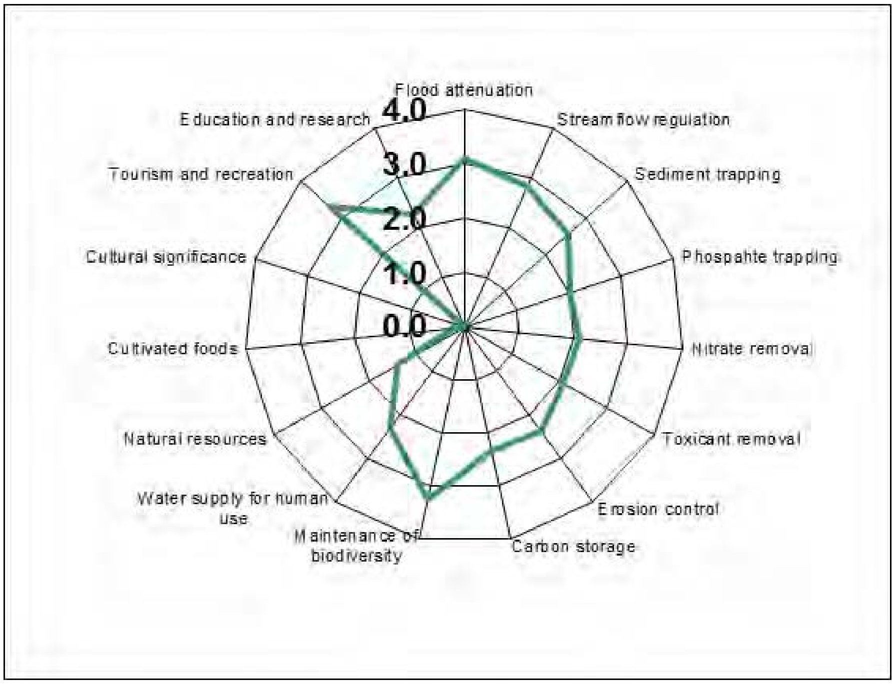

Figure 2: Radial plots indicating the functions performed by the floodplain

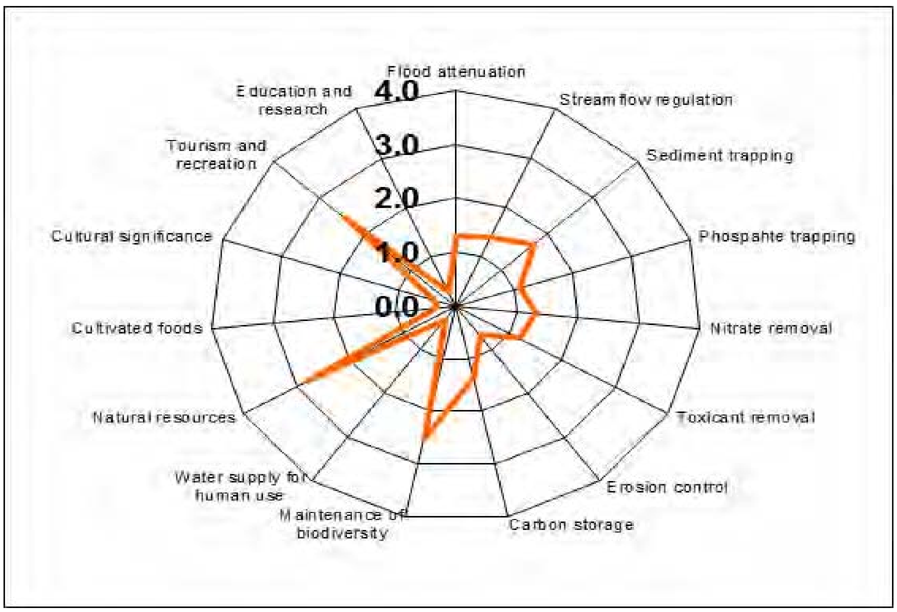

Figure 3: Radial plots indicating the functions performed by the pans

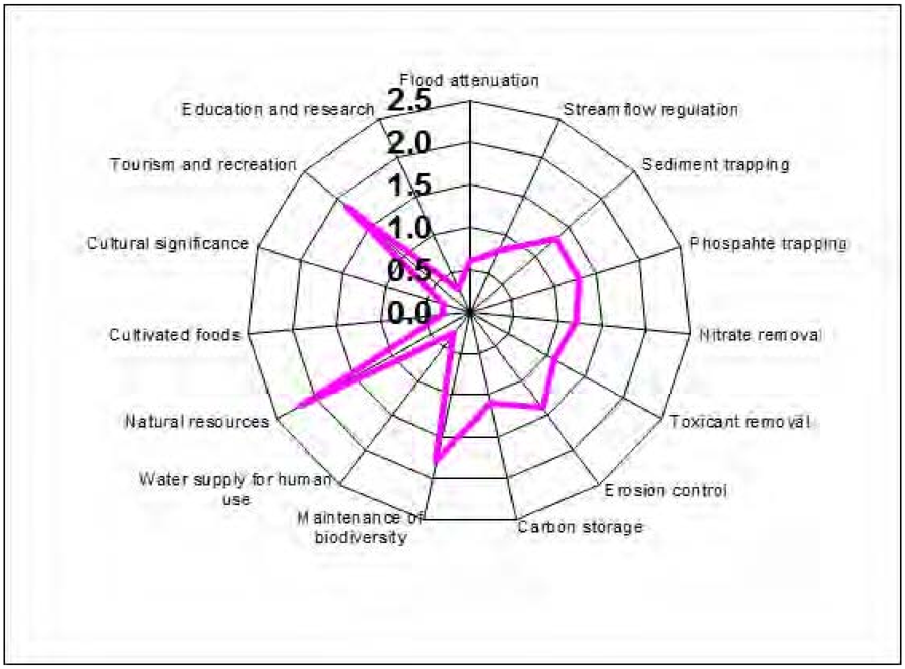

Figure 4: Radial plots indicating the functions performed by the hillope seepage wetlands

Table 12 and Figure 2 indicate a moderately high importance for the ecological services of biodiversity maintenance and tourism and recreation provided for by the floodplain. This is evident with the large number waterfowl and amphibians dependant on the floodplain as a source of habitat and food. Additionally, the ability of the floodplain to attenuate floods is also of a moderately high importance and this ecological service is expected of this type of HGM unit. There is intermediate importance for ecological services such as sediment trapping, stream flow regulation and water quality enhancement capabilities for the floodplain system. This is important to consider taking into account the significance of the Limpopo River. The ability of the wetland to enhance the quality of water is important because of the large number of water user's dependant on the system, these water users include livestock, game as well as humans. Overall the floodplain provides a large number of ecological services ranging from intermediate to moderately important, indicating the value of this system.

The pans and associated hillslope seepage wetlands provide services determined be moderately low to intermediate importance for the enhancement of water quality. This is to be expected owing to the ephemeral nature of these units. These units do support biodiversity with particular reference to the dry periods resulting in the maintenance of biodiversity being determined to be of intermediate importance. Tourism and recreation was determined to be an ecological service of intermediate importance.

8.5 The Present Ecological State (PES)

Two different indices were used to determine the PES of the floodplain and the pan wetland systems. Thus, these two indices have been presented separately in the subsequent sections.

8.5.1 The floodplain

The Index of Habitat Integrity (IHI) was applied to Osorno and Witkopje collectively. This is due to the proximity of these areas to one another as well as assessing the Limpopo floodplain holistically. The results are presented in Table 13. The illustrated PES area for the study area is presented in Appendix C.

Table 13: The PES of the floodplain associated with the Limpopo floodplain for the area

Hydrology	1	100	1.0	*79.3*	**B/C**	
Geomorphology	2	80	0.7	*85.9*	**B**	
Water Quality	3	30	0.7	*87.0*	**B**	
WETLAND LANDUSE ACTIVITIES		**80**	**0.1**			
Vegetation Alteration	1	100	0.1	*97.4*	**A**	

OVERALL SCORE:		**0.5**	
	PES %	**89.4**	
	PES Category:	**A/B**	

Hydrology was awarded a final PES category of B/C with an overall PES % of 79.3 which indicated the hydrology of the floodplain to effectively be largely natural with a few modifications as opposed to moderately modified. The primary modification to the hydrology was as a result of abstraction, inundation and modifications to flows as a result of the numerous small dams, bridges and weirs. Geomorphology was awarded a final PES category of B with an overall PES % of 85.9 which indicated the geomorphology of the floodplain to be largely natural. Modifications to the geomorphology included an increase in sediment supply to the system as a result of vegetation removal and active bank erosion of the channel. Water quality was awarded a final PES category of B with an overall PES % of 87 which indicated the quality of the water of the floodplain to be largely natural. Impacts to water quality may be as a result of sedimentation from vegetation removal as well as by toxicants used for agricultural practices. Lastly vegetation alteration was awarded a final PES category of A with an overall PES % of 97.4 which indicated the vegetation of the floodplain to be unmodified. This is to be expected as a result of no mining, excavation or urbanisation taking place in the area. Overall the vegetation of the floodplain is in a natural state. In spite of the mentioned impacts, none of the listed impacts have been significant enough to seriously modify the system as it remains in a close to natural state.

8.5.2 The pans and associated hillslope seepage wetlands

The scoring of the PES assessment for the pan and hillslope seepage wetland is presented in Table 14. The pans and associated hillslope seepage areas were determined to be in an unmodified state, or close to a natural condition. The hillslope seepage areas associated with the pans are largely natural with a few modifications, but with some loss of natural habitat. The surrounding land uses have not impacted directly on these units and as a result, modifications to the units are negligible. The illustrated PES area for the study area is presented in Appendix C.

Table 14: The PES of the assessed HGM units for the project area

Criteria and attributes	**Pans**	**Hillslope seepage wetlands connected to the pans**
Hydrologic		
Flow modification	3	5
Permanent Inundation	5	5
Water Quality		
Water Quality Modification	4	4
Sediment load modification	3	3
Hydraulic/Geomorphic		
Canalisation	4	4
Topographic Alteration	4	5
Biota		
Terrestrial Encroachment	4	4
Indigenous Vegetation Removal	4	4
Invasive plant encroachment	5	5
Alien fauna	4	4
Overutilisation of biota	4	5
TOTAL MEAN	**4.4**	**4.8**
Overall PES	**Unmodified**	**Unmodified**

8.6 Ecological importance and sensitivity

The findings of the EIS for the assessed wetland areas are presented in Table 15. The ecological importance and sensitivity (EIS) scores determined for the floodplain areas are rated as B for both the Osorno and Witkopje farms. This is an indication that the floodplain is considered to be ecologically important and sensitive. The biodiversity of this floodplain may be sensitive to flow and habitat modifications and the system provides a service in moderating the quantity and quality of water of the Limpopo River. Owing to the ephemeral nature of the pans and associated hilsllope seepage wetlands, as well as considering the local impacts to these units, the EIS of these areas was determined to be moderately modified. This is an indication that that these systems are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these systems is not usually sensitive to flow and habitat modifications. The classified EIS area for the study area is presented in Appendix D.

