ESKOM

Continuation of Ash Disposal Activities at Majuba Power Station

Mpumalanga, South Africa

Aquatic Ecology

Screening and Scoping Assessment

ecotone
Freshwater Consultants

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Prepared For:

Lidwala Consulting Engineers
c/o: Ashlea Strong
P.O. Box 4221
Northcliff, 2115
Tel: 087 351 5145
Cell: 082 786 7819
Fax: 011 793 5476
Fax to email: 086 686 1628
Email: astrong@lidwala.com

Prepared By:

Ecotone Freshwater Consultants
P.O Box 84, Florida, 1710
Cell: +27 84 585 7479
Tel: (011) 672 1375
Fax: 088 011 673 1192
contact@ecotone-sa.co.za
www.ecotone-sa.co.za

Declaration of Independence

I, Gina Walsh, as duly authorised representative of Ecotone Freshwater Consultants CC, hereby confirm my independence (as well as that of Ecotone Freshwater Consultants CC) as a specialist and declare that neither I nor Ecotone Freshwater Consultants CC have any interest, be it business, financial, personal or other, in any activity or application associated with the continuous ashing at Majuba Power Station other than fair remuneration for work performed.

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Full Name: Gina Walsh
Title / Position: Aquatic Ecologist and Partner
Qualification(s): M.Sc (Zoology)
Registration: *Pri. Sci. Nat.* (400192/10)

	Person	Qualifications	Professional Registration - SACNASP	Report Status
Report compiled by	Gina Walsh	MSc (Zoology) UJ '08	*Pr. Sci. Nat*. (400192/10) Aquatic Science, Ecology & Zoology	Final
	Michiel Jonker	MSc (Aquatic health) UJ'09	*Pr. Sci. Nat*. (400275/12) Zoology	
	Marco Alexandre	MSc (Aquatic health) UJ'10	*Cand. Sci. Nat*. (100010/11) Aquatic Science and Zoology	
	Linette Ferreira	MSc (Aquatic health) UJ'09		
Members: Michiel Jonker & Gina Walsh **Registration no:** CK 2008/027022/23				

Limitations and Disclaimer

The spatial and temporal extents of Ecotone's services are described in the proposal, and are subject to restrictions and limitations. A total assessment of all probable scenarios or circumstances that may exist on the study site was not undertaken. No assumptions should be made unless opinions are specifically indicated and provided. Data presented in this document may not elucidate all possible conditions that may exist given the limited nature of the enquiry.

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List of Abbreviations

AEV	Acute Effect values
CCGT	Combined Cycle Gas Turbine
CEV	Chronic Effect values
DEM	Digital Elevation Model
DWA/F	Department of Water Affairs
DS	Downstream
E	Endangered
EX	Exotic
EIA	Environmental Impact Assessment
EPT	Ephemeroptera-Plecoptera-Trichoptera
GIS	Geographic Information System
FRAI	Fish Response Assessment Index
HGM	Hydro-geomorphic
IHAS	Invertebrate Habitat Assessment System
IHI	Index of Habitat Integrity
IUCN	International Union for Conservation of Nature
LC	Least Concerned
MAP	Mean Annual Precipitation
MAPE	Mean Annual Potential Evaporation
MAR	Mean Annual Run-off
MAT	Mean Annual Temperature
MFD	Mean Frost Days
MBCP	Mpumalanga Biodiversity Conservation Plan

NFEPA	National Freshwater Ecosystem Priority Areas
NSBA	National Spatial Biodiversity Assessment
NT	Near Threatened
PES	Present Ecological State
SAGA	System for Automated Geoscientific Analyses
SANBI	South African National Biodiversity Institute
SASS5	South African Scoring System (version 5)
SQ	Sub-quaternary
SRTM	Shuttle Radar Terrain Model
SS	Sensitivity Score
TWI	Topographic Wetness Index
TWQG	Target Water Quality Guidelines
US	Upstream
V	Vulnerable
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area

1. Introduction

Lidwala Consulting Engineers have requested that Ecotone Freshwater Consultants CC undertake the freshwater ecology specialist component of the Environmental Impact Assessment (EIA) for the continuous ashing at the Majuba Power Station. This report provides screening and scoping input and regional context for the purpose of highlighting the current state of the surrounding aquatic environment and identifying potential impacts.

2. Scope of Work

The scope of work encompassed an initial desktop study, focussing on the surface water systems linked to the continuous ashing at the Majuba Power Station, Mpumalanga, in order to determine the possible implications of the proposed development on the associated aquatic ecosystems and guide the detailed plan of study for the EIA phase.

The scope of work encompassed a baseline desktop aquatic ecology survey that incorporates the following aspects:

- Desktop aquatic ecology baseline data collection (referring to potentially occurring aquatic macroinvertebrate and fish species) and a literature review of the area.
- Generation of a desktop sensitivity map pertaining to aquatic ecosystems in a 12 km radius.
- Identification of potential impacts related to the receiving aquatic environment with reference to the proposed Majuba ash disposal facility.
- Presentation of a detailed plan of study for the Environmental Impact Assessment (EIA) phase regarding the aquatic ecological assessment.

The aquatic ecology screening and scoping assessment is subject to the following assumptions and limitations:

- The study was desktop based and relied heavily on Geographic Information System (GIS) for determining low lying areas where surface water flows were better articulated. It thus follows that certain types of wetlands (i.e. seepage zones) might not be reflected on the surface water map. The presence of these wetlands will have to be confirmed during the EIA phase, although the presence of seeps was visually confirmed in the preferred ashing area in the scoping site visit.
- Reference information for aquatic biota of the area is limited. Lists for expected fish and aquatic macroinvertebrate species generated in this report are of a moderate confidence as little historical data exists prior to large scale hydrological alteration induced by surrounding catchment utilisation. The expected lists provided in this

report is a compilation of distributions as set out in the International Union for Conservation of Nature (IUCN) Red Data List database (IUCN, 2012), Skelton (2001) and Frequency of Occurrence (Kleynhans *et al.*, 2007a), the Rivers Database (Dallas *et al.*, 2007) and Mrs. Christa Thirion of DWA Resource Quality Services (*Pers. Comm.*, 2012).

- The legal summary excludes an extensive review of the legal implications for development in relation to affected surface water systems. A professional legal opinion on this aspect of the development should be sought out.

3. Methodology

3.1. Desktop Assessment

3.1.1. Literature Review on the General Study Area

A literature survey and desktop study on the general study area was carried out using available information from reference works (Nel *et al.*, 2004; Mucina & Rutherford, 2006; DWAF, 2007) and previous specialist studies, namely:

- areas of sensitivity (Reddy, 2007) associated with the proposed Combined Cycle Gas Turbine (CCGT) power plant in the Amersfoort Area;
- wetland specialist assessment undertaken at the Majuba Power Station south of the existing ash disposal facility (Lidwala, 2011); and
- the proposed long term coal supply to Eskom's Majuba Power Station (Golder & Associates, 2004).

Main rivers associated with the proposed development were identified and relevant stretches were characterised. Wetland systems located within the study area were identified at a desktop level with the use of shape files obtained from the South African National Biodiversity Institute (SANBI, 2010). General area characteristics were obtained using reference work from Mucina & Rutherford (2006).

3.1.2. Historical Water Quality

The 90^{th} percentile historical water quality monitoring data values were obtained from the Department of Water Affairs (DWA) stations on the Perdewater and the Skulpspruit. The DWA monitoring stations and their localities are listed below:

- C11_90602 (C1H026Q01) Water Quality. Zaaihoek-Majuba Pipe Line Skulpspruit Outlet / Elan. Monitored: 1996/08/28 to 2007/03/28. Resource Quality Directorate, Department of Water Affairs and Forestry. [-27.16250 29.87833]

- C11_177963 Water Quality. Amersfoort-Final Effluent at Amersfoort Waste Water. Monitored: 1999/07/01 to 2006/01/14. Resource Quality Directorate, Department of Water Affairs and Forestry. [-26.98861 29.87333]

3.1.3. Data analysis

Historical water quality from DWA gauging stations were compared to Target Water Quality Ranges (TWQRs) for freshwater ecosystems (DWAF, 1996) (Table 3-1; Table 3-2) while the major ions were compared to benchmark criteria compiled by Kotze (2002) consisting of TWQRs (DWAF, 1996) and source water quality guidelines set by Rand Water (Steynberg *et al.*, 1996; Rand Water, 1998) (Table 3-3). Historical water quality information was represented using colour coding to indicate whether water quality variables were within guideline ranges (Table 3-4).

Table 3-1: Target Water Quality Guideline (TWQG) values, with Chronic (CEV) - and Acute Effect values (AEV) (DWAF, 1996)

Abbreviation	Additional Criteria	TWQG	CEV[1]	AEV [2]
(DO)	06:00 am sample (or lowest instantaneous concentration in 24hr period)	80%-120%		
N (inorganic)	Inorganic nitrogen concentrations should not be changed by more than 15 % from that of the water body under local un-impacted conditions at any time of the year; and the trophic status of the water body should not increase above its present level, though a decrease in trophic status is permissible, and the amplitude and frequency of natural cycles in inorganic nitrogen concentrations should not be changed.			
pH	pH values should not be allowed to vary from the range of the background pH values for a specific site and time of day, by > 0.5 of a pH unit, or by > 5 %, and should be assessed by whichever estimate is the more conservative.			
TDS	TDS concentrations should not be changed by > 15 % from the normal cycles of the water body under un-impacted conditions at any time of the year; and the amplitude and frequency of natural cycles in TDS concentrations should not be changed.			

[1] CEV = is defined as "that concentration or level of a constituent at which there is expected to be a significant probability of measurable chronic effects to up to 5 % of the species in the aquatic community" (DWAF, 1996).
[2] AEV= is defined as "that concentration or level of a constituent above which there is expected to be a significant probability of acute toxic effects to up to 5 % of the species in the aquatic community" (DWAF, 1996).

