APPENDIX K:
FRESHWATER ECOLOGY REPORT

AQUATIC ECOLOGICAL ASSESSMENT AS PART OF THE WATER USE LICENSE AUTHORISATION PROCESS FOR THE ESKOM UCG PROJECT

Prepared for

Royal Haskoning DHV

2014

Report authors **Leandra Jonker**
S. van Staden (Pr. Sci. Nat)
Earl Herdien (Pr Sci Nat)

Report Reference: **SAS 214095**
Date: **April 2014**

SAS CC
CC Reg No 2003/078943/23
Vat Reg. No. 4020235273
91 Geldenhuis Rd
Malvern East, Ext 1

Tel: 011 616 7893
Fax: 086 724 3132
E-mail: admin@sasenvironmental.co.za

FINAL REPORT

Declaration of Independence

This report has been prepared according to the requirements of Section 32 (3b) of the Environmental Impact Assessments Regulations, 2010 (GNR 543). We (the undersigned) declare the findings of this report free from influence or prejudice.

Report Authors:

Stephen van Staden *Pr Sci Nat* (Ecological Sciences) 400134/05
BSc. Hons (Aquatic Health) (RAU);
M.Sc. Environmental Management (RAU).

Field of expertise:
Wetland, aquatic and terrestrial ecology.

_____ Date: 2014/04/30

Stephen van Staden

EXECUTIVE SUMMARY

Scientific Aquatic Services (SAS) and Royal HaskoningDHV (RHDHV) were appointed by Eskom UCG to undertake a Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) analysis of the aquatic and riparian resources as part of the environmental assessment and authorisation process for the Eskom Underground Coal Gasification (UCG) Project's required water use licenses. The project area identified for UCG is located opposite the Majuba Power Station, Amersfoort, Mpumalanga (hereafter referred to as "the proposed project"). The proposed project forms part of a feasibility implementation pilot project with the goal of determining the commercial viability of using UCG as a primary source of fuel to generate electricity.

The following summarizes the results of the aquatic assessment of the Geelklipspruit:

Biota specific water quality

- The EC value between the two sites decreases by 72.2%. The decrease in a downstream direction is seen as an improvement in the water quality.
- The decrease in EC in a downstream direction indicates that no contribution of salts as a result of the Eskom Majuba Plant is likely to be taking place at the current time.
- The pH at GK1 and GK2 may be considered to be largely natural with a 4.0% decrease between the upper and lower sampling points. This change falls within the DWA TWQR (DWAF, 1996) which advocates no change greater than 5% from reference or temporal data. Close monitoring of this trend should however need to continue.
- The dissolved oxygen content at the GK2 site exceeded the 80% saturation while the dissolved oxygen content at the GK1 site falls below the DWA TQWR (DWAF, 1996). The upstream GK1 site is likely to limit the sensitivity and diversity of the aquatic communities present at this point in the system;
- The observed spatial variation in temperature can be ascribed to natural and diurnal variations between sampling times as well as the nature of the stream at each point.

Habitat Assessment

- From the results of the application of the IHIA to the GK1 assessment site, it is evident that there are some impacts at the present time.
- Instream impacts included a large impact from flow modifications, water quality, inundation as well as moderate bed modifications. Overall, the site achieved a 67.8% score for instream integrity.
- The largest riparian zone impacts include exotic vegetation encroachment, bank erosion, water quality and inundation. The site achieved a 71.7% score for riparian zone integrity.
- The site obtained an overall IHIA rating of 69.7%, which indicates moderately modified (Class C conditions). The site, therefore, falls within the DEMC for the quaternary catchment in terms of habitat integrity.
- From the results of the application of the IHIA to the GK2 assessment site, it was observed that instream impacts included a moderate impact from water abstraction, flow modifications, water quality and inundation. Overall, the site achieved a 69.9% score for instream integrity.
- The largest riparian zone impacts include exotic vegetation encroachment, vegetation removal and inundation. The site achieved a 73.6% score for riparian zone integrity.
- The site obtained an overall IHIA rating of 71.7%, which indicates moderately modified (Class C conditions). The site, therefore, falls within the DEMC for the quaternary catchment in terms of habitat integrity.
- Habitat structure and diversity was inadequate for supporting a diverse aquatic macro-invertebrate community.
- Habitat conditions at both sites vary slightly with an increase of 3.3% in habitat conditions at the downstream site and as such, it is expected that a slight variation (increased diversity and sensitivity) in the aquatic communities can be expected at the downstream point.