Table 15: The EIS of the assessed HGM units for the project area

Determinant	Floodplain	Pans	Hillslope seepage wetlands
PRIMARY DETERMINANTS			
Rare & Endangered Species	2	0	0
Populations of Unique Species	3	0	1
Species/taxon Richness	3	2	2
Diversity of Habitat Types or Features	4	2	2
Migration route/breeding and feeding site for wetland species	4	3	2
Sensitivity to Changes in the Natural Hydrological Regime	2	1	1
Sensitivity to Water Quality Changes	2	2	1
Flood Storage, Energy Dissipation & Particulate Removal	3	2	3
MODIFYING DETERMINANTS			
Protected Status	4	0	0
Ecological Integrity	3	4	4
TOTAL MEAN	**3.0**	**1.6**	**1.6**
OVERALL EIS	**Largely natural**	**Moderate**	

8.7 Aquatic Assessment

The South African River Health Programme (RHP) primarily makes use of biological indicators (e.g. fish communities, riparian vegetation, aquatic invertebrate fauna) to assess the condition or health of river systems. The rationale for using biological monitoring is that the integrity of biota inhabiting river ecosystems provides a direct, holistic and integrated measure of the integrity or health of the river as a whole.

8.7.1 Site Selection

Sampling sites were selected so as to identify trends regarding the occurrence of available species within the local aquatic ecosystem. A high flow survey was conducted. This in turn will allow for a comparative basis for which future impacts can be evaluated. Table 16 presents the site name, Global Positioning System (GPS) co-ordinates and biotope description per site. Photographs of the selected sampling sites are provided in Appendix E.

Table 16: The site name, GPS co-ordinates and biotope description for sampled sites

Site name	GPS	Biotopes
Site 1	S 23˚ 37" 38.27' E 27˚ 03" 53.77'	Deep (>1.0m) fast moving reach. Limited marginal vegetation. No stones-in-current (SIC) or stones-out-current (SOC). No riffles/rapids. Gravel, sand and mud (GSM) available.
Site 2	S 23˚ 34" 07.34' E 27˚ 07" 45.66'	Deep channel (>1m) with fast steady flow. Limited marginal vegetation with no emergent vegetation. No stones-in-current (SIC) or stones-out-current (SOC). No riffles/rapids. Gravel, sand and mud (GSM) available

Site 1 is positioned adjacent to the farm Osorno 700 LQ. It is positioned in a well-defined channel with steep embankments on the right hand bank. The width of the stretch of river surveyed was approximately 8m with fast moving water with no broken water surfaces evident. The surveyed reach of river was deep (>1.0m). The only biotopes available at the sites were GSM and limited vegetation, with SIC and SIC not available to be sampled. There was no aquatic vegetation available at the site. Water colouration was muddy (brown) due to the high rainfall (>70mm) experienced during the survey. Site 2 is positioned adjacent to the farm Witkopje 238 LQ, further downstream of Site 1. This site is positioned in a well-defined channel and the reach of river is approximately 7m wide. The site is characterised by sand banks and fast flowing water. No SIC or SOC were available to be sampled and no aquatic vegetation was present to be sampled. GSM was the only biotope available to be sampled.

8.7.2 Water Quality

The measurements of selected *in situ* (pH, DO, temperature and TDS) water quality parameters were recorded using a hand held accredited calibrated water quality multi-meter, with the results presented in Table 17. Indicator organisms which live within freshwater aquatic ecosystems are directly affected by water quality. It is therefore essential to collate this data to better understand the responses of biota within the streams. The data presented for this component is for a single high flow survey. Dissolved oxygen was the only water quality parameter measured that would be a limiting factor for aquatic biota. The overall water quality for all three sites was determined to be moderately modified (Table 17).

Table 17: The water variables measured and the recorded values for the sites sampled

	Value Recorded	
	Site 1	**Site 2**
Water Parameter Measured		
DO Concentration (mg/l)	3.79	3.6
DO Saturation (%)	63	66.8
TDS Conductivity (mg/l)	239	244
pH	6.5	6.5
Temperature (˚C)	28.9	28.4
EcoClassification	**C**	**C**

According to Mason (1991), dissolved oxygen (DO) is possibly the most important measure of water quality, especially for aquatic life. Both the survival and functioning of aquatic biota is dependent on the maintenance of aquatic DO concentrations because it is required for the respirations of all aerobic organisms. Thus it may be stated that DO concentrations provide a useful measure of ecosystem health (DWAF, 1996). The median guideline for DO for the protection of aquatic biota is >5.0 mg/l (Kempster *et al*., 1980). The low DO concentration at both sites may be attributed to high rainfall experienced prior to the survey period. This would result in organic matter and pollutants being flushed down into the system where they will be decomposed which would result in a low DO. The decomposition of organic matter by micro-organisms is a process which uses up oxygen.

According to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), the target water quality range for an aquatic ecosystem is between 80 – 120 % of DO saturation. The minimal allowable dissolved oxygen values according to DWAF (1996a) are not less than 60 % for sub-lethal effects and not less than 40 % for lethal effects, respectively. The DO saturation for Sites 1 and 2 are both above the minimal allowable DO limit (> 60 %). This low DO saturation may be attributed to the high rainfall experienced prior to the survey, flushing pollutants and organic matter into the system which is then decomposed.

The *in situ* Total Dissolved Salt (TDS) concentrations for both sites were similar. According to the DWAF (1996) guidelines, macroinvertebrate fauna appear to be sensitive to salinity, with acute toxic effects likely to occur in most of the sensitive species at salinities in excess of 1000 mg/l, Both sampled sites had a TDS concentration below 1000 mg/l.

According to DWAF (1996) both geology and the atmosphere influence the pH of natural waters. Fresh water systems are mostly well buffered and more or less neutral, with a range from 6.5 to 8.5. As a result of the presence of bicarbonates of the alkali and alkaline earth metals most fresh water systems are slightly alkaline (DWAF, 1996). According to Alabaster and Lloyd (1982) the pH target for fish health is presented as ranging between 6.5 and 9.0, as most species will tolerate and reproduce successfully within this pH range. The *in situ* pH values for both sampled sites was within this range. According to Dallas and Day (2004) due to the problems associated with the interpretation of pH measurements, many biologists are skeptical about the use of pH in the assessment of water quality in general.

According to the DWAF water quality guidelines (1996), the temperature of water plays an important role for aquatic ecosystems by affecting rates of chemical reactions and therefore also the metabolic rates of organisms. The rate of development, reproductive periods and emergence time of organisms are all affected by temperature. The temperatures of inland waters in South Africa generally range from 5 - 30 ˚C (DWAF, 1996). The temperatures recorded at both sites were within this range.

The users of water downstream of study area, such as rural communities as well as farming communities are reason for concern. These communities are dependent on the water to fulfil basic human needs, such as drinking, watering, washing, bathing etc. Poor water quality would impact on the health of the water users. Currently the water is determined to be in a moderately modified state. However, taking into consideration the high rainfall experienced during the survey period it may be concluded that the water quality is a close to natural state. The proposed mining activities may impact on the quality of water as mining activities progress.

8.7.3 Habitat Quality

The structure and function of the aquatic community in a stream is influenced both by the quality and availability of the instream and riparian habitat; for this reason evaluation of habitat quality and availability is critical to any assessment of aquatic biota.

8.7.3.1 Index of Habitat Integrity (IHI)

The scores recorded for the sites sampled regarding IHI with an overall ecological classification per site is presented in Table 18. The scores for this component have been combined from a single high flow survey.

Table 18: The habitat scores for IHI recorded for the sampled sites

	Habitat Assessed	Site 1	Site 2
IHI	Insteam Habitat Integrity Score	84	88
	Riparian Zone Habitat Integrity	78	82
	Total	162	170
	Percentage	81.00	85.00
	EcoClassification	**B**	**B**

Based on the IHI scores, habitat at both sites is in a largely natural state which indicates no large disturbances to the system. The assessment of the riparian vegetation and instream channel indicated that no anthropogenic activities were having a significant impact on the system. Criteria considered for this index which may be responsible for the small impact on the quality of available habitat included exotic vegetation, water abstraction and bank erosion. However, in spite of this, the overall integrity of available habitat was in a very good state.

8.7.3.2 Integrated Habitat Assessment System (IHAS)

The total IHAS values determined for the study area ranged from 43 (Site 1) to 49 (Site 2) and are presented in Table 19. Based on the IHAS scores, habitat availability was poor at all the sampling sites. The total IHAS, habitat sampled and stream condition scores were low for both the sampled sites. These low scores may be attributed to a lack of habitat diversity for the sampled reaches and the high flow conditions would have a compounding affect. In particular, the stones-in-current (SIC) biotope was absent from both sites. Additionally, no aquatic vegetation and limited marginal vegetation was available to be sampled. Both sites were characterized by deep (> 1m) and wide (> 5m) channels with fast flowing water. Based on the assessment, habitat availability can be considered a limiting factor of aquatic macroinvertebrate diversity at both the sampling sites.

Table 19: The habitat scores for IHAS recorded for the sampled sites

	Biotope	Site 1	Site 2
IHAS	Stones in current	0	0
	Vegetation	8	11
	Other habitats	15	16
	Stream condition	20	22
	IHAS score (100)	43	49
	EcoClassification	**C**	**C**

8.7.3.3 Habitat Assessment for High and Low Gradient Streams

The generic habitat assessment approach formulated by USEPA for high and low gradient streams (Plafkin *et al*., 1989) was used in conjunction with the IHAS methodology and applied at the sites. Evaluations in terms of epifaunal substrate/available cover, pool substrate, pool variability, channel alteration, sediment deposition, channel sinuosity, flow, bank vegetation protection, bank stability, riparian vegetation and zone width were made for each of the sampling sites. The results from this assessment are presented in Table 20.

Table 20: USEPA habitat condition results for the survey.