Table 3-2: Trophic status classification as represented by the TWQGs for aquatic ecosystems (DWAF, 1996)

Const. Abr.	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic
N (inorganic)	<0.5	0.5-2.5	2.5-10	>10
N:P	40	25	20	10
PO_4 (inorganic)	<5	5.0-25.0	25-250	>250

Table 3-3: Benchmark criteria for Ideal, Tolerable and Intolerable values for major ions (Kotze, 2002)

	Ideal mg/L	Tolerable mg/L	Intolerable mg/L
Ca	150		>150
Cl	50	150	>150
Mg	70		>70
K	50	400	>400
Na	50	100	>100
SO_4	80	500	>500
EC	450*	1000*	>1000*

* ($\mu S\text{-}cm^{-1}$)

Table 3-4: Colour codes used to indicate the ranges of water quality variables (Adapted from DWAF, 1996; Kotze, 2002)

Toxicity	Colour
Above TWQR	
Above CTV	
Above ATV	
Trophic Status	
Oligotrophic	
Mesotrophic	
Eutrophic	
Hyper-eutrophic	
Biotic Tolerance	
Tolerable	
Intolerable	

TWQR = Target Water Quality Range; CTV = Chronic Toxicity Values; ATV = Acute Toxicity Values.

3.1.4. Expected Macroinvertebrate and Fish Species

A potential aquatic macroinvertebrate species list was compiled using the Rivers database (Dallas *et al.*, 2007), Gerber & Gabriel (2002) and expert opinion (Mrs. Christa Thirion, *Pers. Comm*, 2012). Potential fish species and their respective conservation status and habitat preferences were identified using expert opinion and reference works from the Rivers database (Dallas *et al.*, 2007), Skelton (2001), Kleynhans (2007), Kleynhans *et al.* (2007) and IUCN database (IUCN, 2012).

3.2. Sensitivity Analysis

3.2.1. Modelling

The System for Automated Geoscientific Analyses (SAGA) GIS standard terrain model was used to model the areas where water would accumulate in the landscape, and therefore increase the potential for wetlands to develop. This module models various topographic features related to hydrology, which include channels and the Wetness Index. In the absence of 5 m contours for the area from the Chief Surveyor-General, the Shuttle Radar Terrain Model (SRTM) and Digital Elevation Model (DEM) were used. The DEM was obtained from the Global Land Cover Facility website[3] and is provided at 80 m x 90 m resolution, but for the purpose of the modelling the resolution was adjusted to 100 m x 100 m. In addition, 1:50 000 river (Chief Directorate – Surveys and Mapping, 2629 and 2729), NSBA rivers (Nel *et al.*, 2004) and SANBI wetlands (SANBI, 2010) were also considered and superimposed on the Wetness Index. A high sensitivity was assigned to these areas.

3.2.2. Sensitivity Mapping

The sensitivity mapping divides the study area (12 km radius) into three different categories (Table 3-5) based on the degree of sensitivity. These categories include:

1. **High Sensitivity**: Permanent and seasonal wetness associated with rivers/streams and wetland areas. These areas have a high sensitive and should be avoided.
2. **Moderate Sensitivity**: Temporary wetness associated with areas of moderate sensitivity. These areas should also be avoided where feasibly possible.
3. **Low Sensitivity**: Terrestrial areas with low slopes. Associated with areas of least sensitivity with regards to surface water.

Table 3-5: Description of the categories used during the sensitivity mapping

Category	Colour Coding	Description
High Sensitivity	(red)	Permanent and seasonal wetness
Moderate Sensitivity	(orange)	Temporary wetness
Low Sensitivity	(green)	Terrestrial areas with low slopes

[3] Global Land Cover Facility: http://glcf.umiacs.umd.edu/

4. Results

4.1. General Study Area

4.1.1. Ecoregion Characteristics

Majuba Power Station is located between Volksrust and Amersfoort in Mpumalanga Province. The study area falls in the Mesic Highveld- and Dry Highveld Grassland bioregions and is associated with three vegetation types: The Soweto Highveld- and Amersfoort Highveld Clay Grassland vegetation types, and the Bloemfontein Karroid Shrubland vegetation type (Table 4-1; Figure 4-1).

Table 4-1: Environmental variables and geomorphologic description of the study area (Mucina & Rutherford, 2006)

Bioregion	Mesic Highveld Grassland		Dry Highveld Grassland
Vegetation Type	**Soweto Highveld Grassland**	**Amersfoort Highveld Clay Grassland**	**Bloemfontein Karroid Shrubland**
Landscape features	Gently to moderately undulating landscape; in places not disturbed: scattered small wetlands, narrow stream alluvia, pans and occasional ridges or rocky outcrops.	Undulating grassland plains, with small scattered patches of dolerite outcrops cover.	Slightly sloping flanks of dolerite outcrops.
Geology and soils	Shale, sandstone or mudstone. Soils are deep and reddish on flat plains.	Vertic clay soils derived from dolerite.	Dolerite intrusions. Layer of sand of Aeolian origin overlying sheets of dolerite.
MAP (mm)	662	694	566
MAT (ºC)	14.8	14.0	15.0
MFD (d)	41	42	40
MAPE (mm)	2060	1877	2201
Status	E	V	LC

MAP: Mean Annual Precipitation; **MAT:** Mean Annual Temperature; **MFD:** Mean Frost Days; **MAPE:** Mean Annual Potential Evaporation; **E:** Endangered; **V:** Vulnerable; **LC:** Least Concerned

Landscape features for the Soweto Highveld Grassland include gently to moderately undulating plains. Small scattered wetlands, narrow streams, pans, hillslope seeps and occasional ridges or rocky outcrops interrupt the continuous grassland cover. Undulating grassland plains with small scattered patches of dolerite outcrops are characteristic of the Amersfoort Highveld Clay Grassland, while the Bloemfontein Karroid Shrubland is characterised by slightly sloping flanks of dolerite outcrops (Table 4-1).

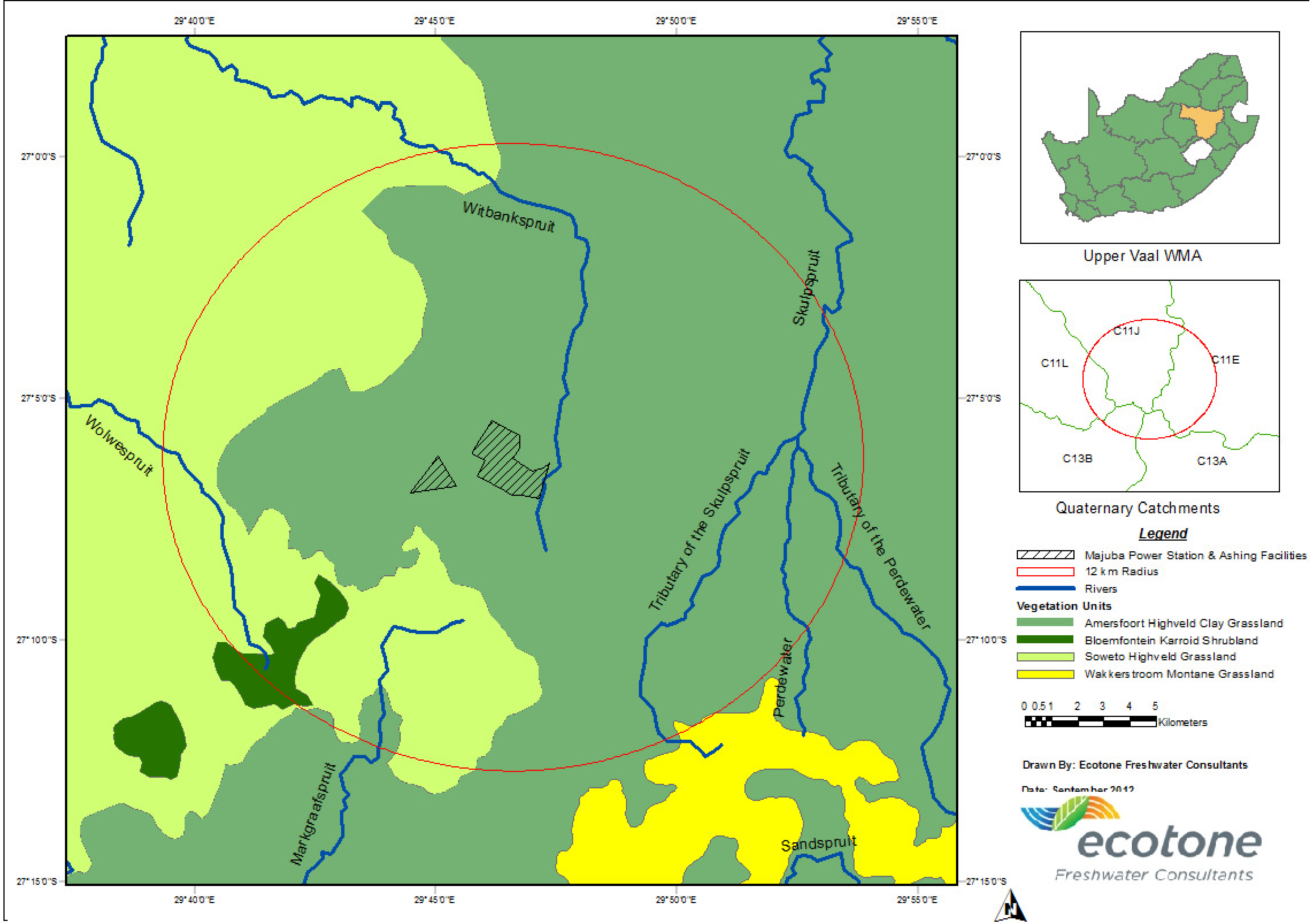

Figure 4-1: Vegetation units associated with the study area (Nel *et al.*, 2004; Mucina & Rutherford, 2006).

The geology of the Soweto Highveld Grassland mainly consists of shale, sandstone or mudstone of the Madzaringwe Formation or the intrusive Karoo Suite dolerites, which feature prominently in the area (Mucina & Rutherford, 2006). The soils are deep and reddish on flat plains. The geology and soils of the Amersfoort Highveld Clay Grassland are characterised by vertic clay soils derived from dolerite. The Bloemfontein Karroid Shrubland is characterised by dolerite intrusions embedded within sediments of the Adelaide Subgroup and a shallow layer of sand that overlies sheets of dolerite (Table 4-1).

The Mean Annual Precipitation (MAP) and Mean Annual Temperature (MAT) in the area ranges between 662 and 694 mm, and 14.0 and 14.8 ^{o}C, respectively (Table 4-1). The conservation status of the Soweto Highveld Grassland is Endangered, where Amersfoort Highveld Clay Grassland is classed Vulnerable (Mucina & Rutherford, 2006).