Aquatic macro-invertebrate community assessment

- The streams at the GK1 and GK2 sites may be considered to be in a Class E (severely impaired) condition according to the Dickens & Graham (2001) classification system. Both sites can be classified as a Class E/F condition according to the Dallas (2007) classification system.

- Spatially, between the upstream and the downstream sites, the SASS5 score decreased by 7.4% while the ASPT score increased by 23.3%. This is likely due to the bedrock present at the downstream site and can be considered natural variation.
- It is clear that the MIRAI results in terms of (Ecological Category classification) correlate with the results obtained using the SASS class classifications. Both GK1 and GK2 can be classified as Class D (Largely modified) conditions with only tolerant taxa present at the time of the assessment.
- From the results of the current assessment, it is thus unlikely that some impacts as a result of the Eskom Majuba Plant are taking place on this section of the stream although the system as a whole can be considered to be impaired.
- The construction of the proposed service road as well as the development of the UCG Project will have an effect on the sensitivity and diversity of the system. It is imperative that all mitigation measures be adhered to, to minimise the impact and prevent further degradation of the system due to the proposed project.

Fish community assessment

- It is clear that slow-shallow and shallow-deep conditions predominate in the GK1 system, while fast-shallow and slow-shallow predominate the GK2 system.
- The fish expected in the GK1 system will therefore be limited to fish with high intolerance values for fast flowing water while the GK2 system will be expected to host species with a high intolerance value for deep habitats and water column cover.
- In general some significant limitations on the fish community can be expected with the degree of impact determined by the severity of the water quality and migration barriers on the system.
- It is clear that the EC calculated for the FRAI largely corresponds to that obtained for the macro-invertebrate classification which would be expected since the drivers affecting the two assemblages are largely similar. Both the GK1 and GK2 sites can be classified as largely modified (Class D) systems with regards to fish sensitivity and diversity.

Riparian Vegetation Response Assessment

- The score attained for the VEGRAI indicated that the riparian system falls into the category B/C.
- This indicates that the area has suffered a moderate loss of natural habitat, biota and basic ecosystem functions.
- There has been slight erosion of the study area.
- A small amount of alien invasive vegetation is also present, most notably within the riparian zones, and can be attributed to the anthropogenic disturbances of the area over the years.

<u>The following summarizes the Process Stream results:</u>

Biota specific water quality

- Water quality based on the biota specific parameters may be considered poor for the P. Stream site;
- The EC at P. Stream may be considered to be significantly elevated from natural conditions;
- The pH at P. Stream may be considered as largely natural;
- The dissolved oxygen content at the P.Stream site falls below the 80% saturation. The water in this system is likely to limit the sensitivity and diversity of the aquatic communities present or exposed to this water;
- DO can be considered as unsuitable for sustaining an aquatic community; and
- The temperature was normal for the time of the year when sampling took place.

Habitat Assessment

- From the results of the application of the IHIA to the P. Stream assessment site, instream impacts were found to include large impacts from flow, bed and channel modifications as well as moderate water quality modifications. Overall, the site achieved a 56.6% score for instream integrity.
- The largest riparian zone impact was found to be from the effect of erosion at the site. The site achieved a 61.7% score for riparian integrity.
- The site obtained an overall IHIA rating of 59.1%, which indicates largely modified (Class D conditions). The site, therefore, falls below the DEMC for the quaternary catchment. Further degradation of this point should be prevented as far as possible.
- The P. Stream site indicated habitat structure and diversity that is inadequate for supporting diverse aquatic macro-invertebrate communities.

Aquatic macro-invertebrate community assessment

- The Process Stream may be considered to be in a Class E/F condition according to the Dallas (2007) classification system and in a Class E (severely impaired) condition according to the Dickens & Graham (2001) classification system.
- From the table above it is clear that the MIRAI results in terms of (Ecological Category classification) correlate with the results obtained using the SASS class classifications. The P. Stream can be classified as largely modified (Class D) in terms of the macro-invertebrate sensitivity and diversity, and is likely due to the erosion and channel modification present at the site.