Habitat Parameter	Location	
	Site 1	Site 2
Epifaunal substrate/Available cover	3	3
Pool substrate characterisation	6	6
Pool variability	6	6
Sediment deposition	6	6
Channel flow status	14	14
Channel alteration	18	18
Channel sinuosity	13	13
Bank stability (L) & (R)	18	18
Vegetative protection (L) & (R)	18	18
Riparian vegetative zone width (L) & (R)	18	18
Total Score	120	120
Habitat Condition (%)	60	60
Habitat Description	Good	Good

Based on the USEPA habitat assessment index, the habitat integrity associated with both sites was determined to be good. This is in spite of a number of criteria being considered either poor or marginal in quality. This is also identical to the findings from IHI assessment. The epifaunal substrate and available cover was poor for both sites assessed, this indicates that the relative quantity and variety of natural structures in the system, such as cobble (riffles), large rocks, fallen trees, logs and branches are absent resulting in a loss of habitat diversity. Both sites were also awarded marginal scores for pool substrate characterization, pool variability and sediment deposition. This may be attributed to the high rainfall experienced during the survey increasing the flow velocity for the system, affecting these components. Both sites were also awarded a score of suboptimal for channel flow status and this can be expected due to the high volume of water moving through the system. Bank stability, vegetative protection and riparian vegetative zone width scored equally high for both sites, thus the allocated score was optimal. This is attributed to the well-established riparian areas resulting in both the LHB and RHB being stable with little signs of erosion. Additionally, the riparian zone for both reaches was populated predominantly by native vegetation and consisted of trees, shrubs and non-woody macrophytes. Vegetative disruption was also absent from these areas. The overall habitat was determined to be in a good state.

8.7.4 Aquatic Invertebrates Assessment

8.7.4.1 South African Scoring System version 5 (SASS5)

SASS results are expressed both as an index score (SASS score) and the average score per recorded taxon (ASPT value). From this data it is possible to establish the integrity or health of a river. The total score per site is calculated by summing the taxon scores and the average score per taxon (ASPT) is calculated by dividing this total score by the number of taxa. Both scores are considered when determining water quality impairment. During the survey, a total of 18 invertebrate families/taxa were collected from the two sites on the Limpopo River.

The macroinvertebrate diversity of the sampling sites collected during the study period by means of the SASS 5 method was 18 taxa for both sites (Table 21). A reason for the low diversity may be as a result of the combination of the absence of selected biotopes such as stones and the high flow conditions experienced during the survey. As a result of the high flow conditions, the biotopes of stones-in-current and stones-out-of-current were not available to be sampled. Additionally, there was no aquatic vegetation and on limited marginal vegetation was available to be sampled. Thus it is assumed that should these biotopes be present the macroinvertebrate diversity for both sites should increase. Additionally, it is recommended by Dickens and Graham (2002) to apply the SASS5 methodology in low/moderate flow hydrology systems. As a result of the high flow conditions, results of the SASS5 survey have been interpreted with caution as the extreme hydrology would be a limiting factor for macroinvertebrate diversity. As a result of these factors, the SASS5 results may not provide an accurate indication of water quality for the sampled sites and this should be kept in mind when interpreting the results.

At both the sites in the study the invertebrate community consisted largely of species tolerant to pollution. This observation is also reflected in the ASPT observed at the two sites. Although this may be a reflection of poor water quality the extremely high flow conditions may have a compounding effect. Species such as Aeshnidae, Atyidae and Hydraenidae are relatively sensitive with a sensitivity rating of 8.0. These were most sensitive macroinvertebrates sampled during the survey. The macroinvertebrate assemblages were dominated by taxa (Chironomidae, Corixidae and Nepidae) which all have low sensitivity ratings ranging from 1.0 to 3.0. The absences of taxa with a low tolerance to poor water quality was most probably not related to poor water quality as there are few sources of pollution upstream of the study area. The absence of sensitive taxa may be attributed to lack of habitat diversity for the sampled reaches.

Table 21: The recorded macroinvertebrates sampled from the two sites and the associated sensitivity per taxon. The SASS5 results of the sampled sites.

Taxon	Sensitivity	Site 1	Site 2
Aeshnidae	8	√	√
Atyidae	8	√	√
Baetidae	6	√	√
Belostomatidae	3	√	√
Chironomidae	2	√	√
Coenagrionidae	4	√	√
Corbiculidae	5	√	√
Corixidae	3	√	√
Dytiscidae	5	√	√
Gerridae	5	√	√
Gyrinidae	5	√	√
Hydraenidae	8	√	√
Hydrophilidae	5	√	√
Libellulidae	4	√	√
Nepidae	3	√	√
Notonectidae	3	√	√
Potamonautidae	3	√	√
Veliidae	5	√	√
SASS		85	85
No. of taxa		18	18
ASPT		4.72	4.72
EcoClassification		**D**	**D**

The total SASS 5 score in the study area was 85 for both sites (Table 21). The average score per taxon (ASPT) values was 7.72 for both sampled sites (Table 21). Suggested guidelines for the interpretation of SASS5 scores according to Chutter (1998) are presented in Table 22.

Table 22: The suggested SASS5 and ASPT interpretations (Chutter, 1998)

SASS5	ASPT	Suggested interpretation
> 100	> 6	Water quality natural, habitat diversity high
< 100	> 6	Water quality natural, habitat diversity reduced
> 100	< 6	Borderline case between water quality natural and some deterioration in water quality
50 - 100	< 6	Some deterioration in water quality
< 50	Variable	Major deterioration in water quality

From these guidelines it can be concluded that there is some deterioration in water quality at both sites. However, this is not conclusive and as there are no recognizable anthropogenic activities taking place above stream of the sites to impact on the water quality, it can be concluded that the low SASS5 score and ASPT values is a result of a lack of available biotopes with the high flow conditions having a compounding affect. In general, a low ASPT is a reflection of poor water quality. Where habitat change is the main cause of changes in community structure, SASS scores will be low but, the ASPT will be less affected (Dickens and Graham, 2002).

The SASS5 and ASPT scores assigned to the different biological bands for the Limpopo Plain and a brief description of each class is presented in Table 23. This indicates that both sites are in a largely modified state. The position of the two sites within biological bands with reference to the SASS data interpretation guidelines (Dallas, 2007) is presented in Figure 5. Taking into consideration the absence of relevant biotopes it can be concluded that modifications to the system are not deteriorating water quality. Additionally, there is expected to be an improvement in the ecological classification of the sites during a survey when flow hydrology is reduced to be low or moderate in velocity.

Table 23: The ecological classes assigned to the SASS5 and ASPT scores and a description thereof as per the SASS5 Data Interpretation Guidelines (Dallas, 2007) for the Limpopo Plain.

Class	SASS 5 Score	ASPT	Condition
A	> 143	>5.8	Natural/unmodified
B	115 – 143	5.5 – 5.8	Minimally modified
C	94 – 115	5.1 – 5.5	Moderately modified
D	72 – 94	4.6 – 5.1	Largely modified
E	<72	<4.6	Seriously modified

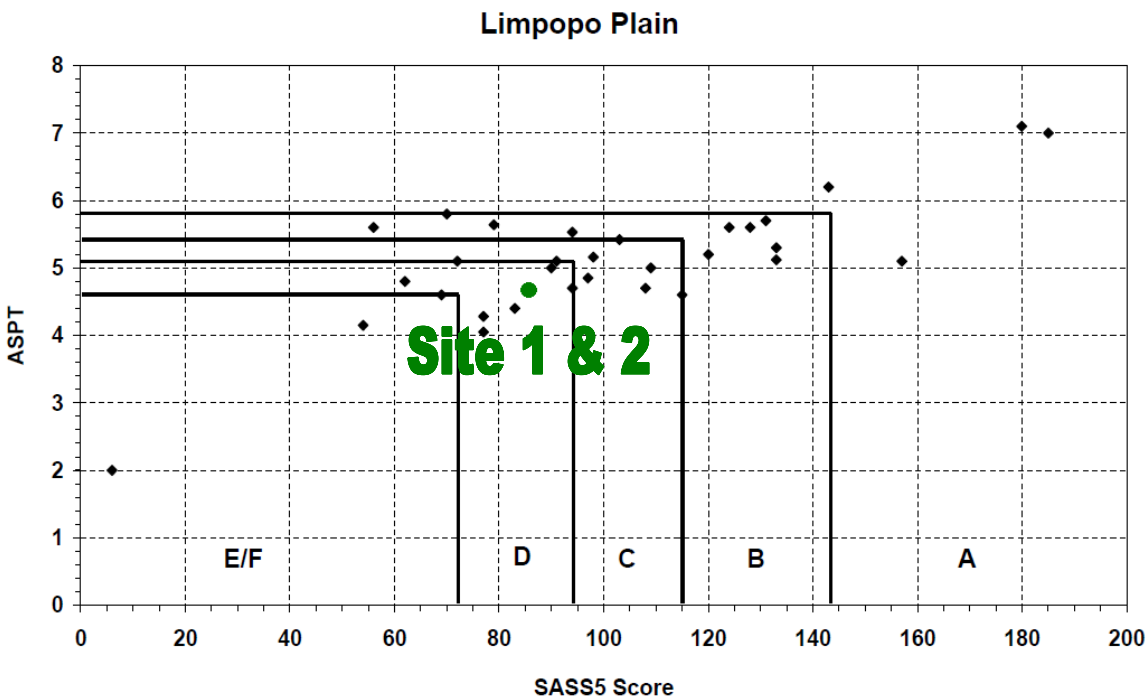

Figure 5: The SASS5 and ASPT scores of the two selected sampling sites positioned with the biological bands for the Limpopo Plain region.

8.7.5 Fish Assessment

A total of 8 fish species were sampled during the survey. No exotic fish species were sampled during the survey. A list of sampled fish species with the relevant abbreviations is presented in Table 24. The FAII aims to measure the biological integrity of a river as based on the attributes of the fish assemblage's native to the river. No IUCN Red Data fish species were sampled. The FAII score determined for project is presented in Table 25.

Table 24: The expected and sampled fish species with the respective abbreviations

Abbreviation	Scientific name	Common name
BRAD	*Barbus radiatus*	Beira barb
BTRI	*Barbus trimaculatus*	Threespot barb
CCAR *	*Cyprinus carpio*	Carp
CGAR	*Clarias gariepinus*	Sharptooth catfish
LMOL	*Labeo molybdinus*	Leaden labeo
PPHI	*Pseudocrenilabrus philander*	Southern mouthbrooder
SINT	*Schilbe intermedius*	Silver catfish
PPHI	*Pseudocrenilabrus philander*	Southern mouthbrooder
SINT	*Schilbe intermedius*	Silver catfish
SZAM	*Synodontus zambezensis*	Brown squeaker
TSPA	*Tilapia sparrmanii*	Banded tilapia

Note: (*) denotes an exotic species

Table 25: The calculated FAII score and ecological class determined for fish sampled.