The MAP of the Bloemfontein Karroid Shrubland (566 mm) is lower when compared to the MAP of the other two vegetation types and has a conservation status of Least Threatened. The Mean Annual Potential Evaporation rate (MAPE) of the vegetation types of both bioregions exceeds the MAP of the respective vegetation types, thus a net loss in precipitation is experienced. The area associated with the Majuba Power Station receives a MAP of approximately 750 mm (Figure 4-2). Data for the period 2007 to 2011 indicates that the year 2009 had the highest rainfall (840 mm).

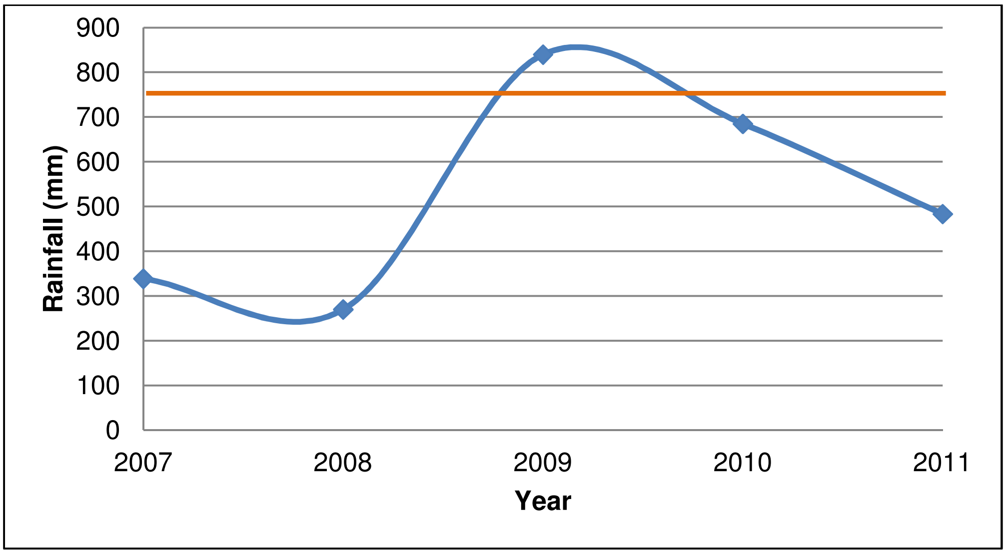

Figure 4-2: Mean Annual Precipitation (orange line) and annual precipitation for period 2007 to 2011.

4.1.2. River and Catchment Characterisation

The study area considered in the screening and scoping phases encompasses a 12 km radius around the current infrastructure, and falls over five quaternary catchments in the Upper Vaal Water Management Area (WMA) with the Majuba Power Station located in C11J (Figure 4-3). The study area in relation to the National Freshwater Ecosystem Priority Areas (NFEPA) and the Mpumalanga Biodiversity Conservation Plan are provided in Figures 4-4 and 4-5. Portions of the study area are located in a Freshwater Ecosystem Priority Area (FEPA) and these systems were identified as being in a good condition (NFEPA – Nel *et al.,* 2011) and therefore need to be maintained in order to contribute to the biodiversity of the area (Figure 4-4). The remainder of the study area is located in an Upstream Management Area. Anthropogenic activities taking place in these areas need to be monitored in order to prevent the degradation of FEPAs and Fish Support Areas located downstream (Figure 4-4). According to the MBCP (Ferrrar & Lötter, 2007) the study area is located in an "Ecosystem Maintenance" sub-catchment (Figure 4-5).

The characterisation of the rivers located within the study area (12 km radius) showed that with the exception of the Skulpspruit (order two river) all of the remaining associated systems are order one rivers/streams (Table 4-2). The Witbankspruit (running along the eastern boundary of the Majuba Power Station), Skulpspruit and the Markgraafspruit are all perennial with the remainder of the systems being classed as non-perennial (Figure 4-3; Table 4-2). Numerous smaller streams are shown in the 1:50 000 river coverage (Figure 4-3). Non perennial rivers located in drier climates hold different characteristics to those located in wetter climates and function differently to their perennial counterparts (Rossouw *et al*., 2005). They therefore require focused attention with regards to ecosystem management.

The tributary of the Witbankspruit as indicated in Figure 4-3 will be affected by the proposed ash disposal facility. The aquatic ecosystems in the immediate vicinity include:

- A pan to the south of the existing ashing activity (Figure 4-6 A);
- The tributary of the Witbankspruit which is a valley bottom system to the east of the current ash disposal facility footprint (running south to north) (Figure 4-6 C and D);
- A tributary of the Witbankspruit to the west of the existing ash disposal facility ;
- Various zero order tributaries of the aforementioned system; and
- Visually observed seeps.

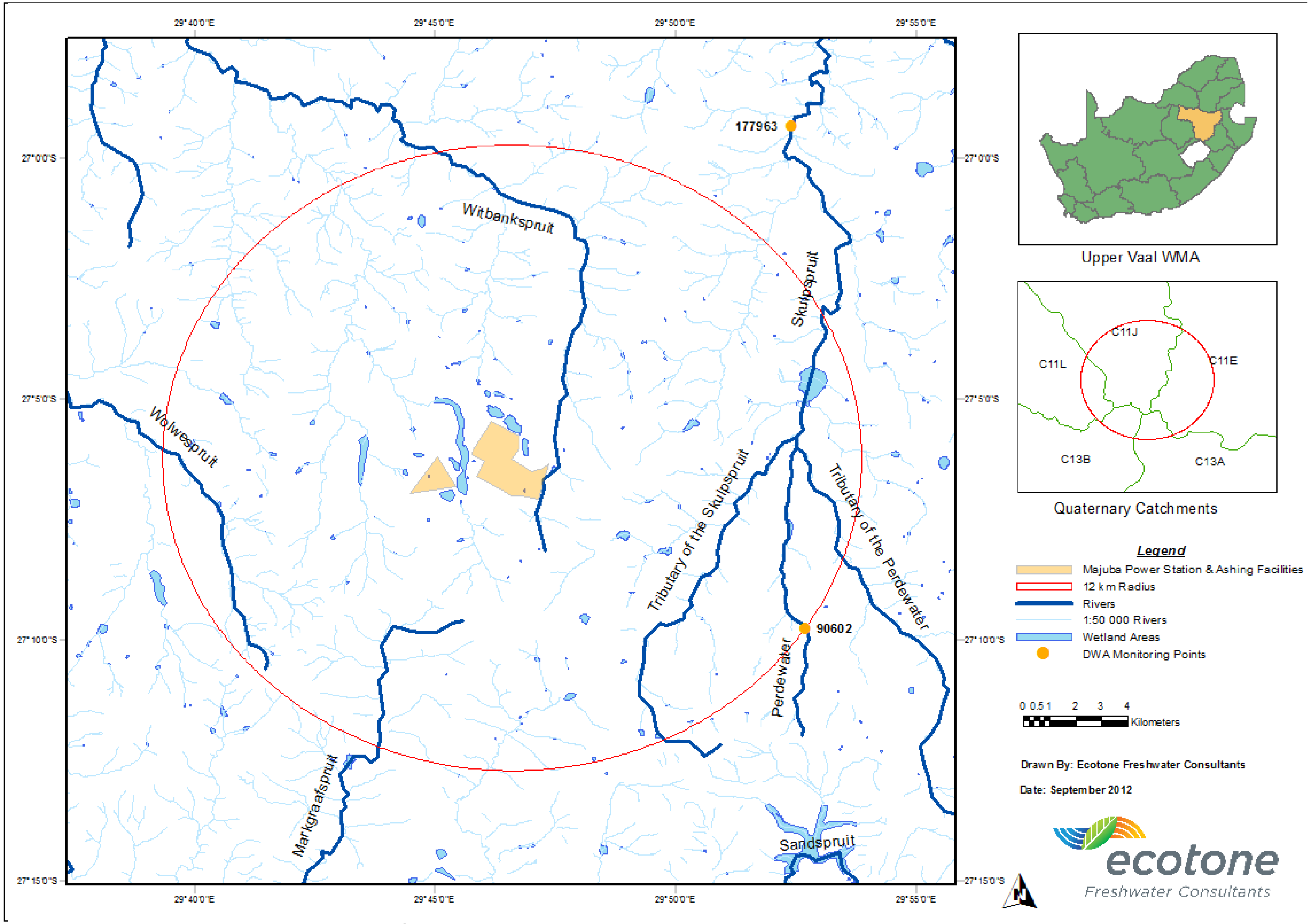

Figure 4-3: Map indicating the 12 km radius study area and DWA monitoring points associated with the proposed Majuba ash disposal facility (Nel *et al.,* 2004; Chief Directorate – Surveys and Mapping, 2629 and 2729; SANBI, 2010).