Fish community assessment

- It is clear that slow-shallow conditions predominate in the system followed by slow-deep conditions.
- The fish expected in the area will therefore be limited to fish with high intolerance values for flowing water and to a lesser degree species with a high intolerance value for deep habitats and water column cover.
- In general some significant limitations on the fish community can be expected with the degree of impact determined by the severity of the water stress on the system.
- From the above it is clear that the EC calculated for the FRAI largely corresponds to that obtained for the MIRAI which would be expected since the drivers affecting the two assemblages are largely similar. Because the habitat flow and cover conditions (and hence potential drivers) were fairly homogenous between the sites (see section 4.12), the EC values between the sites were also similar. The P.Stream can be classified as largely modified in terms of fish sensitivity and diversity present at the site at the time of the assessment.

Riparian Vegetation Response Assessment

- The score attained for the VEGRAI indicated that the riparian system falls into the category C.
- This indicates that the area has suffered a moderate loss of natural habitat, biota and basic ecosystem functions.
- There has been significant erosion of the study area and can be attributed to the anthropogenic disturbances of the area over the years.

Based on the impact assessment it is evident that there are six possible impacts on the aquatic ecology of the area observed. In considering the impacts and mitigation, it is assumed that a high level of mitigation will take place without high prohibitive costs. From the table it is evident that prior to mitigation, the impacts on groundwater, subsidence, and instream flow and refuge are medium- high level impacts, which can be mitigated and will be reduced to low and very- low level impacts. The impacts from wastewater generation, loss of aquatic habitat and loss of aquatic biodiversity and sensitivity are medium-low level impacts, when mitigation takes place, these impacts on aquatic ecology in the area will be reduced to very low level impacts.

Based on the findings of this study it is the opinion of the aquatic ecologists that the proposed UCG project be considered favourably, from an aquatic ecological point of view, provided that the mitigatory measures presented in this report are strictly adhered to.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

BGIS	Biodiversity Geographic Information Systems
°C	Degrees Celsius.
DEMC	Desired Ecological Management Class
DWA	DWA
EAP	Environmental Assessment Practitioner
EIA	Environmental Impact Assessment
EMC	Ecological Management Class
GIS	Geographic Information System
HGM	Hydrogeomorphic Units
IHI	Index of Habitat Integrity
m	*meter*
NAEHMP	National Aquatic Ecosystem Health Monitoring Programme
NBA	National Biodiversity Assessment
NFEPA	National Freshwater Ecosystem Priority Areas
NSBA	National Spatial Biodiversity Assessment
NWCS	National Wetland Classification System
PEMC	Present Ecological Management Class
REC	Recommended Ecological Category
RHP	River Health Program

1 INTRODUCTION

1.1 Background

Scientific Aquatic Services (SAS) and Royal HaskoningDHV (RHDHV) were appointed by Eskom UCG to undertake a Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) analysis of the aquatic and riparian resources as part of the environmental assessment and authorisation process for the Eskom Underground Coal Gasification (UCG) Project's required water use licenses. The project area identified for the Eskom UCG is located opposite the Majuba Power Station, Amersfoort, Mpumalanga (hereafter referred to as "the proposed project"). The proposed project forms part of a feasibility implementation pilot project with the goal of determining the commercial viability of using UCG as a primary source of fuel to generate electricity.

When compared to conventional coal mining, UCG has a number of potential environmental benefits. In particular, surface disturbance is minimised relative to the disturbance caused by conventional mining, and the *in situ* gasification of coal allows many of coal's potentially hazardous combustion products and leachable contaminants to remain in the ground (LLNL, 2011). Despite these potential benefits, however, the process still creates environmental risks;

- First is the risk of groundwater contamination. Organic contaminants such as polycyclic aromatic hydrocarbons (PAHs) may be generated during combustion of coal, and trace metals in the coal may be released through geochemical reactions induced by the UCG process (LLNL, 2011).Contaminants may also be released from adjacent geologic units. These organic and metal contaminants could migrate and contaminate groundwater aquifers.
- Second, because the *in situ* burning of coal creates cavities in the subsurface, there is a risk of ground subsidence, whereby the overlying rock layers partially collapse into the newly created void space (LLNL, 2011). Subsidence creates a hazard for any surface infrastructure that might be present above the UCG zone, and may create detrimental changes in surface or groundwater hydrology above the cavity.

In addition, there are other potential adverse impacts to human health and the environment associated with UCG. For example, uncontrolled migration and leakage of syngas to the surface could result in adverse impacts to local ecosystems and human settlements (LLNL, 2011). Contaminants released from the coal and adjacent geologic units during the UCG process could also be released at the surface, contaminating surface water and/or air (LLNL, 2011).