EXPECTED SPECIES					OBSERVED SPECIES				
Species	**General Intolerance**	**Frequency of Occurrence**	**Health**	**Expected per Species**	**Species**	**General Intolerance**	**Frequency of Occurrence**	**Health**	**Expected per Species**
BMAR	2.6	2	5	9.1	**BRAD**	2.3	3	5	9.2
BMAT	3	2	5	10.5	**BTRI**	2.2	3	5	8.8
BPAU	1.8	2	5	6.3	**CGAR**	1.4	3	5	5.6
BRAD	2.2	1	5	6.6	**LMOL**	3.2	3	5	12.8
CGAR	1.4	1	5	4.2	**PPHI**	1.3	3	5	5.2
LCYL	3.1	2	5	10.85	**SINT**	1.7	3	5	6.8
LMOL	3.2	2	5	11.2	**SZAM**	2.3	3	5	9.2
LROS	2.4	2	5	8.4	**TSPA**	1.3	3	5	5.2
MACU	2.3	2	5	8.05					
MBRE	2.3	2	5	8.05					
OMOS	1.3	2	5	4.55	FAII				62.8
PPHI	1.3	2	5	4.55					
SINT	1.7	2	5	5.95		Relative FAII			57.22
SZAM	2.3	1	5	6.9		**EcoClassification**			D
TSPA	1.3	2	5	4.55					
FAII				109.75					

The FAII category for the study is a "D", largely modified. This indicates a clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. A "D" class suggests that there may be an impairment of fish health that may become more evident at the lower end of this class. However, this was not the case for the sampled species that were all in good health. A single fish species that is not expected to occur in the region and was sampled is *Barbus radiatus* (Beira barb). A total of 16 fish species are expected to occur in the catchment area. The reason being for not sampling any additional species may be attributed to sampling methods which included only the use of fyke nets. However, the extreme high flow conditions experienced during the survey is considered to be the primary reason for the system appearing to be in a largely modified state. Most of the fish sampled all have a high tolerance of various environmental conditions with the exception of *Labeo molybdinus* (Leaden labeo) that has an intolerance of 3.2. The closer thss value is to 5, the more sensitive the fish species is. The general intolerances of the most of the sampled fish indicate that they are hardy species which can tolerate adverse environmental conditions. The FAII score should increase if a greater stretch of river is sampled as well as if additional sites are sampled upstream and downstream. The FAII score may also increase if various sampling techniques are carried out at different times of the day.

9 RECOMMENDATIONS FOR WETLANDS

The outcome of this assessment promotes the establishment of recommendations to conserve the wetlands in this study area. It is in this light that a conservation plan has been formulated for this study. Game farming and tourism and recreation are largely responsible for the current impacts on the biodiversity and water quality of the wetlands in the study area as a result of alterations to surface hydrology for the system, due to weir and dam construction in the Limpopo River. While it is evident from the study that these impacts have affected the ecological state of the wetlands there has been no evidence of any of these impacts seriously affecting the underlying hydrology (key driver) supporting the wetlands. The primary ecological services provided for by the floodplain are flood attenuation, biodiversity maintenance and tourism and recreation. No services assessed for the pans and associated hillslope seepage areas were determined to be of high ecological importance.

It is recommended that no further impacts to the floodplain wetland area be considered or carried out so as to preserve the ecological services provided by this system. As a result of this, a 300m buffer zone has been allocated to the floodplain and a 100m buffer zone has been assigned to the pans and associated hillslope seepage wetlands. The size of the buffer area has been determined as a result of the ecological state of the ecosystems, the functioning of the ecosystems as well as the ecological importance and sensitivity of the associated ecosystems. This buffer zone will adequately allow for the conservation of the wetland area and ensure the continuation of ecological functioning of the system. Mitigation measures for the proposed mining activities are discussed below. The proposed railway line is situated on the periphery of a pan and hillslope seepage wetland system within the 100m buffer zone. In spite of this, the impacts to the wetland system are expected to be negligible but an attempt should be made to relocate the railway line to accommodate the buffer zones.

The development of any conservation plan should contain clearly defined objectives. The development of the recommendations for the plan assumes that the maintenance of water quantity and quality suitable for aquatic and terrestrial biodiversity and human uses within the wetlands in the study area is one of the primary objectives. As a result of focussing on water quality management as a vital ecological service provided for by the wetlands, taking into consideration the proximity of the Limpopo River and the significance thereof, conservation of the wetland area is vital. The recommendations given below should therefore be considered in this light. A vital component in attempting to attain the specified objectives is to try and protect the wetland area and the associated ecological services as a whole.

A conservation plan aimed at improving the PES of the wetland area of the floodplain specifically and the associated ecological functioning to improve water quality and biodiversity maintenance should therefore be directed at managing the land use practices in the area and the direct use and conversion of the wetland resources. As a result of users dependant on the water resource (Limpopo River), namely agriculture, livestock, humans and fauna and flora, the development of an integrated water quality management plan (IWQMP) is therefore crucial to ensure minimal impact to the quality and quantity of available water reporting downstream of the study area. Key components to consider for such a plan are:

- Adhere to the allocated 300m buffer zone;
- Relocate the railway line to accommodate the 100m buffer zones;
- Make use of existing access roads;
- No unnecessary water abstraction from the Limpopo River ;
- No trenches or drainage lines are to be constructed in the wetland area; and
- No construction to take place within the wetland and buffer zone.

Considering the nature of the proposed mining activities, it may be assumed that the impacts to the wetlands will be significant if mitigation measures are not adhered to. If these mitigation measures are adhered to, this will ensure the long term conservation of the wetland area. A small portion of the wetland area has been impacted on by agricultural practices on the Osorno farm. However, sub-surface water dynamics are not impacted on by these activities. In addition to this, it may also be concluded that the quantity of water recharging the Limpopo River from the wetland area will not be affected if mining activities adhere to the mitigation measures. Additionally this will ensure that the wetland units will maintain ecological functioning which is crucial for the system. Recommendations are made to conserve the floodplain area.

In a post opencast mined landscape wetland rehabilitation is impractical due to the requirements to maintain a free draining area as well as maintain wetland function. Wetland rehabilitation is very difficult to achieve. With this in mind it is re-emphasised that if the wetland area is conserved no wetland rehabilitation plan would be required. Conservation of the wetland area could be developed as part of a Social Responsibility Programme (SRP) which could include a partnership with Working for Wetlands for example, the national statutory programme responsible for wetland conservation in South Africa.

10 RECOMMENDATIONS FOR THE AQUATIC ECOSYSTEM

In order to consider the overall state of the assessed aquatic system, the drivers (water quality and habitat) and responses (invertebrates and fish) components are grouped and considered.

Based on results obtained from the recent survey, it can be concluded that the ecological integrity of the instream habitats of the Limpopo River are currently regarded as largely natural, this is in spite of the high flow conditions experienced during the survey. The extreme high flow conditions did appear to affect the ecological integrity of certain biophysical attributes assessed. However, this was taken into consideration and due to the nature of the system assessed it may be concluded that these affects are moderate. It is assumed that during natural high flow conditions the state of the habitat will improve.

The impacts associated with the current land use practices are further contributing to an existing moderately impacted ecosystem. The potential causes for the decline in integrity of the local ecosystem are the result of impacts to water quantity as well as impacts to ecological functioning. Such impacts include sedimentation from vegetation removal and road construction as well as abstraction of water from the Limpopo River to water fields and fill dams. Additional impacts to the system include weir and bridge construction resulting in inundation of areas upstream of the obstructions and loss of water downstream of the obstructions, as well as flow modifications. These obstructions will thus result in a loss of valuable habitat to the system. The proposed mining activities will have a significant impact on both the water quality and quantity of the receiving systems if mitigation measures are not adhered to. It may be assumed that impacts to the system as a result of the mining activities may be irreversible or extremely expensive to try and correct

In terms of biota, the aquatic macroinvertebrate community is considered to consist predominantly of tolerant species. With reference to the response components (fish and invertebrates), it can be concluded that the system is modified. These results may be attributed to the extreme high flow conditions experienced during the survey. Overall the survey indicated the biotic integrity of the system to be in a largely modified state but this may not be an accurate and true representation of the systems when taking into consideration the high flow conditions. Thus it may be assumed that in spite of the results of the survey, the system is indeed in a close to natural state and may improve during periods of natural flow conditions. As a result of this, careful management should be put into place so as to avoid unnecessary impacts to the systems. Adopted management strategies should only be applied if proven to be effective and successful with similar projects in other areas. Due to the ecological importance of the Limpopo River as well as taking into consideration the proximity of the mining activities to the system, an aquatic biomonitoring strategy has been proposed.

10.1 Proposed Monitoring Strategy

In order to directly measure, assess and report on the health, status and trends of the aquatic ecosystem associated with a particular development, an aquatic monitoring programme is required. An additional purpose of a monitoring program is to assess the compliance of a water-user with the Resource Quality Objectives of the water resource, identified by means of a reserve determination.

To ensure that the future Resource Quality Objectives, to be designated for the catchment, are attained, it is recommended that a responsibility-driven approach towards the management of the aquatic ecosystem associated with the study area be followed. The purpose for such a monitoring strategy will be to examine the long-term environmental trends of the aquatic resources associated with the mining activities in a practical and achievable manner.

The proposed indices for the monitoring strategy include IHI, IHAS, SASS5, FAII and basic *in situ* water chemistry. In addition to this, toxicant screening should also be implemented and where toxicants are identified definitive analysis carried out. The frequency for such a monitoring programme should be implemented bi-annually during the construction and operation phase of the project, and then annually after closure of the mine until rehabilitation of the area is satisfactory. Thereafter, any non-compliance with the Resource Quality Objectives should be identified and mitigated accordingly.

In the unlikely event of any pollution event occurring, the frequency of the monitoring strategy should be adjusted accordingly. This will help to identify the source of the event and mitigation can be formulated accordingly. It is strongly recommended that an assessment of the aquatic ecosystem be conducted as soon as possible after such an event. This will help to identify the magnitude and severity of such an event on the health of the aquatic ecosystem. A follow-up survey should be conducted approximately two months after the event in order to determine the effectiveness of the applied mitigation measures.

11 MITIGATION MEASURES

Due to the location of the wetland area and the aquatic ecosystem in relation to one another, as well as the dependency on one another to maintain and support ecological functions, mitigation measures have been considered jointly for both systems. It is assumed that impacts to either of the systems will have an indirect impact to the other system.