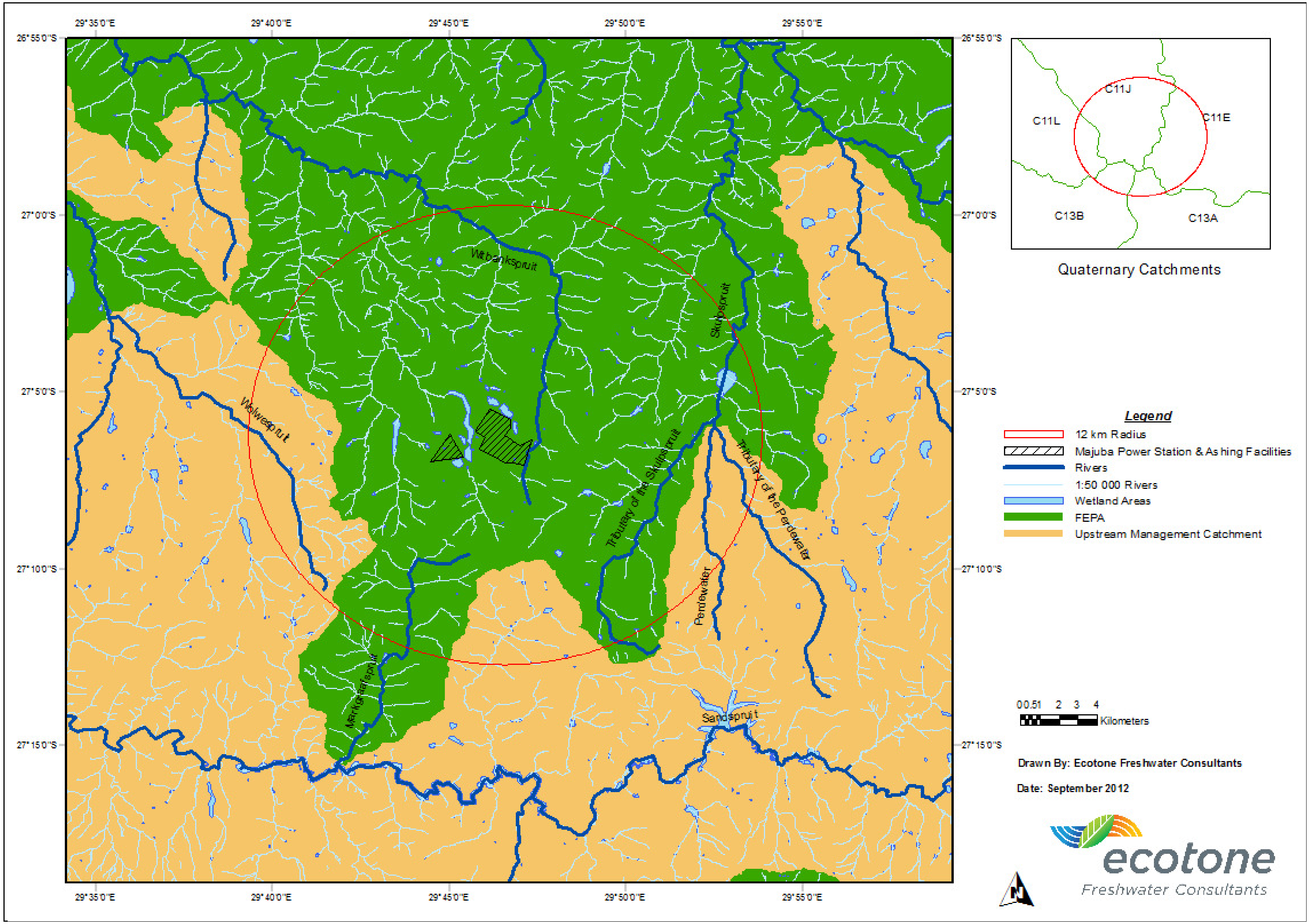

Figure 4-4: Map indicating the study area in relation to the NFEPAs (Nel *et al.*, 2004; SANBI, 2010; Nel *et al.,* 2011).

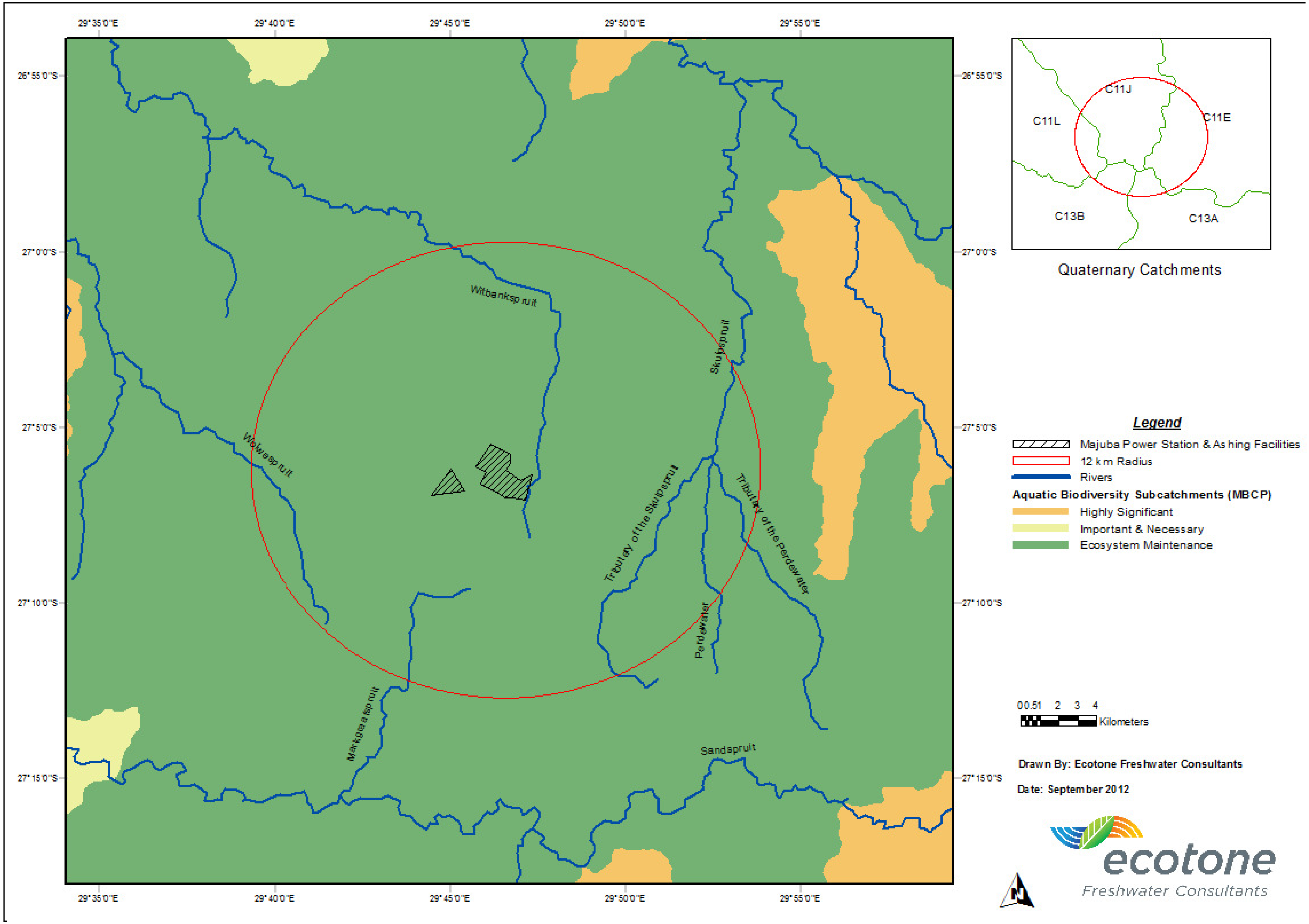

Figure 4-5: Map indicating the study area in relation to the MBCP (Nel *et al.*, 2004; Ferrrar & Lötter, 2007).

Table 4-2: Characterisation of the system associated with the study area

River	**Perdewater**	**Tributary of Perdewater**	**Skulpspruit**	**Tributary of Skulpspruit**	**Witbankspruit**	**Wolwespruit**	**Markgraafspruit**
River Order	1	1	2	1	1	1	1
Hydrological Class	-	Non-perennial	Perennial	Non-perennial	Perennial	Non-perennial	Perennial
River Signature				Highveld3			
Conservation status				Critically Endangered			
PES (Nel *et al.*, 2004)	**C**	**C**	**C**	**C**	**C**	**E-F**	**C**
Aquatic Ecoregion				Highveld			
Water Management Area				Upper Vaal			
Quaternary catchment	**C11E**	**C11E**	**C11E**	**C11E**	**C11J**	**C11L**	**C13B**
PES (DWAF, 2007)	**C**	**C**	**C**	**C**	**C**	**E-F***	**C**
EIS (DWAF, 2007)				**Moderate**			

PES: Present Ecological State; **EIS:** Ecological Importance and Sensitivity; * DWAF, 2000

Figure 4-6:Photographs taken during the screening/scoping survey: facing south towards the pan and channelled valley bottom system (A); facing north at the existing ash disposal facility on the 35 year ashing line (B); facing east toward a dam and the Majuba Power Station (C); and facing southeast at the tributary of the Witbankspruit.

Six attributes were used to obtain the Present Ecological State (PES) on desktop quaternary catchment level by the National Spatial Biodiversity Assessment (NSBA - Nel *et al*., 2004). These attributes predominantly refer to habitat integrity of instream and riparian habitat. The surrounding catchments are affected by agricultural activities, waste water treatment works, infrastructural development in the form of power stations and mines (refer to Section 4.1.3).

According to the NSBA (Nel *et al*., 2004) and DWAF (2007) with the exception of the Wolwespruit, all the associated systems fall in a C ecological category, indicating a moderately modified ecosystem state (Table 4-2). The Wolwespruit; however, classed in an E-F ecological category, indicating that this system is critically modified and is in an unacceptable state. The Ecological Importance and Sensitivity (EIS - DWAF, 2007) of all the associated catchments are considered moderately sensitive due to the expected presence of flow intolerant (*Labeobarbus aeneus* & *Labeobarbus kimberleyensis*) and unique / endemic

(*Labeo capensis & Austroglanis sclateri*) fish species, and the system's sensitivity to changes in flow and water quality.

The systems in the immediate area have "Highveld 3" river signatures, which Nel *et al.* (2004) assigns a status of critically endangered (Table 4-2). The ascribed river status indicates a limited amount of intact river systems carrying the same heterogeneity signatures nationally. This implies a severe loss in aquatic ecological functioning and aquatic diversity in similar river signatures on a national scale (Nel *et al.*, 2004).

4.1.3. Catchment Drivers of Ecological Change

The study area falls within the Upper Vaal Water Management Area (WMA) which includes the Vaal, Klip, Wilge, Liebenbergsvlei and Mooi Rivers. It covers a catchment area of 55 565 km^2 and includes the Vaal Dam, Grootdraai Dam and Sterkfontein Dam (DWAF, 2004). The Upper Vaal WMA is the most populous WMA in South Africa, with more than 80 % of the population residing in the area downstream of the Vaal Dam, and approximately 97 % living in an urban environment. Land use in the WMA is dominated by cultivated dry land agriculture with the main crops being maize and wheat. About 75 % of the irrigation is upstream of major storage dams and is supplied from rivers or farm dams (DWAF, 2004).