Potentially affected surface water resource features, the focus of this report, found on and in the vicinity of the proposed development belt, were investigated to provide a reference in terms of the surface water resources. This assessment was done in line with the National Environmental Management Act (1998), the Environmental Impact Assessment Regulations (2006 and 2010) and the National Water Act (1998).

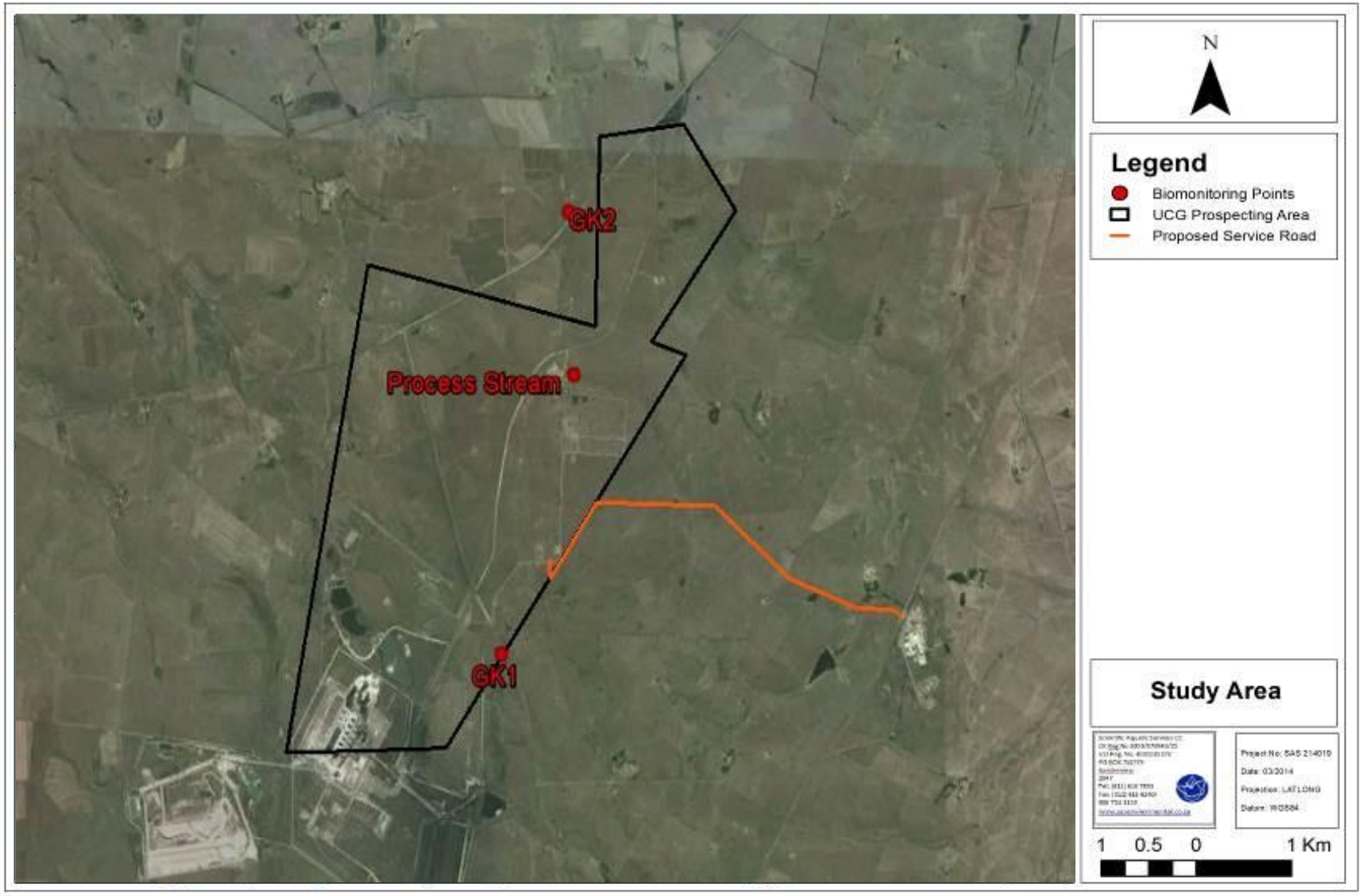

Figure 1: Location of the study area depicted on an aerial photograph in relation to surrounding areas

1.2 Legislative Requirements

National Environmental Management Act (107 of 1998) and the Environmental Impact Assessment Regulations (2010)

In terms of undertaking an EIA process and in terms of compliance with NEMA, any proposed activity, whether serving a maintenance purpose or for development, needs to be checked for 'listed activities', as defined by NEMA (NEMA Impact Assessment Regulations), which may have potentially detrimental impact on the environment and therefore require environmental authorisation from the relevant authorising body. Government Notice 544 Activity 11 relates to the fulfillment of a Basic Assessment, where construction "occurs within a watercourse or within 32 metres of a watercourse, measured from the edge of a watercourse, excluding where such construction will occur behind the development setback line".