11.1 Sedimentation

During the site preparation phase, erosion is expected to take place as a result of the exposed soil surface. The duration of this impact is considered to be short. However, soil is likely to be washed down off of the stockpiles resulting in erosion of these piles, this will occur during the working life of the mine. The impact of this is considered to be a moderately localized impact and can be successfully mitigated.

Mitigation

This may include the construction of a low berm, approximately 1.0m – 1.5m high for the length of area between the opencast workings/soil stock piles and the wetland areas. The purpose of these berms would be to intercept flows containing suspended soils and create a depositional environment, inhibiting sediment introduction into the downslope wetland areas.

11.2 Water Quality Management

The proposed mining activities may result in the possible disruption of the weathered aquifer, which could result in the groundwater as well as rainwater coming into contact with pyrite containing spoils. If this is not adequately addressed in a water management plan, this may result in a reduced pH and elevated sulphate and metal concentrations in water entering the catchment area with particular reference to the Limpopo River.

Mitigation

Institute a well-developed water management plan to ensure that clean water is intercepted and diverted around the opencast workings. This water management plan should prove to have been successful with similar projects and situations elsewhere.

11.3 Water Quantity Management

The proposed mining activities may result in the dewatering of the surrounding aquifers which are potentially a valuable water source to the adjacent wetland areas. As a result of the potential loss of water, wetland areas may recede, causing a loss of ecological services. .

Mitigation

All construction activities will be planned and managed to ensure that there will not be a dramatic reduction in catchment size and water reporting to the wetland. Opencast establishment will dewater the surrounding aquifers and the impacts will be unavoidable, because of this mitigation will not be possible.

12 CONCLUSIONS

Taking into consideration the ecological importance as well as significance of the goods and services provided for by the Limpopo River, conservation of this valuable water resource is vital.

It is in light of this that recommendations have been made to not impact on the wetland area associated with the study site as well as adhere to the allocated buffer zone. Additionally, recommendations have also been made to implement an aquatic biomonitoring programme so as to monitor potential impacts to the Limpopo River by the proposed mining activity. Mitigation measures have been proposed for associated mining activities to limit the impact of these activities to the water resource.

The findings of the assessment which has been carried out to assess the ecological state of the Limpopo River and associated wetland system associated with the Boikarabelo Coal mine, indicates that the overall water resource to be in a largely natural to moderately modified state. The level of impact, of the stressors in the general area to the local ecosystem is generally low and as a result modifications to the ecological state of the system are low. Impacts to the system were identified to be dam/weir construction (hydrological alteration), vegetation removal as well as habitat loss and degradation. Based on these findings, the importance of managing the water quality and quantity of the area is of utmost importance due to the nature of the system and the ecological classification of the response indicators. Finally, the proposed railway line is not expected to have an impact on the assessed wetland systems.

13 DESCRIPTION OF POTENTIAL IMPACTS

The impacts associated with the various activities for each phase of the mining operation will be addressed in this section. Impacts will be discussed with reference to the duration, extent, severity, likelihood and significance. The activities that will result in the impacts have been discussed. Further detail on the activities can be found in the EIA report.

13.1 Construction phase

Activity 3: Removal of topsoil

Impacted environment: Aquatic ecosystems

Description: The clearing and removal of topsoil will result in the removal of vegetated areas causing open areas to become exposed. This will increase the potential load of sedimentation of the water resources due to erosion of the exposed areas and topsoil stockpiles during periods of high rainfall. These exposed areas will also become eroded as a result of high winds moving across the areas. The removal of the topsoil and vegetation reduces the potential for recharge of shallow aquifers that feed wetland areas, which in turn reduces the flow in water resources. This activity is considered to be medium in duration as it will be required for the construction and operating phases of the mine. The impact will be local in extent with impacts likely to occur further downstream away from the site. The severity of the impact was determined to be severe.

Impact assessment:

Parameter	Description	Rating
Duration	Medium term	3

Parameter	Description	Rating
Extent	Local	3
Severity	Serious	4
Likelihood	Certain	7
Significance	Minor	70%

Activity 8: Blasting and development of initial bench for mining

Impacted environment: Aquatic ecosystems

Description: The establishment of the mining area by means of blasting in order to develop the initial bench for mining will dewater surrounding aquifers. There will be a reduction on surface water quantity due to reduction in catchments size. The wetlands within the study area are linked to perched aquifers which provide a water source through lateral seepage and interflow. The potential loss of these aquifers will in turn result in a loss of certain wetland areas. This activity is considered to be medium in duration as it will be required for the life of mine. The impact will be local in extent with impacts likely to occur further downstream away from the site. The severity of the impact was determined to be very severe.

Impact assessment:

Parameter	Description	Rating
Duration	Medium term	3
Extent	Local	3
Severity	Significant	6
Likelihood	Certain	7
Significance	Major	84%

13.2 Operational phase

Activity 14: Mining process removal of coal (bench mining)

Impacted environment: Aquatic ecosystems

Description: The removal of coal by means of bench mining will result in an increased reduction in catchment size for the area. Thus, there will be a reduction on surface water quantity due to reduction in catchments size entering the system. Some wetlands within the study area are linked to perched aquifers which provide a water source through lateral seepage and interflow. The loss in seepage areas and the loss of the aquifers will in turn result in a loss of certain wetland areas. This activity is considered to be medium in duration as it will be required for the life of mine. The impact will be local in extent with impacts likely to occur further downstream away from the site. The severity of the impact was determined to be very severe.

Impact assessment:

Parameter	Description	Rating
Duration	Permanent	5
Extent	Local	3
Severity	Very significant	7
Likelihood	Certain	7
Significance	Major	105%

Activity 18: Water use on site, storage of water and water treatment

Impacted environment: Aquatic ecosystems

Description: Due to the scarcity of water for the region, taking into consideration the ecological importance and significance of the Limpopo River, the use of water on site should be made with caution. Water to be used on site, is water that would naturally support wetland areas which in turn provide water for the Limpopo floodplain. The use of water on site will result in a loss of wetland areas due to less water being made available to the wetland areas. In addition to this, leaks and spillages associated with the dirty water storage facilities may also result in dirty water being introduced into the system. This activity is considered to be medium in duration as it will be required for the life of mine. The impact will be local in extent with impacts being transported downstream away from the site by the wetlands. The severity of the impact was determined to have moderate effects.

Impact assessment:

Parameter	Description	Rating
Duration	Medium term	3
Extent	Local	3
Severity	Moderate	3

Parameter	Description	Rating
Likelihood	Certain	7
Significance	Minor	63%

Activity 23: Rehabilitation as mining progresses via backfilling of overburden (where possible)

Impacted environment: Aquatic ecosystems

Description: This is difficult to consider for the application of bench mining which will alter the topography of the area, thus altering flow dynamics for the catchment. A single rehabilitation method which could be considered is revegetation of exposed areas with the purpose of creating suitable seepage areas. Sedimentation of the water resources due to erosion of the rehabilitated areas will be limited through the revegetation of the area. This activity will assist by reducing runoff velocity and limiting the reduction in recharge of shallow aquifers that feed wetlands. This activity is considered to be medium in duration as it will be required for the operational phase as well as the decommissioning phase. The extent will be local with effects being noted further downstream away from the site. The severity of the impact was determined to be negative and moderate.

Impact assessment:

Parameter	Description	Rating
Duration	Medium term	3
Extent	Local	3
Severity	Moderate	3
Likelihood	Certain	7
Significance	Minor	63%

13.3 Decommissioning phase

Activity 27: Rehabilitation of void (where possible)

Impacted environment: Aquatic ecosystems

Description: The replacement of overburden and topsoil throughout the life of mine as well as the final replacement during the decommissioning phase may result in the restoration of the catchment size prior to being impacted on. However, the replacement of overburden cannot replace the functionality of the old topography, as the existence of the wetlands is linked to the presence of perched aquifers which would have been removed due to the mining operation. This activity is considered to be medium in duration as it will be required for the decommissioning phase. The extent will be local with effects being noted further downstream away from the site. The severity of the impact was determined to be negative and moderate.

Impact assessment:

Parameter	**Description**	**Rating**
Duration	Medium term	3
Extent	Local	3
Severity	Moderate	3
Likelihood	Certain	7
Significance	Minor	63%

Activity 28: Spreading of sub-soils and topsoil (where possible)

Impacted environment: Aquatic ecosystems

Description: In the event that the replacement of soils in the correct soil profile formation is conducted, and the permeability differential between the topsoil layer and the underlying spoil layer are suitable, sub-surface flow dynamics may be restored to a lesser degree. However, it is most unlikely that the sub-surface flow dynamics will be restored to any practical extent. In addition to this, for rehabilitation for land use capability, the aim is to ensure transmissivity of water through the soil/spoil interface.This activity is considered to be medium in duration as it will be required for the decommissioning phase. The extent will be local with effects being noted further downstream away from the site. The severity of the impact was determined to be negative and moderate.

Impact assessment:

Parameter	**Description**	**Rating**
Duration	Medium term	3
Extent	Local	3
Severity	Moderate	3
Likelihood	Certain	7
Significance	Minor	63%

Activity 29: Re-vegetation areas disturbed by infrastructure

Impacted environment: Aquatic ecosystems

Description: Sedimentation of the water resources due to erosion of the rehabilitated areas will be limited through the re-vegetation of the area. Re-vegetation will also help to reduce runoff velocity for the area and increase seepage potential for wetland areas. In addition to this, the size of seepage areas would be increased. This activity is considered to be medium in duration as it will be required for the decommissioning phase. The extent will be local with effects being noted further downstream away from the site. The severity of the impact was determined to be negative and moderate.

Impact assessment:

Parameter	**Description**	**Rating**
Duration	Medium term	3
Extent	Local	3
Severity	Moderate	3
Likelihood	Certain	7
Significance	Minor	63%

Activity 30: Profiling and contouring to assist in drainage lines

Impacted environment: Aquatic ecosystems

Description: Due to the nature and impacts to topography associated with bench mining, it is extremely difficult to rehabilitate the area to represent the original catchment conditions. In spite of this, profiling and contouring of the area is important to allow for diffuse flow across the system to allow for infiltration of surface water. Efforts should be made to reduce flow velocity across the catchment as well as reduce slope gradients to limit erosion of the area. This activity is considered to be medium in duration as it will be required for the decommissioning phase. The extent will be local with effects being noted further downstream away from the site. The severity of the impact was determined to be negative and moderate.