The majority of the water requirements of the WMA are for the urban, industrial and mining sectors (77 %), with 11 % for irrigation, 8 % for power generation and the remaining 4 % for rural water supplies. The Upper Vaal WMA is subdivided into three sub-areas, with the study area located in the "upstream of the Vaal Dam" sub-area. Geographically, over 73 % of the total requirements for water are in the sub-area "downstream of the Vaal Dam" and nearly 20 % in the sub-area "upstream of the Vaal Dam". Most of the irrigation in the WMA is in the sub-area "downstream of the Vaal Dam" (DWAF, 2004). The available water and total requirements for the year 2000, including transfers between WMAs is shown in Table 4-3.

Table 4-3: Reconciliation of requirements and available water for the year 2000 (million m^3/a) without yield of Mohale Dam (DWAF, 2004)

Sub-area	MAR	Local yield	Transfers in	Transfers out	Local requirement	Deficit
Wilge	868	59	0	0	60	**-1**
US of Vaal Dam	**1109**	**184**	**118**	**67**	**216**	**19**
DS of Vaal Dam	446	889	1224	1343	769	1

MAR: Natural Mean Annual Run-off; **US**: Upstream, **DS**: Downstream

The majority of the water requirements in the sub-area “upstream of Vaal Dam” are for mining and bulk industrial use, with a considerable portion allocated for urban use and power generation (DWAF, 2004). The expected future growth in the petro-chemical industry and the increasing need of power generation in the region are putting pressure on the water requirements of the sub-area at present.

4.2. Historical Water Quality

Historical water quality data was obtained from DWA water monitoring points located on the Perdewater and Skulpspruit (Figure 4-4):

- Upstream of the Majuba Power Station at DWA gauging station C11_90606 on the Perdewater, upstream of the confluence with the Skulpspruit.
- Downstream of the Majuba Power Station at DWA gauging station C11_177963, downstream of the Amersfoort Waste Water Treatment Works.

These monitoring stations provide minimum, maximum, median and 90th percentile values for the variables measured between the period of 1996 and 2007 (Table 4-4). The monitoring points are located Upstream (Perdewater – 90602) and downstream (Skulpspruit – 177963) of the study area. The monitoring point located on the Perdewater showed better water quality when compared to monitoring point located downstream on the Skulpspruit. Despite the pH values falling above CEV, the remainder of the values were within the TWQRs and benchmark criteria (DWAF, 1996; Kotze, 2002).

The Skulpspruit (downstream) reflected poor water quality with all the variables measured being considerably higher than the values obtained at the Perdewater weir (Table 4-4). Sodium, Cl, SO_4 and NH_4(N) values were all within the tolerable range while the electrical conductivity fell within the intolerable range (Kotze, 2002). The NO_3(N) and PO_4(P) values were considerably higher when compared to Perdewater, indicating severe organic enrichment, most likely as a result of effluent from the Amersfoort Waste Water Treatment Works.

Table 4-4: DWA 90th percentile water quality values for monitoring stations located on the Perdewater and Skulpsruit systems

Variable	Abb	Unit	C11_90602				C11_177963			
			Perdewater				Skulpspruit			
			Min Max	90th percentile	Median	n	Min Max	90th percentile	Median	n
Position in relation to the Majuba Power Station			Upstream				Downstream			
Flow		m^3s	4.1 0	**3.0**	0	n=6604	**No data**			
pH		H^1+ ions	9.73 6.85	**8.74**	7.88	n=90	8.8 6.4	**7.9**	7.5	n=61
Electrical Conductivity	EC	$mS\text{-}m^{-1}$	29.5 7.8	**13.3**	11.51	6.4	137 35	**115**	97	n=61
Total Dissolved Solids	TDS	ppm	223 56.88	**94.24**	85.0	n=88	**No data**			
Calcium	Ca	mg/l	33.03 5.759	**12.6**	8.16	n=90	60.3 13.4	**44.22**	28.2	n=39
Magnesium	Mg	mg/l	13.06 0.75	**5.53**	4.6	n=90	42.8 4.6	**32.97**	18.3	n=39
Potassium	K	mg/l	3.12 0.592	**1.73**	1.24	n=89	26.1 25.7	**26.02**	25.9	n=2
Sodium	Na	mg/l	13.79 1.0	**6.03**	5.2	n=89	110 9.8	**83.74**	62.3	n=23
TAlkilinity	Tal	mg/l	120.0 23.85	**45.3**	40.53	n=90	494 141	**423**	318	n=2
Chloride	Cl	mg/l	10.52 2.0	**6.65**	5.0	n=90	101 15.0	**84.6**	63.5	n=52
Fluoride	F	mg/l	0.23 0.05	**0.18**	0.13	n=88	0.6 0.05	**0.4**	0.2	n=34
Silica	Si	mg/l	11.06 0.57	**6.16**	5.18	n=90	**No data**			
Sulphate	SO_4	mg/l	44.6 2.0	**14.4**	10.9	n=90	130.0 29.0	**98**	67	n=40
Ammonium	NH_4(N)	mg/l	0.1 0.015	**0.06**	0.02	n=90	75.0 0.05	**58.56**	36.2	n=61
Nitrate	NO_3(N)	mg/l	1.14 0.005	**0.29**	0.2	n=90	31.2 0.05	**18.87**	0.3	n=61
Phosphate	PO_4(P)	mg/l	0.1 0.003	**0.03**	0.02	n=	17.4 0.05	**14.5**	8.6	n=60

4.3. Expected Freshwater Diversity and Species of Conservation Concern

4.3.1. Expected Macroinvertebrate Species

A list of macroinvertebrates expected to occur in the study area or indicating the possibility of occurrence was determined for the major drainage lines (Table 4-5; Figure 4-7). Each taxon was allocated a rating score of either 1, 3 or 5: a rating of 5 indicates that the specific taxon has been sampled within that sub-quaternary (SQ) reach and is likely to be sampled; a rating of 3 indicates that the taxon has not been sampled in the SQ reach but has been sampled in a similar SQ reach and the probability of occurrence has been extrapolated; a rating of 1 indicates that the taxon has not been sampled in the SQ reach or any other similar SQ reach but is thought to be potentially present taking into account the available habitat, water quality and associated land use activities. The majority of expected macroinvertebrates are of low to moderate sensitivity, scoring between 3 and 8 (Gerber & Gabriel, 2002). A total of five relatively sensitive taxa are expected to occur within the study area, namely Heptageniidae, Athericidae, Dixidae, Leptophlebiidae and Tricorythidae. Sensitivity scores of these taxa ranged between 9 and 13 (Gerber & Gabriel, 2002) representing taxa that are moderately to highly intolerant to alterations in water quality (pollution).

Table 4-5: Macroinvertebrate species expected to occur, or indicating the possibility of occurrence, in the different sub-quaternary reaches located within the study area. Taxa in red are considered sensitive taxa

ID		A	B	C	D	E	F	G	H
	SS	Perdewater	Tributary of the Perdewater	-	Skulpspruit	Tributary of the Skulpspruit	Witbankspruit	Wolwespruit	Markgraaffspruit
Porifera	**5**				5				
Turbellaria	**3**	1	1	1	5	1	1	1	1
Oligochaeta	**1**	1	1	1	5	1	1	1	1
Hirudinea	**3**	1	1	1	1	1	1	1	1
Potamonautidae	**3**	1	1	1	5	1	1	1	1
Atyidae	**8**	1	1	1	5	1	1	1	1
Hydracarina	**8**	1	1	1	5	1	1	1	1
Baetidae > 2 Sp	**12**	1	1	1	5	1	1	1	1
Caenidae	**6**	1	1	1	5	1	1	1	1
Heptageniidae	**13**							**1**	
Leptophlebiidae	**9**	1	1	1	5	1	1	1	1
Tricorythidae	**9**				5				
Coenagrionidae	**4**	1	1	1	5	1	1	1	1
Lestidae	**8**				5				
Aeshnidae	**8**	1	1	1	1	1	1	1	1
Gomphidae	**6**	1	1	1	5	1	1	1	1
Libellulidae	**4**	1	1	1	5	1	1	1	1
Belostomatidae	**3**	1	1	1	1	1	1	1	1
Corixidae	**3**	1	1	1	5	1	1	1	1
Gerridae	**5**	1	1	1	1	1	1	1	1
Hydrometridae	**6**	1	1	1	1	1	1	1	1
Naucoridae	**7**	1	1	1	1	1	1	1	1
Nepidae	**3**	1	1	1	1	1	1	1	1

ID		A	B	C	D	E	F	G	H
	SS	**Perdewater**	**Tributary of the Perdewater**	**-**	**Skulpspruit**	**Tributary of the Skulpspruit**	**Witbankspruit**	**Wolwespruit**	**Markgraaffspruit**
Notonectidae	**3**	1	1	1	5	1	1	1	1
Pleidae	**4**	1	1	1	1	1	1	1	1
Veliidae/Mesoveliidae	**5**	1	1	1	5	1	1	1	1
Ecnomidae	**8**								1
Hydropsychidae 1 Sp	**4**	1	1	1		1	1	1	1
Hydropsychidae > 2 Sp	**12**				5				
Hydroptilidae	**6**	1	1	1	1	1	1	1	1
Leptoceridae	**6**	1	1	1	1	1	1	1	1
Dytiscidae	**5**	1	1	1	5	1	1	1	1
Elmidae/Dryopidae	**8**	1	1	1	1	1	1	1	
Gyrinidae	**5**	1	1	1	5	1	1	1	1
Haliplidae	**5**				5				
Hydraenidae	**8**				5				
Hydrophilidae	**5**	1	1	1	5	1	1	1	1
Athericidae	**10**								1
Ceratopogonidae	**5**	1	1	1	5	1	1	1	1
Chironomidae	**2**	1	1	1	5	1	1	1	1
Culicidae	**1**	1	1	1	1	1	1	1	1
Dixidae	**10**								1
Muscidae	**1**	1	1	1	1	1	1	1	1
Simuliidae	**5**	1	1	1	5	1	1	1	1
Tabanidae	**5**	1	1	1	1	1	1	1	1
Tipulidae	**5**								1
Ancylidae	**6**	1	1	1	5	1	1	1	1
Lymnaeidae	**3**								1