In terms of the proposed project, a specialist review is required to identify potential development setbacks according to NEMA as well as to provide consideration and guidelines to development within these setback areas in a responsible and authorised manner (due diligence). This implies the endorsement of environmental best practise for the proposed project development implementation (i.e. if the potential project is likely to impact a water resource, due diligence in authority compliance and mitigation measure needs to be developed, as far as possible).

National Water Act, 1998 (Act No. 36 of 1998)

The National Water Act guides the management of water in South Africa. The Act aims to regulate the use of water and activities that may impact on water resources through the categorisation of 'listed water uses' encompassing water extraction and flow attenuation within catchments as well as the potential contamination of water resources, where the Department of Water Affairs (DWA) is the administering body in this regard.

In terms of the proposed development and its nature, a specialist assessment is needed to provide DWA with the necessary information related to the proposed project's water uses and the potential impacts on the water resources of the area. It is the client's intention to register and license all water uses related to the UCG project.

National Environmental Management: Protected Areas (Act 57 of 2003)

The Act regulates the implementation scope for conserving, amongst others:

- World or National Heritage Sites (SAHRA)
- National Protected Areas (South African National Parks)
- Provincial Protected Areas

- Protected Catchment Areas
- Other Reserves, Parks

National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004)

The National Environmental Management: Biodiversity Act is a subsidiary of NEMA and relates to:

- The management and conservation of biological diversity within South Africa, and of the components of such biological diversity;
- The use of indigenous biological resources in a sustainable manner; and
- The fair and equitable sharing among stakeholders of benefits arising from bioprospecting involving indigenous biological resources.

In terms of the scope of this assessment, consideration will be identified where relevant in accordance with this Act.

Other Acts and Policies

- National Water Resource Strategy (2004)
- Water Services Act (No. 108 of 1997).
- Constitution of the Republic of South Africa (No. 108 of 1996)
- Mpumalanga Biodiversity Conservation Plan (2006 and 2007)

1.3 Assumptions and Limitations

- Most of the information used to characterised potentially affected water resource for this report is sourced from DWA and DEA online GIS tools. This is supplemented by the use of Google Earth.
- The composition of aquatic biota in the study area, prior to major disturbance, is unknown. For this reason, reference conditions are hypothetical, and are based on professional judgement and/or inferred from limited data available.
- Aquatic, wetland and riparian ecosystems are dynamic and complex. Some aspects of the ecology of these systems, some of which may be important may have been overlooked. The findings of this study were largely based on a single site visit undertaken late in the low flow season at a time when extremely low flows were being experienced. A more reliable assessment would have required that seasonal assessments take place with at least one assessment in the high flow season also undertaken.

2 METHOD OF ASSESSMENT

2.1 Aquatic Ecological Assessment sites and site selection

Aquatic biomonitoring was undertaken at two sites in the current assessment along the Geelklipspruit as well as one site on the Process Stream.

Table 1 below presents geographic information with regards to the monitoring points on the Geelklipspruit system as well as the Process Stream. Figure 1 visually presents the locations of the various points along the Geelklipspruit.

Table 1: Location of the biomonitoring points with co-ordinates

Site	Detailed Site Description	GPS coordinates	
		South	East
Riverine assessment points			
GK1	Geelklipspruit: Upstream point of the UCG Project area.	27°5'26.54"S	29°47'31.26"E
GK2	Geelklipspruit: Downstream of the UCG Project area.	27°2'33.29"S	29°48'3.09"E
P. Stream	Process Stream: Midpoint of UCG Project area. The Process Stream confluences with the Geelklipspruit.	27°3'36.97"S	29°48'6.98"E

The sites were all visually assessed. The Invertebrate Habitat Assessment System (IHAS), Intermediate Habitat Assessment Integrity Assessment (IHIA), Fish Habitat Cover Ratings (HCR), the South African Scoring System version 5 (SASS5) and Macro-Invertebrate Risk Assessment Index (MIRAI) for the assessment of the macro-invertebrate community, the Fish Risk Assessment Index (FRAI) and the Riparian Vegetation Response Assessment (VEGRAI) in order to assess the risks to the aquatic and riparian ecology were employed at sites GK1, GK2 and P. Stream in addition to the analyses of biota specific water quality. The protocols of applying the indices were strictly adhered to and all work was carried out by a South African River Health Program (SARHP) accredited assessor.