Impact assessment:

Parameter	**Description**	**Rating**
Duration	Medium term	3

Parameter	Description	Rating
Extent	Local	3
Severity	Moderate	3
Likelihood	Certain	7
Significance	Minor	63%

13.4 Post Closure phase

Activity 33: Post-closure monitoring and rehabilitation

Impacted environment: Aquatic ecosystems

Description: Monitoring of the Limpopo River should be ongoing throughout the life of the mine. Biomonitoring of the system will assist with the identification of impacts to the ecological integrity (health) of the system from the surrounding activities. This assessment should include the monitoring of abiotic (driver) and biotic (response) attributes. This activity is considered to be medium in duration as it will be required for the life of mine. The extent will be local with effects being noted further downstream away from the site. The severity of the impact was determined to be positive and moderate.

Impact assessment:

Parameter	Description	Rating
Duration	Medium term	3
Extent	Local	3
Severity	Moderate	3
Likelihood	Certain	7
Significance	Minor	63%

14 CUMULATIVE IMPACTS

The dominant activities in the immediate and surrounding area are recreational hunting and game viewing. These activities have not impacted on the underlying hydrology of the area. Impacts associated with the surrounding activities include alterations of flow dynamics by means of damming, loss of habitat by means of vegetation clearing and loss of seepage areas as a result of the hardening of surfaces by road infrastructure and buildings. However, the impacts to aquatic and wetland systems associated with the current land use activities are minor. The cumulative loss of wetlands resulting from the proposed mining activities would be moderately low should the project not impact on the wetland areas. However, taking into consideration the worst case scenario, the mining activities would result in the loss of wetland areas and the removal of aquifers which support wetland areas. As a result of this, the significance of this cumulative impact was determined to be 67/100 (moderately high).

15 DECRIBED MITIGATION MEASURES

The objectives described for the recommended mitigation and/or management measures for each identified impact associated with each activity are presented below in Table 25. Table 25 lists the relevant activities for each phase of the mining operation and provides information pertaining to the legal requirements, recommended actions plans, timing, responsible person and significance after mitigation.

Table 26: Information pertaining to the recommended mitigation measures for the identified impacts associated with each activity.

Activity	Objectives	Mitigation/Management measure	Frequency of mitigation	Legal Requirements	Recommended Action Plans	Timing of implementation	Responsible Person	Significance after Mitigation
CONSTRUCTION PHASE								
Removal of topsoil (Activity 3)	Limit erosion of exposed areas and stockpiles as well as sediment load reporting to wetlands	Keep the footprint of the disturbed area to the minimum and designated areas only. Vegetate and wet stockpiles to limit erosion. Berms created below the piles to trap particles and runoff from the stockpile	Daily	National Water Act (Act 36 of 1998)	Suspensions within wetland areas will be removed without impacting on the wetland areas. The storm water management programme should be re-assessed and the effectiveness and suitability of the berms evaluated	Construction and operational phases	Environmental Co-ordinator	Moderate alteration
	Limit reduction in the re-charge of aquifers	Removal of vegetation during stripping and dump operation will be minimised to reduce the risk of the aquifers being drained and not properly recharged.	Daily	National Water Act (Act 36 of 1998)	Compensation will be made for lost wetland areas and the rehabilitation programme re-evaluated	Construction and operational phases	Environmental Co-ordinator	Moderate alteration
Blasting and development of initial bench for mining (Activity 8)	All construction activities will be planned and managed to ensure that there will not be a dramatic reduction in catchment size and water reporting to the wetland.	Bench mining will dewater the surrounding aquifers and the impacts will be unavoidable, because of this mitigation will not be possible.	Daily	National Water Act (Act 36 of 1998)	Limit the loss of aquifers to the footprint area only.	Construction phase	Environmental Co-ordinator	Very significant
OPERATIONAL PHASE								
Mining process removal of coal (bench mining)	All removal activities will be planned and managed to ensure that there will not be a	The continuous removal of coal will dewater the surrounding aquifers and the impacts will be unavoidable, because of this	Daily	National Water Act (Act 36 of 1998),	Limit the loss of aquifers to the footprint area only.	Operational phase	Environmental Co-ordinator	Very significant

(Activity 14)	dramatic reduction in catchment size and water reporting to the wetland.	mitigation will not be possible.						
Water use on site, storage of water and water treatment (Activity 18)	Avoid unnecessary waste of water as well as contamination of water.	A water management programme will be implemented to prevent excessive use of water and limit loss of water to the system. Additionally, water will be recycled and dirty water treated.	Weekly	National Water Act (Act 36 of 1998),	Investigation into the maintenance of equipment as well as management of the operation	Construction, operational and decommissioning phases.	Environmental Co-ordinator	Minor
Rehabilitation as mining progresses via backfilling of overburden (where possible) (Activity 23)	The restoration of seepage areas for the system	The placement of topsoil and the removal of infrastructure as well as suitable vegetation of the areas will result in the restoration of seepage areas for the system	Weekly	National Water Act (Act 36 of 1998),	The relevant specialists should be consulted for this activity and the original studies considered to assist with the compilation and implementation of the rehabilitation efforts	Decommissioning phase	Environmental Co-ordinator	Serious
	The restoration of sub-surface flow dynamics to the system	Soil will be placed in the original profile layout and not compacted too an extreme						
	The restoration of surface flow dynamics to the catchment	Profiling and contouring of the surface will restore surface drainage to the area						
Rehabilitation of void (where possible) (Activity 27)	The restoration of seepage areas for the system	The placement of topsoil and the removal of infrastructure as well as suitable vegetation of the areas will result in the restoration of seepage areas for the system	Weekly	National Water Act (Act 36 of 1998)	The relevant specialists should be consulted for this activity and the original studies considered to assist with the compilation and implementation of the rehabilitation efforts	Decommissioning phase	Environmental Co-ordinator	Serious
	The restoration of sub-surface flow dynamics to the system	Soil will be placed in the original profile layout and not compacted too an extreme						
	The restoration of surface flow dynamics to the catchment	Profiling and contouring of the surface will restore surface drainage to the area						

Spreading of sub-soils and topsoil (where possible) (Activity 28)	Restore the natural surface and sub-surface flow dynamics of the system as well as allow for effective seepage for the area	Soils are to be replaced in the original soil profile. Soils are not to be compacted too much, in order to allow interflow for the system.	Weekly	National Water Act (Act 36 of 1998)	The relevant specialists should be consulted for this activity and the original studies considered to assist with the compilation and implementation of the rehabilitation efforts	Decommissioning phase	Environmental Co-ordinator	Serious
Re-vegetation areas disturbed by infrastructure (Activity 29)	Restore the size of the impacted/disturbed catchment area	The footprint of the area disturbed by the mining operation will have topsoil and overburden replaced to restore the total catchment area.	Weekly	National Water Act (Act 36 of 1998)	The relevant specialists should be consulted for this activity and the original studies considered to assist with the compilation and implementation of the rehabilitation efforts	Decommissioning phase	Environmental Co-ordinator	Serious
Profiling and contouring to assist in drainage lines (Activity 30)	Restore the surface flow dynamics to the catchment	Restore the topography of the catchment to represent as close to possible the original topography of the catchment.	Weekly	National Water Act (Act 36 of 1998),	The relevant specialists should be consulted for this activity and the original studies considered to assist with the compilation and implementation of the rehabilitation efforts	Decommissioning phase	Environmental Co-ordinator	Serious
POST CLOSURE PHASE								
Post-closure monitoring and rehabilitation (Activity 33)	Monitor impacts to the catchment by determining the integrity of the Limpopo River	Implementation of aquatic biomonitoring for the life of mine. Assessing the integrity of biophysical attributed associated with the aquatic environment	Bi-annually	National Water Act (Act 36 of 1998),	The biomonitoring programme should also include toxicity testing of water and sediment for the system.	Construction, operational and decommissioning phases	Environmental Co-ordinator and aquatic ecologist	Minor (Positive)

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Appendix A: Curriculum Vitae (CV) and declaration of independence

ANDREW HUSTED

Mr Andrew Husted
Aquatic Ecologist
Digby Wells & Associates

EDUCATION

2006 - 2007:	BSc Masters in Aquatic Health – University of Johannesburg (UJ)
2005 – 2006:	BSc Hons. Zoology – Aquatic Health – Rand Afrikaans University (RAU)
2005 – 2003:	BSc Natural Science – Zoology & Botany (RAU)

EMPLOYMENT

January 2006 – June 2007: Econ@UJ, as an aquatic ecologist
August 2007 – present: Digby Wells and Associates, as an aquatic ecologist:

EXPERIENCE

Before joining Digby Wells & Associates (DWA) I was employed by Econ@UJ, a consortium based at the University of Johannesburg specializing in aquatic ecology as a researcher and project manager. I was involved in a number of projects at all levels. Through this I gained a wealth of experience in terms of aquatic assessments, which included ecological state assessments as well as biomonitoring programmes. Additional responsibilities included project management as well as co-ordination of specialists and report writing. I was also responsible for the management of other master degree studies, ensuring work was completed correctly and the deliverables were met as well as written articles were correct and accurate.

The River Health Programme is a national programme in which I have had extensive training on both a provincial and national level. I am a registered and recognised user of the programme. In addition to this, I have been involved in the formulation of the programme on an ongoing basis. Through this, I have a good understanding of the benefits and uses of such a programme, as well as the limitations offered by it. I am also an accredited South African Scoring System version 5 (SASS5) practitioner, a requirement of the RHP. I have received training on the RHP and the relevant indices in order to familiarise myself with the latest tools.

I am also currently part of the first group of consultants to be trained by DWAF during a year long training programme (2008). This training will allow me to be recognised by DWAF as a competent wetland delineator. The programme not only allows for wetland areas to be delineated but also for ecological services offered by the wetlands to be identified and described as well as for the integrity (health) of the wetland unit to be established. I also received a certificate of competence from Rhodes University for tools which are considered for wetland delineations as well as the WET-Management series. An additional area of speciality which is being developed is the design of a rehabilitation or conservation strategy for wetland offset areas.

I have also had the opportunity to undergo training with Rivers of Life in the use of the fish community structure to assist with the determination of the ecological state of lotic systems, such as dams and lakes. This training was conducted of a one year period and took place in Selebi-Phikwe, Botswana. In addition to this, I also received training in the application of telemetry to Tigerfish (*Hydrocynus vittatus*) both in Botswana and the Limpopo province. This included the capture of the species, as well as the sedation, transport, tagging and stocking of the species into a different system. In addition to this, the training required the monitoring of tagged individuals throughout the year which included 24 hour surveys. The aim of such a component is to conduct an assessment of the behaviour of the tagged populations.

In an endeavour to continue to improve my skills and specialist knowledge of my areas of interest, continuous training is required. Also considering the environment we live in today and demand for goods and services from our natural systems, there is a growing need to better understand our ecosystems. Owing to complexity of wetlands and the demands and stresses placed on these systems, I was trained in the soil classification of wetlands as well as the rehabilitation methods and techniques widely adopted to better understand this specialist area.