ID		A	B	C	D	E	F	G	H
	SS	**Perdewater**	**Tributary of the Perdewater**	**-**	**Skulpspruit**	**Tributary of the Skulpspruit**	**Witbankspruit**	**Wolwespruit**	**Markgraaffspruit**
Physidae	**3**	1	1	1	1	1	1	1	1
Planorbinae	**3**	1	1	1	1	1	1	1	1
Corbiculidae	**5**	1	1	1	5	1	1	1	1
Sphaeriidae	**3**	1	1	1	1	1	1	1	1

SS = Sensitivity Score (Dickens & Graham, 2001)

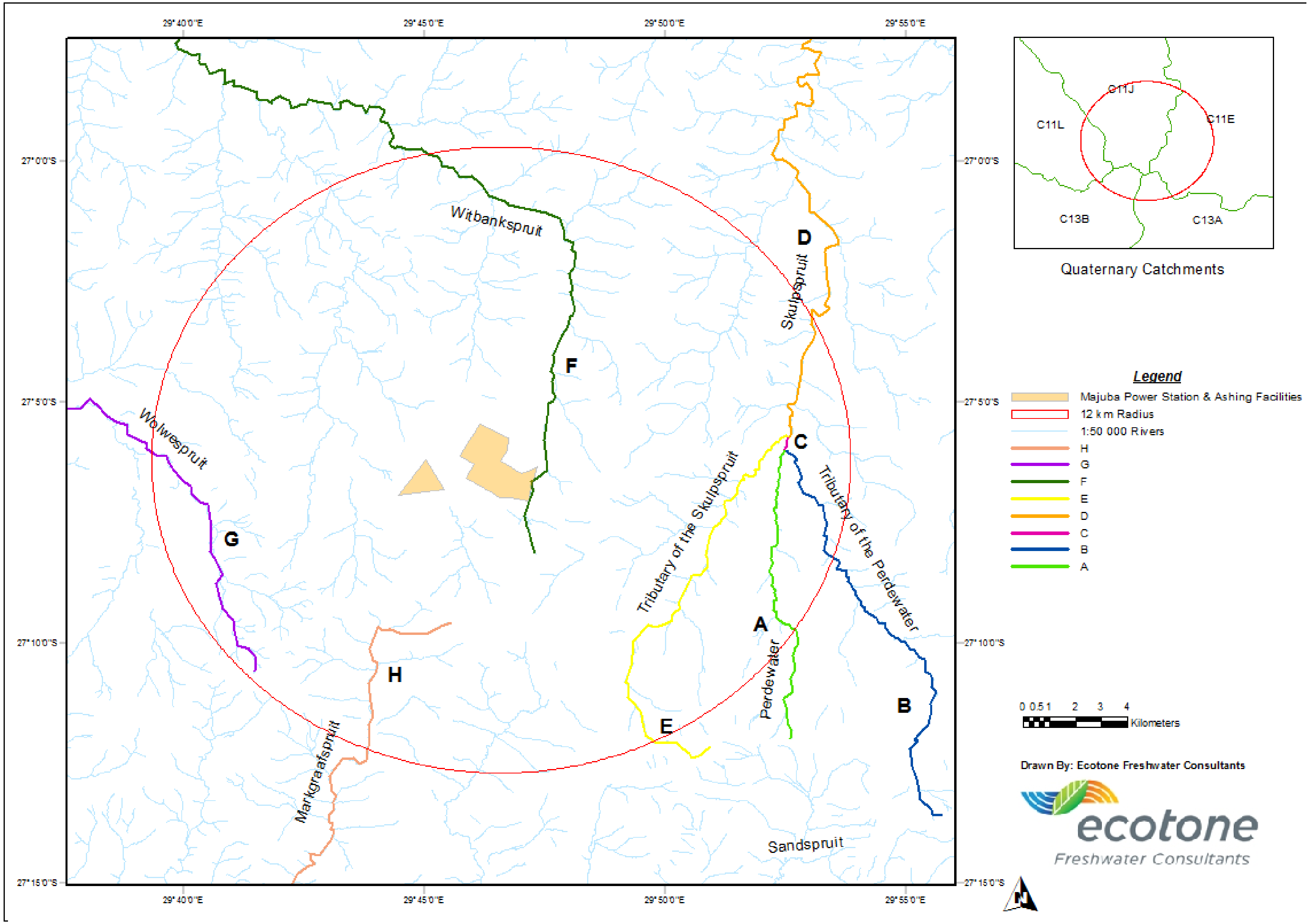

Figure 4-7: Sub-quaternary catchments related to the expected macroinvertebrate species lists (Chief Directorate – Surveys and Mapping, 2629 and 2729; *Pers. Comm.* Mrs. Christa Thirion, 2012).

4.3.2. Expected Fish Species

A summary of the expected fish families, species and IUCN conservation status is provided in Table 4-6. The area of study provides potential refuge for four fish families represented by approximately 12 species, none of which have conservation status and are listed as Least Concern (LC) by the IUCN (2012). *Barbus neefi* and *Barbus pallidus* are expected to occur in the study area (IUCN, 2012) and both species are moderately intolerant to alterations in water quality making them good indicators of ecosystem health.

Table 4-6: Fish species expected to occur, or indicating the possibility of occurrence, in the river systems associated with the study area

Family	Genus and Species	Common Name	IUCN Status
Austroglanididae	*Austroglanis sclateri*	Rock Catfish	LC
Clariidae	*Clarias gariepinus*	Sharptooth Catfish	LC
Cyprinidae	*Barbus anoplus*	Chubbyhead Barb	LC
Cyprinidae	*Barbus neefi*	Sidespot Barb	LC
Cyprinidae	*Barbus pallidus*	Goldie Barb	LC
Cyprinidae	*Barbus paludinosus*	Straightfin Barb	LC
Cyprinidae	*Cyprinus carpio*	Common Carp	EX
Cyprinidae	*Labeobarbus aeneus*	Smallmouth Yellowfish	LC
Cyprinidae	*Labeo capensis*	Orange River Labeo	LC
Cyprinidae	*Labeo umbratus*	Moggel	LC
Cichlidae	*Pseudocrenilabrus philander*	Southern Mouthbrooder	LC
Cichlidae	*Tilapia sparrmanii*	Banded Tilapia	LC

LC: Least Concern; **EX**: Exotic

4.3.3. Expected Odonata (dragonflies) Species

Approximately 58 Odonata species are expected to occur in the 12 km radius from Majuba Power Station. All of the 58 species are listed as LC according to the IUCN database (IUCN, 2012).

4.3.4. Expected Mollusca (snails, limpets) Species

A total of 10 mollusc species are expected to occur in the study area, of which 9 species are listed as LC. Only one species, namely *Burnupia caffra,* is listed as Data Deficient (DD) due to taxonomic uncertainty. *Burnupia caffra* are frequently unobserved during sampling surveys due to their extremely small size (2 - 4 mm). The genus *Burnupia* needs taxonomic revision as the numbers of species are extremely uncertain (Appleton *et al.*, 2010).

5. Sensitivity Analysis

The rationale applied with the aquatic sensitivity assessment is based on the premise that all watercourses or potential watercourse areas are sensitive. The catchment size, slope and position in the landscape predominantly determine the potential for water accumulation. Once accumulated other factors such as underlying geology and soil permeability also contribute towards the nature of particular wetness expressed. For the purpose of this assessment a Wetness Index was applied and superimposed by existing drainage lines and wetland areas. The result of the Wetness Index was consistent with known drainage lines and wetland areas and the application thereof is thus deemed suitable.

The SAGA Wetness Index, which is based on a modified catchment area calculation, is similar to the Topographic Wetness Index (TWI). The modified catchment area does not consider flow as very thin film and predicts raster cells situated in valley floors with a small vertical distance to a channel, a more realistic, higher potential soil moisture compared to the standard TWI calculation (Boehner *et al.,* 2002).

The Wetness Index highlights areas with a propensity for water to accumulate within the study area, thereby indicating areas of low, moderate and high sensitivity from a soil water or possible wetland perspective (Figure 5-1). Areas highlighted in red have a high sensitivity and should be excluded during the planning of the proposed Majuba ash disposal facility. The construction and operational phase activities may result in potential alterations/impacts to the ecological integrity of the receiving aquatic ecosystems. The impacts related to the proposed activities are discussed in Section 6. Areas highlighted in orange are deemed moderately sensitive. If expansion activities infringe on these areas, suitable mitigation measures are pertinent to limit the impacts on the receiving aquatic environment. The integrity and functioning of watercourses is directly dependant on their surrounding land area (Dodds & Oaks, 2008). Areas of low sensitivity are highlighted in green and will potentially have the least impact on the rivers/streams and wetlands located in the study area (Figure 5-1). The field verification that will be carried out during the EIA phase will provide additional information regarding the suitability of the identified low sensitivity areas.

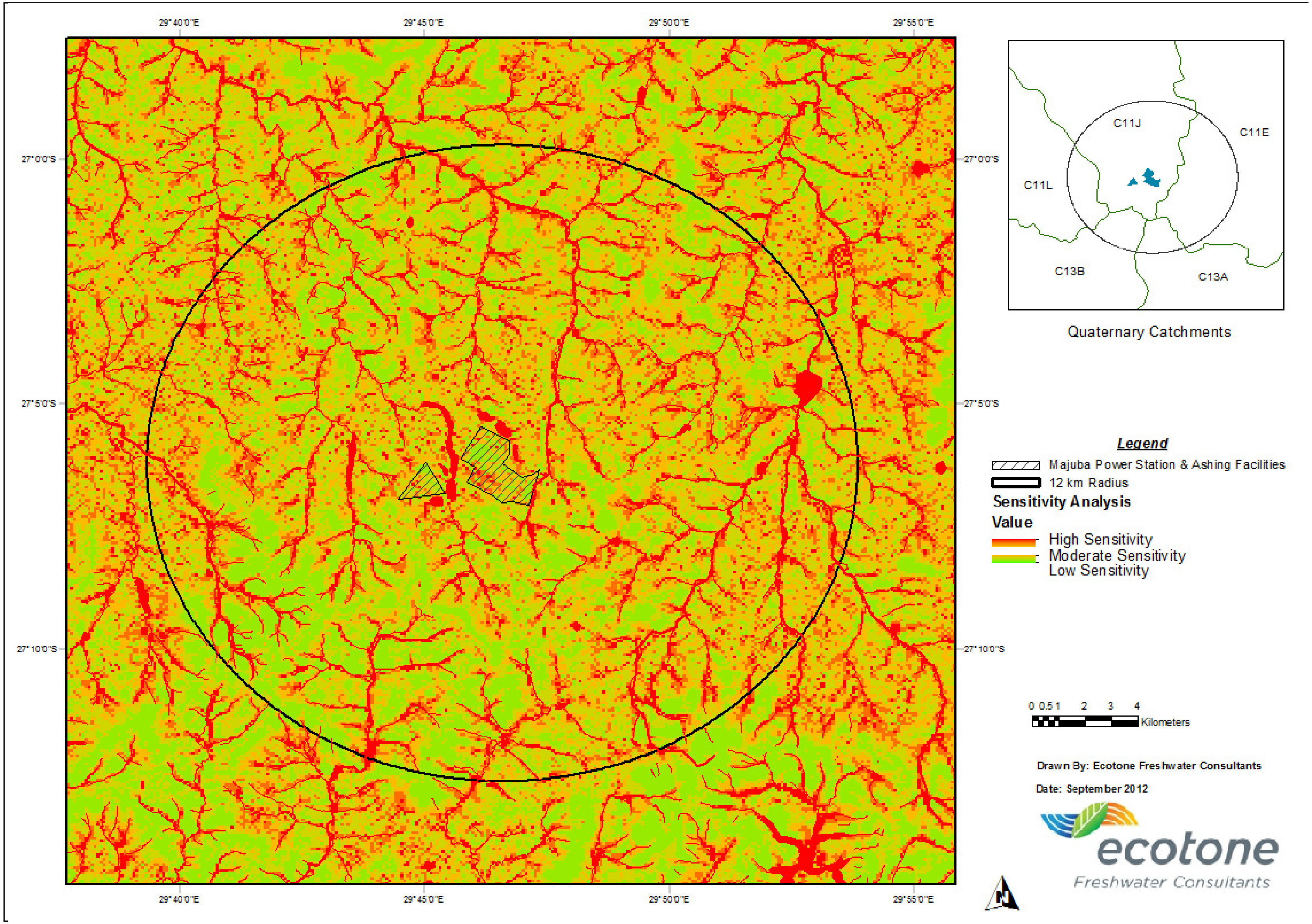

Figure 5-1: Sensitivity analysis of the 12 km associated with the proposed Majuba ash disposal facility.

6. Potential Impacts Identified

Impacts on the aquatic ecology may be summarised under three main drivers: (1) alteration to surface water quality, (2) alteration to hydrology, and (3) alteration in geomorphology. Changes to any of the abiotic drivers, due to activities related to the proposed ash disposal facility, will elicit biological responses in the receiving aquatic communities. The potential impacts identified consider five main impacts which are listed and discussed below:

1. Impacts on surface water quality;
2. Impacts on hydrology;
3. Impacts related to erosion and sedimentation;
4. Impacts on aquatic biota; and
5. Impacts on aquatic ecosystem services.

6.1. Impacts on Surface Water

6.1.1. Heavy Metal Contamination

The contents of coal ash may vary depending on where the coal was mined and the ash may potentially contain toxic metals, which include arsenic, lead, mercury, cadmium, chromium and selenium (Gottlieb *et al.*, 2010). These contaminants may enter the receiving environment via leachate from ash disposal facilities and the leaching rate may be affected by a number of factors, namely:

- the size and depth of the disposal ponds, and the pressure created by the waste;
- the underlying geology;
- the slope of the landscape; and
- the most vital factor being whether the disposal site is lined (Gottlieb *et al.*, 2010).

6.1.2. Increases in Sediment Loads and Turbidity

The implication of increased sediment loads may directly or indirectly be the result of construction and/or operational activities for the proposed ash disposal facility. Ash may become airborne and find its way into the aquatic ecosystems in the area, changing the pH of the water and smothering the substrate. Even though the increase in sediment loads will impact on water quality, it will also result in changes in the in-stream and riparian habitat templates. Increased sediment loads act as an abiotic driver that alters water quality and aquatic habitat. Increased turbidity, total suspended solids and siltation in the aquatic ecosystem, stemming from the increased sediment deposition due to construction activities is considered an issue.

6.1.3. Toxicants

Construction material, hydrocarbons (oil, diesel, etc.), solvents and other pollutants spilling/leaking from construction machinery and equipment during the construction phase may have a severe impact on the receiving aquatic environment.

6.2. Impacts on Hydrology

The proposed ash disposal facility will result in the loss of the MAR associated with the surface area of the area to be covered by the ash disposal facility and associated infrastructure. Subsequently, the seasonal hydrological patterns in associated streams and rivers will be disrupted. Changing the hydrology of a river or stream also results in other environmental problems, and is usually accompanied by increased rates of erosion, decreased substrate diversity, channel incision and uniform velocity-depth classes (Rosgen, 1993; Simon & Thorne, 1996; Rosgen 1996; Johnson, 2006).

6.2.1. Altering Environmental Flows

In a study carried out by Lloyd *et al.* (2004) ecological responses to flow modifications in rivers were examined, where 86 % of the studies recorded ecological changes in community structure. In a similar study by Poff & Zimmerman (2010) 92 % of the studies examined had reported negative ecological changes in response to a range of different types of flow alterations. In addition, fish consistently responded negatively to changes in flow, irrespective of whether the magnitude of the flow increased or decreased (Poff & Zimmerman, 2010).

6.2.2. Alterations in Base Flows

The hydrological regime associated with the rivers/streams in the study area are characterised by peak flows during the summer months and lower base flows during the winter months. The continuous ashing at Majuba Power Station may possibly result in lowered base flows in the receiving systems due to the loss of the catchment area. Base flow is important as it defines habitat availability.

6.3. Impacts Related to Erosion and Sedimentation

Changes in the rates of erosion and sedimentation are often associated with changes in land use. Typical sources of sediment during the construction phase are in-stream activities, stockpiles, excavation and clearing of vegetation. Changes to erosion and sedimentation rates, during the operational phase, are more related to alteration in hydrology. Increased turbidity and sedimentation resulting from erosion have several adverse effects on the aquatic environment. Sedimentation will alter the water quality (increased turbidity) and substrate composition of the receiving aquatic environments, as well as the marginal habitats due to excessive reed growth and alien vegetation encroachment as a result of the deposited sediment.

6.3.1. Increases in Turbidity

Suspended sediment will result in an increase in turbidity. This, in turn, will result in a decrease in primary production, increased bacterial activity and a decrease in oxygen saturation. Fine sediment suspended within the water column can potentially reduce the rate of photosynthesis; affect macroinvertebrate community structures; decrease the feeding efficiency and growth rates of fish populations and increase the incidence of disease (CMA, 2008). Studies have shown that an increase in turbidity impedes fish reproduction, particularly where breeding requires visual mate recognition and visual stimuli for breeding behaviour (Bash *et al.,* 2001; Zeynep, 2007). Similarly, some predators require clear water for hunting and might be adversely affected by decreased visibility due to increased turbidity. This might have a significant impact on aquatic ecology, as changes in predation pressure will alter aquatic communities.

6.3.2. Decreases in Habitat Diversity

Any sediment that is more than the natural sediment transport capacity of a watercourse will be deposited; this depositing process is called sedimentation and might smother more suitable habitat structures, such as woody debris or cobble sections. A loss in habitat diversity, due to sedimentation, will inevitably translate into a loss of aquatic organisms with specific habitat requirements. Conversely high-velocity water, from discharge structures or flood water management systems, may scour natural substrates downstream of receiving watercourses, degrading habitat for fish and other wildlife.

6.4. Impacts on Aquatic Biota

Aquatic biota consist of in-stream communities (periphyton, macrophytes, invertebrates and fish) and riparian and wetland communities. Impacts on aquatic biota may manifest in a number of different ways, but will nearly always be the result of alteration in natural hydrology, water quality or geomorphology. Some exceptions are alien introduction, as well as direct removal of riparian- and wetland vegetation (Dudgeon *et al.,* 2006).

6.4.1. Decreases in Habitat Diversity and Habitat Fragmentation

The direct loss of river and wetland areas through clearing of riparian and wetland habitat will result in a complete, but localised, loss of aquatic habitat. Aquatic habitat fragmentation may be the result of chemical (water quality) or physical (hydrology, erosion and sedimentation) migration barriers. Any of the impacts listed under water quality (Section 6.1), hydrology

(Section 6.2) and erosion and sediment (Section 6.3) might result or contribute to habitat fragmentation.

6.4.2. Alterations in Aquatic Community Structure

The alteration in aquatic community structures might directly be attributed to changes in water quality, quantity and timing, or indirectly, due to changes in habitat availability. Changes in community structures are typically characterised by a decrease in diversity and higher abundances of more tolerant species. Specialised species (like rheophilic fish and niche feeders) are the first to respond negatively to changes in the aquatic environment.

6.4.3. Acute and Chronic Toxicity

Hazardous and toxic compounds might enter surface water systems at acute toxicity concentrations. This impact might present itself during construction and operational phases. The prolonged exposure of aquatic biota to sub lethal contaminants that may find their way into surface water systems might result in chronic toxicity and may manifest itself through a number of different ways i.e. carcinogenic, mutagenic and teratogenic effects on exposed communities.

6.4.4. Alien Encroachment and Infestation

In places where wetland and riparian habitats may be removed, opportunistic alien pioneers might encroach. Alien vegetation increases biomass, fire intensity and evapo-transpiration, decreases river flows, surface water run-off and groundwater recharge (Görgens & Van Wilgen, 2004; Chamier *et al*., 2012).

6.4.5. Removal of Riparian and Wetland Vegetation

Riparian and wetland vegetation provides cover, breeding habitat and migration corridors for wildlife, serves to trap sediment and fine silt, and helps with energy dissipation during flood events (Levick *et al.,* 2008; Howe *et al.,* 2008). The proposed activities, particularly during the construction phase, will impact on riparian and wetland vegetation. Disturbances of the riparian and wetland areas will lead to a decrease in ecosystem services and will also lead to the possible establishment of alien vegetation. In addition, the removal of riparian vegetation may increase the amount of sediment entering the system. Vegetation removal may lead to some specific issues, which are:

- Compaction of soils;
- Dispersal of exotic plant species;
- Decrease water infiltration, resulting in increased flow volumes and peak run-off rates;
- Acceleration of erosion rates; and

- Solar radiation could result in an increase in water temperature, thus affecting primary production (Kleynhans *et al.,* 2007b).