Special areas of interest include:

- **Aquatic ecosystem integrity, importance and sensitivity:**
  River Health Programme Training – Rivers of Life
  - Fish survey
    - Fish Assemblage Integrity Index (FAII) or if required the Fish Response Assessment Index (FRAI).
    - Fish Health Index (FHI)
    - Biodiversity report highlighting IUCN listed species.
  - Invertebrate survey
    - South African Scoring System Verison 5 index and if required the Macro Invertebrate Response Assessment Index (MIRAI).
    - Biodiversity report highlighting IUCN listed species.
  - Riparian and wetland vegetation survey
    - Application of the Vegetation Response Assessment Index (modification from RVI).
    - Rapid assessment of the ecological state of Wetland ecosystems.
    - Biodiversity report highlighting IUCN listed species.
  - Habitat surveys
    - Index of Habitat Integrity (IHI)
    - Integrated Habitat Assessment System (IHAS)
    - Habitat Quality Index (HQI)

- Water quality assessment
  - Oxygen content and saturation, conductivity, pH and temperature (in situ).
  - General nutrient, salinity and toxic components of the samples.

- **Wetland Delineation:**
  Wetland & Riparian Delineation Training - DWAF
  - Terrain Unit Indicator – helps to identify those parts of the landscape where wetlands are more likely to occur
  - Soil Form Indicator – identifies the soil forms, which are associated with prolonged and frequent saturation
  - Soil Wetness Indicator – identifies the morphological "signatures" developed in the soil profile as a result of prolonged and frequent saturation
  - Vegetation Indicator – identifies hydrophilic vegetation associated with frequently saturated soils

- **Wetland Assessments:**
  Wetland & Riparian Delineation Training - DWAF
  - Determine the Present Ecological State (PES) of wetlands
  - Determine the Ecological Importance and Sensitivity (EIS) of wetlands
  - Apply the wetland Index of Habitat Integrity (IHI)
  - Identify services provided by the wetlands (WET-EcoServices)

- **Wetland Ecological Assessments:**
  WET- Management Series Training – Rhodes University
  - Applying WET-EcoServices for an assessment
  - Applying WET-Health for an assessment

- **Wetland Offset Strategies:**
  - The identification of sites within a catchment with sufficient wetland area to compensate for the loss of wetlands elsewhere
  - Identification and description of wetland types and the respective conditions
  - Development of a rehabilitation or conservation strategy

- **Telemetry:**
    - Capture, tag and release suitable individuals
    - Monitor the initial recovery and initial behaviour of the tagged individuals
    - Continuous monitoring exercise of the tagged individuals
    - Review and report on the programme undertaken

- **Estuarine Ecological State, Importance and Sensitivity Assessments:**
    - Estuarine Fish Condition Index

TRAINING

- Wetland and Riparian Delineation Course for Consultants (Certificate of Competence) – DWAF
- The threats and impacts posed on wetlands by infrastructure and development: Mitigation and rehabilitation thereof – Gauteng Wetland Forum
- Ecological State Assessment of Lentic Systems using Fish Population Dynamics – University of Johannesburg/Rivers of Life
- Soil Classification and Wetland Delineation – Terra Soil Science
- Wetland Rehabilitation Methods and Techniques - Gauteng Wetland Forum
- Application of the Fish Response Assessment Index (FRAI) and Macroinvertebrate Response Assessment Index (MIRAI) for the River Health Programme
- Tools for a Wetland Assessment (Certificate of Competence) – Rhodes University

PRESENTATIONS

- Zoology postgraduate colloquiums 2005, 2006 and 2007.
- Department of Water Affairs and Forestry (Bronkhorstspruit). Findings of a wetland assessment and aquatic assessment conducted for a project for Xstrata Coal South Africa, November 2008.
- Department of Water Affairs and Forestry (Pretoria). Findings of two case studies conducted for accreditation and recognition by DWAF as a competent wetland specialist, November 2008.

- Harress Pickel Consult AG (Selebi Phikwe, Botswana). Environmental study to establish the baseline biological and physical conditions of the Letsibogo Dam near Selebi Phikwe, Botswana. (Programme “Economic Diversification of the Mining Sector”, 8 ACP BT 13). October 2009.
- Xstrata Coal South Africa (Oogies). Formulation of a Biodiversity and Land Management Plan, November 2009, April 2010.
- Exxaro Coal Pty (Ltd) (Belfast area). EIA Feedback meeting for the Public Participation Process. Findings of the integrated wetland assessment and the formulated wetland offset strategy for the project, April 2010
- BHP Biliton Energy Coal South Africa (Johannesburg). Findings of the aquatic assessments and wetland assessments conducted for the respective project area, May 2010.
- Xstrata Coal South Africa (Oogies). Submission of a Biodiversity and Land Management Plan, July 2010.
- The International Society of Limnology conference (Cape Town). Use of bio-telemtry to evaluate the advantages and disadvantages of using Tigerfish (*Hydrocynis vittatus*) as a management option for the control of alien species in souther African impoundments. Case study: Letsibogo Dam, Botswana, August 2010.
- The International Association of Impact Assessments South Africa conference (Pretoria). The management of biodiversity in areas associated with mining through the application of a GIS based, integrated Biodiversity Land Management Plan (BLMP), August 2010.

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Co. Reg. No. 1999/05985/07

SPECIALIST DECLARATION OF INDEPENDENCE

I, Andrew Husted, declare that I –

- Act as the independent specialist for the undertaking of a specialist section for the proposed project Boikarabelo Coal mine and railway network;
- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2006;
- Do no have nor will have a vested interest in the proposed activity proceeding;
- Have no, and will not engage in, conflicting interests in the undertaking of the activity;
- Undertake to disclose, to the competent authority, any information that have 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 Environmental Impact Assessment Regulations, 2006;