6.4.6. Species with Conservation Status

A few species with conservation status may potentially occur in the study area. According to South African Bird Atlas Project 2, the Blue Crane has been recorded in the PENTAD grid squares associated with the study area and may potentially breed in wetland areas:

- Blue Cranes (*Anthropoides paradiseus*) are listed as Vulnerable according to the IUCN database (IUCN, 2012). *A. paradiseus* breeds in natural grass- and sedge-dominated habitat and may infrequently breed near or within wetland areas (Barnes 2000).

Additional species that may potentially occur within the rivers and wetlands associated with the study area (Cook, 2011) include:

- Giant Bullfrogs (*Pyxicephalus adspersus*) are Near Threaded (NT) in South Africa (Minter *et al*. 2004) due to anthropogenic activities resulting in habitat loss.
- Grey Crowned Cranes (*Balearica regulorum*) are listed as Endangered according to the IUCN database (IUCN, 2012) and inhabit wetlands (Hockey *et al.,* 2005), riverbanks (Meine & Archibald, 1996), shallowly flooded plains (Urban *et al.,* 1986) and temporary pools (del Hoyo *et al.,* 1996).
- Wattled Cranes (*Bugeranus carunculatus*) are listed as Vulnerable according to the IUCN database (IUCN, 2012). In South Africa *B. carunculatus* breed on undisturbed permanent wetlands (small) that are surrounded by grassland (Hockey *et al*. 2005) where disturbance from humans are minimal (Archibald & Meine, 1996). They may opportunistically breed on ephemeral/seasonal wetlands which may also be used essential post-breeding dispersal areas (Archibald & Meine, 1996).

No fish with conservation status are expected to occur in the study area, however, *B. neefi* and *B. pallidus are* moderately intolerant to alterations in water quality and are expected to occur in the study area (Refer to Section4.3.2). In addition, macroinvertebrates with a low tolerance to alterations in water quality may potentially occur in the study area (Refer to Section 4.3.1).

6.5. Impacts on Aquatic Ecosystem Functions and Services

The degree to which impacts, discussed in previous sections, will influence aquatic ecosystem functions and services will depend on the nature of the impact and the nature of the receiving watercourse (i.e. the ability to provide a particular service, which is different for lakes, wetlands and streams) (Kotze *et al*., 2009). Some services are indirectly beneficial to local society and pertain to sustaining ecological functionality, such as flood and erosion control, water purification, biodiversity and carbon storage.

The proposed Majuba ash disposal facility may result in the alteration or destruction of aquatic habitat and subsequent loss of associated functions, which include flood attenuation; stream flow augmentation; enhancement of water quality and biodiversity. Wetland functions associated with each hydro-geomorphic (HGM) type is summarised in Table 6-1. The different HGM types associated with the study area will be determined during the EIA phase.

Table 6-1: Preliminary ratings of the hydrological benefits likely to be provided by wetlands (Kotze *et al.,* 2009)

Wetland HGM	Regulatory Benefits Potentially Provided by the Wetland							
	Flood Attenuation		Stream flow regulation	Enhancement of Water Quality				
	Early wet season	Late wet season		Erosion control	Sediment trapping	Phosphates	Nitrates	Toxicants
Floodplains	++	+	0	++	++	++	+	+
Valley-bottom: Channelled	+	0	0	++	+	+	+	+
Valley-bottom: Un-channelled	+	+	+	++	++	+	+	++
Hillslope seep: Connected to a stream channel	+	0	+	++	0	0	++	++
Hillslope seep: Connected to a stream channel	+	0	0	++	0	0	++	+
Pan / depression	+	+	0	0	0	0	+	+

Rating: 0 Benefit unlikely to be provided to any significant extent; + Benefit likely to be present at least to some degree; ++ Benefit very likely to be present (and often supplied to a high level)

The sections below provide a general overview of the available and indirect aquatic ecosystem services:

6.5.1. Flood Attenuation

Floodplain systems provide an important service related to flood attenuation. The importance of the service is a function of the size and location of the floodplain in its catchment. Valley bottom wetlands, reflecting seasonal variation in wetness might also play a role in flood attenuation, particularly during the early wet season before their seasonal zones become saturated. Flood attenuation services might be impaired or lost through canalisation or any other activity that will inhibit the ability of the watercourse to retain and slowly release flood water.

6.5.2. Stream Flow Regulation

In seasonal streams and rivers, surrounding wetlands play an important role in stream flow regulation. The ability of surface water systems, and particularly wetlands, to provide a stream flow regulation service might be inhibited or lost through any activity that will decrease surface roughness (loss of vegetation cover or soil compaction), increase impermeable surfaces or any other activity that will influence the permeability and soil-resident time of surface water run-off.

6.5.3. Enhancement of Water Quality

This service is mostly limited to wetland systems, where surface water is exposed to a number of purification processes like reduction, adsorption, mineralisation and ion exchange. Natural water purification processes typically require low energy environments with sufficient surface area for adsorption and carbon for reduction. Activities that result in a change in energy of a particular system (i.e. channelisation or entrenchment caused by erosion) will inhibit this ecosystem service.

6.5.4. Erosion Control

River ecosystems may provide the function of the retention of soil within the ecosystem, thereby preventing the loss of soil by means of the riparian vegetation cover and soil retention (Costanza *et al.,* 1997).

6.5.5. Refugia

River and wetlands associated with the study area may provide different micro habitat types, cover units, flows and depths, and thus may potentially house different fish and invertebrates with different habitat preferences. Wetland and riparian vegetation is adapted to tolerate reducing environments and play an important role in providing habitat for other aquatic species.

6.5.6. Maintaining Longitudinal and Lateral Connectivity

Rivers and their associated riparian zones provide migratory connectivity for both aquatic and terrestrial species and thereby maintain both aquatic and terrestrial biodiversity (Costanza *et al.,* 1997).

7. Plan of study for the EIA phase

An aquatic ecology survey will be undertaken to ascertain the PES and EIS of the rivers and wetlands located in the study area and relevant potential alternatives. The aquatic ecology assessment will be in line with national and provincial minimum requirements. The Scope of Work that will be encompassed to reach the objective is summarised and outlined below and the following information will be generated in the form of a detailed freshwater ecology report.

7.1. Rivers

Approximately six aquatic biomonitoring sites will be strategically chosen and biomonitoring methodology applied to ascertain the PES of the associated systems. This assessment will involve the characterisation of the aquatic environment and related biota, as well as the generation of PES data with the use of the following response and driver metrics:

Response metrics:

- Aquatic macroinvertebrate assessment - using the South African Scoring System version 5 or SASS 5 (Dickens & Graham, 2002). In addition, the percentage of Ephemeroptera-Plecoptera-Trichoptera taxa (%EPT) will be determined.
- Fish community assessment – using the Fish Response Assessment Index (FRAI - Kleynhans, 2007).
- Riparian vegetation assessment – using the Riparian Vegetation Response Assessment Index (VEGRAI - Kleynhans *et al*., 2007b).
- Diatom community assessment - collection according to Taylor *et al.* (2005) and analysis according to Lecointe *et al.* (1993).

Drivers:

- Habitat assessment – Invertebrate Habitat Assessment System (IHAS - McMillan, 1998) and Index of Habitat Integrity (IHI - Kleynhans, 1996).
- Water quality analysis - selected *in situ* variables (at all biomonitoring sites). These variables will include pH, conductivity, total dissolved solids, oxygen saturation and concentration.

7.2. Wetlands

- The study area will be divided into two parts; (1) the areas encompassed by the boundaries of the two alternatives identified (primary study area) and (2) a secondary area consisting of a 500 m buffer.

- Wetland delineation and mapping (1:10 000) of wetlands associated with two alternatives identified during the scoping assessment, using DWAF (2005) methodology. The delineation of wetlands within the primary study area will be verified during the field assessment. The delineation of wetlands within the secondary study area will be on desktop level.
- Generation of PES and EIS data for the wetlands using Wet-EcoServices (Kotze *et al*., 2009) and Wet-Health (MacFarlane *et al*., 2009). A level two assessment will be done for wetlands within the primary study area and a level 1 assessment will be done for wetlands within the secondary study area.
- Identification of current impacts, including point and non-point source impacts.

7.3. Deliverables

- An analysis of habitat biotopes, diatom-, macroinvertebrate- and fish community structures and *in situ* water quality.
- An analysis of the PES and EIS of relevant wetlands.
- A wetland delineation and application of relevant buffer zones to delineated wetlands. Wetland verification will only be carried out on wetlands associated with the recommended site alternatives.
- A detailed report on the status of the surface water ecology and wetlands.
- Identification of current impacts on rivers and wetland systems, including point and non-point source impacts.
- An impact assessment with regards to impacts of the proposed Majuba ash disposal facility on the surrounding aquatic ecosystems.
- Recommend site alternatives.

7.4. Limitations/Assumptions

The following limitations and assumptions apply to the aquatic component of the study:

- The aquatic survey can only be carried out if sufficient rainfall has triggered a sufficient flow. Flow is essential for the river biomonitoring to be carried out.
- The study does not include quantitative data related to population dynamics of the aquatic biota.
- Wetland verification will only be carried out on wetlands associated with alternatives identified during the scoping assessment.
- The wetland study will be carried out on a 1:10 000 scale.

8. Conclusion

The study area falls in the “upstream of Vaal Dam” sub-area of the Upper Vaal WMA, where mining, industry, agriculture, residential areas and power generation are the main catchment drivers of ecological change. The ecological integrity associated with the study area is in a moderately modified PES, with a moderate EIS. The Wolwespruit; however, classed in an E-F ecological category according to desktop information, indicating that this system is critically modified and in an unacceptable state. The proposed ash disposal facility will potentially contribute to ecological change in the study area, of which include: changes in surface water quality, hydrology, erosion, sedimentation, and aquatic community structures. The study area appears to compose of numerous and diverse hydro-geomorphic units, which may potentially provide a number of ecological services and functions, including providing potential refugia for wetland dependent red data species. The proposed ash disposal facility may result in the alteration or destruction of aquatic habitat and subsequent loss of associated functions, such as flood attenuation, stream flow augmentation, enhancement of water quality and biodiversity.

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