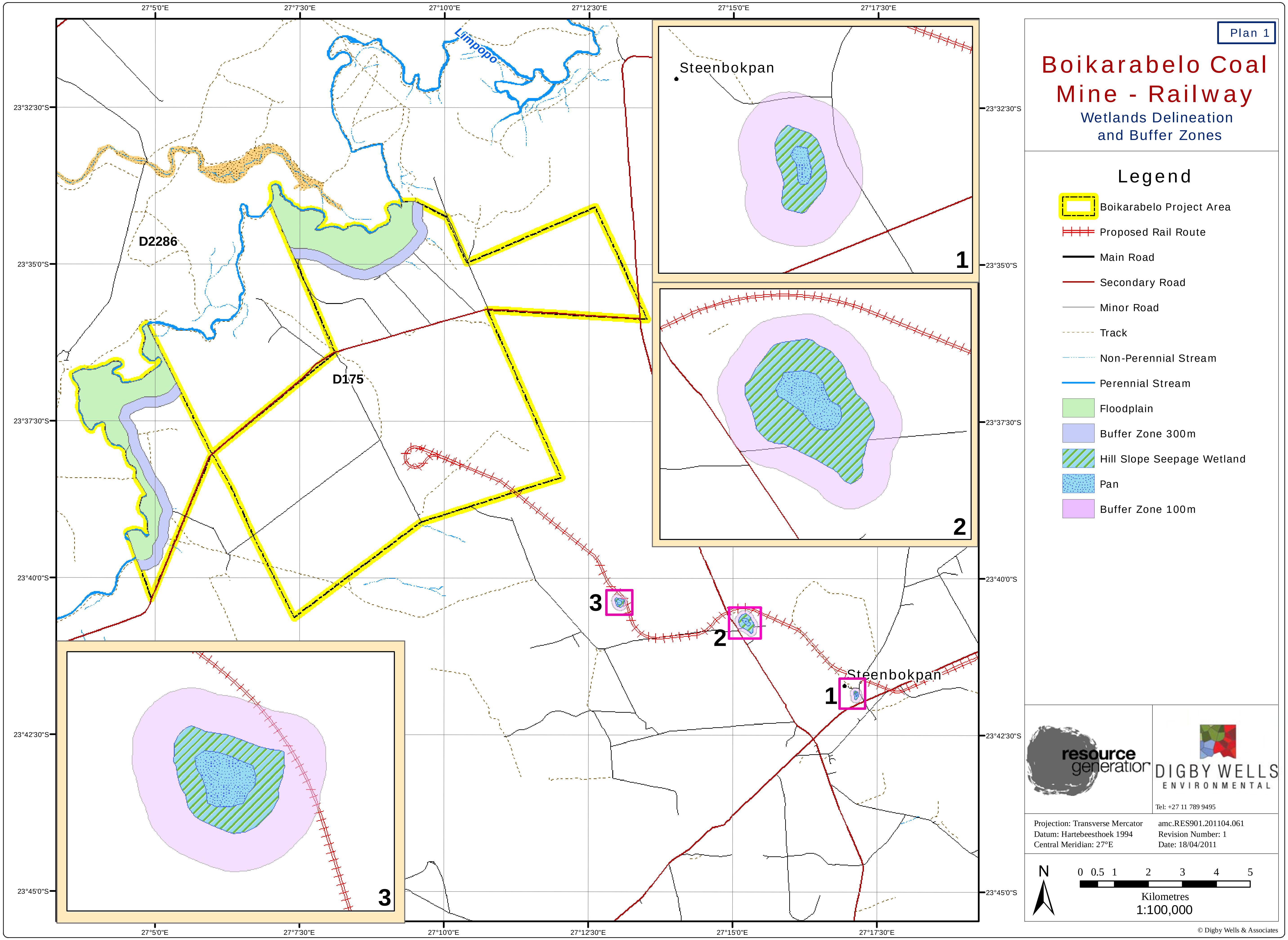
Andrew Husted
Name of the specalist

Signature of the specalist

Digby Wells and Associated (Pty) Ltd
Name of company

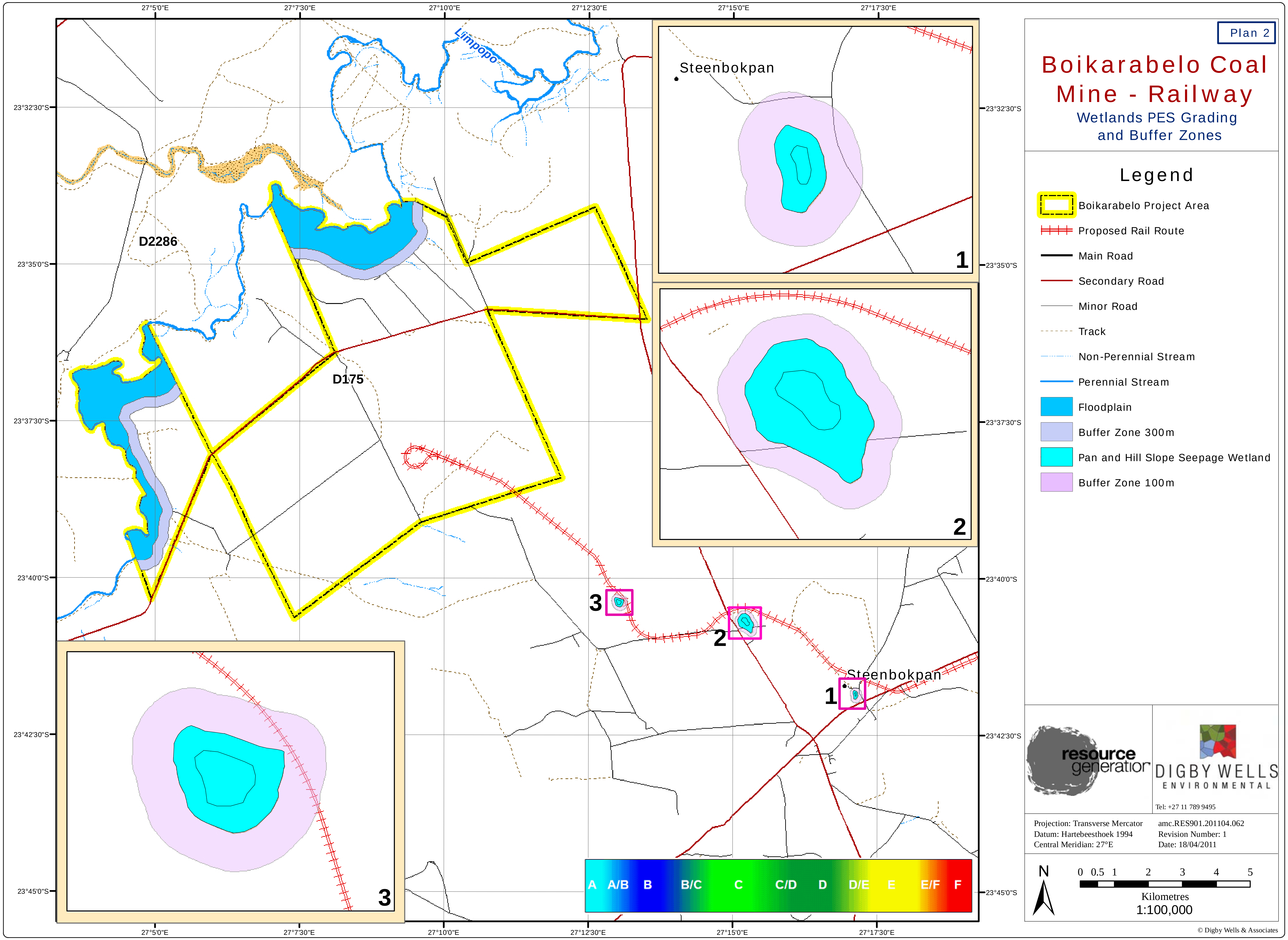
April 2011
Date

Appendix B: Distribution and extent of wetland types in the study area.



Plan 1
Boikarabelo Coal Mine - Railway
Wetlands Delineation and Buffer Zones
Legend
Boikarabelo Project Area
Proposed Rail Route
Main Road
Secondary Road
Minor Road
Track
Non-Perennial Stream
Perennial Stream
Floodplain
Buffer Zone 300m
Hill Slope Seepage Wetland
Pan
Buffer Zone 100m
Limpopo
D2286
D175
Steenbokpan
1
2
3
27°5'0"E
27°7'30"E
27°10'0"E
27°12'30"E
27°15'0"E
27°17'30"E
23°32'30"S
23°35'0"S
23°37'30"S
23°40'0"S
23°42'30"S
23°45'0"S
resource generation
DIGBY WELLS ENVIRONMENTAL
Tel: +27 11 789 9495
Projection: Transverse Mercator
Datum: Hartebeesthoek 1994
Central Meridian: 27°E
amc.RES901.201104.061
Revision Number: 1
Date: 18/04/2011
N
0 0.5 1 2 3 4 5
Kilometres
1:100,000
© Digby Wells & Associates

Appendix C: The Present Ecological State (PES) of wetlands in the study area


Plan 2
Boikarabelo Coal Mine - Railway
Wetlands PES Grading and Buffer Zones
Legend
Boikarabelo Project Area
Proposed Rail Route
Main Road
Secondary Road
Minor Road
Track
Non-Perennial Stream
Perennial Stream
Floodplain
Buffer Zone 300m
Pan and Hill Slope Seepage Wetland
Buffer Zone 100m
Limpopo
D2286
D175
Steenbokpan
1
2
3
A
A/B
B
B/C
C
C/D
D
D/E
E
E/F
F
27°5'0"E
27°7'30"E
27°10'0"E
27°12'30"E
27°15'0"E
27°17'30"E
23°32'30"S
23°35'0"S
23°37'30"S
23°40'0"S
23°42'30"S
23°45'0"S
resource generation
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Tel: +27 11 789 9495
Projection: Transverse Mercator
Datum: Hartebeesthoek 1994
Central Meridian: 27°E
amc.RES901.201104.062
Revision Number: 1
Date: 18/04/2011
N
0 0.5 1 2 3 4 5
Kilometres
1:100,000
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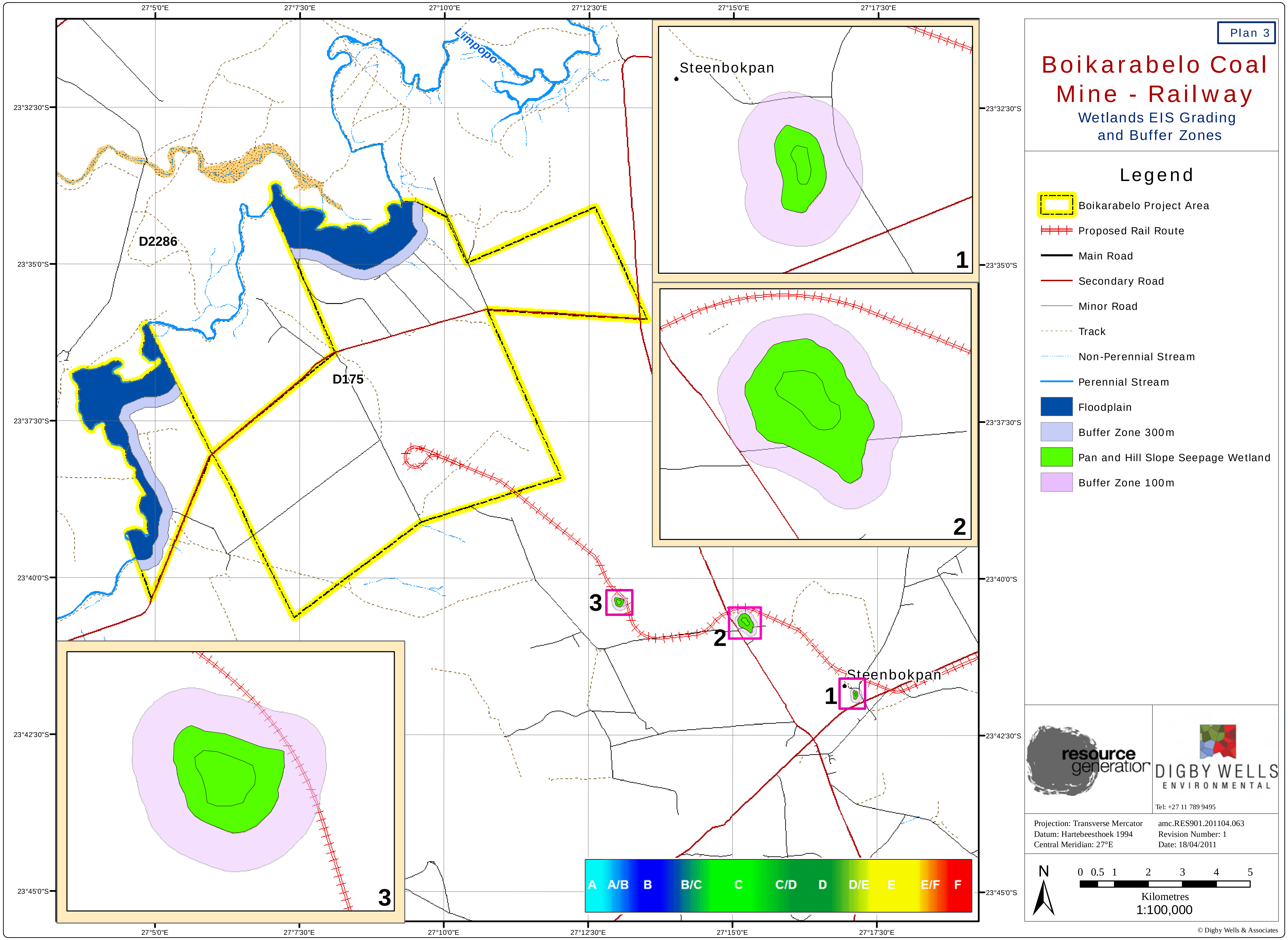
Appendix D: The Ecological Importance and Sensitivity (EIS) of wetlands in the study area


Plan 3
Boikarabelo Coal Mine - Railway
Wetlands EIS Grading and Buffer Zones
Legend
Boikarabelo Project Area
Proposed Rail Route
Main Road
Secondary Road
Minor Road
Track
Non-Perennial Stream
Perennial Stream
Floodplain
Buffer Zone 300m
Pan and Hill Slope Seepage Wetland
Buffer Zone 100m
Limpopo
D2286
D175
Steenbokpan
1
2
3
A
A/B
B
B/C
C
C/D
D
D/E
E
E/F
F
27°5'0"E
27°7'30"E
27°10'0"E
27°12'30"E
27°15'0"E
27°17'30"E
23°32'30"S
23°35'0"S
23°37'30"S
23°40'0"S
23°42'30"S
23°45'0"S
resource generation
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amc.RES901.201104.063
Revision Number: 1
Date: 18/04/2011
N
0 0.5 1 2 3 4 5
Kilometres
1:100,000
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Appendix E: Photographs taken from within the study area.

The reach of the Limpopo River sampled at Site 1

The reach of the Limpopo River sampled at Site 2

Samples of the *Synodontis sp* collected during the survey

A fyke net used to sample the fish species within the Limpopo River