2.2 Visual Assessment of Aquatic Assessment Points

Each site was selected in order to identify current conditions, with specific reference to impacts from surrounding activities where applicable. Both natural constraints placed on ecosystem structure and function, as well as anthropogenic alterations to the systems identified, was identified by observing conditions and relating them to professional experience. Photographs of each site were taken to provide visual records of the conditions at the time of assessment. Factors which were noted in the site-specific visual assessments included the following:

- Upstream and downstream significance of each point, where applicable;
- Significance of the point in relation to the study area;
- stream morphology;
- instream and riparian habitat diversity;
- stream continuity;
- erosion potential;
- depth flow and substrate characteristics;
- signs of physical disturbance of the area; and
- other life forms reliant on aquatic ecosystems.

2.3 Physico-chemical Water Quality Data

On site testing of biota specific water quality variables took place on all sites where surface water was present. The results of on-site biota specific water quality analyses were used to aid in the interpretation of the data obtained by the biomonitoring. Results are discussed against the guideline water quality values for aquatic ecosystems (DWAF, 1996 vol. 7).

2.4 Intermediate Habitat Integrity Assessment (IHIA)

It is important to assess the habitat of riverine systems in order to aid in the interpretation of the results of the community integrity assessments by taking habitat conditions and impacts into consideration. The general habitat integrity of the sites was assessed based on the application of the Intermediate Habitat Integrity Assessment for (Kemper; 1999). The Intermediate Habitat Integrity Assessment (IHIA) protocol, as described by Kemper (1999), was used using the site specific application protocols. This is a simplified procedure, which is based on the Habitat Integrity approach developed by Kleynhans (1996). The IHIA is conducted as a first level exercise, where a comprehensive exercise is not practical. The Habitat Integrity of each site was scored according to 12 different criteria which represent the most important (and easily quantifiable) anthropogenically induced possible impacts on the system. The instream and riparian zones were analysed separately, and the final

assessment was then made separately for each, in accordance with Kleynhans' (1999) approach to Habitat Integrity Assessment. Data for the riparian zone is, primarily interpreted in terms of the potential impact on the instream component. The assessment of the severity of impact of modifications is based on six descriptive categories with ratings. Analysis of the data was carried out by weighting each of the criteria according to Kemper (1999). By calculating the mean of the instream and riparian Habitat Integrity scores, an overall Habitat Integrity score can be obtained for each site. This method describes the Present Ecological State (PES) of both the in-stream and riparian habitats of the sites. The method classifies Habitat Integrity into one of six classes, ranging from unmodified/natural (Class A), to critically modified (Class F).

Table 2: Classification of Present State Classes in terms of Habitat Integrity [Based on Kemper 1999]

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

2.5 Invertebrate Habitat Suitability (Invertebrate Habitat Assessment: IHAS)

The Invertebrate Habitat Assessment System (IHAS) was applied to sites GK1, GK2 and P.Stream according to the protocol of McMillan (1998). This index was used to determine specific habitat suitability for aquatic macro-invertebrates, as well as to aid in the interpretation of the results of the South African Scoring System version 5 (SASS5) scores. Scores for the IHAS index were interpreted according to the guidelines of McMillan (1998) as follows:

- <65%: habitat diversity and structure is inadequate for supporting a diverse aquatic macro-invertebrate community.
- 65%-75%: habitat diversity and structure is adequate for supporting a diverse aquatic macro-invertebrate community.

- >75%: habitat diversity and structure is highly suited for supporting a diverse aquatic macro-invertebrate community.

2.6 Aquatic Macro-Invertebrates: South African Scoring System (SASS5)

Aquatic macro-invertebrate communities of the accessible sites were investigated according to the method, which is specifically designed to comply with international accreditation protocols. This method is based on the British Biological Monitoring Working Party (BMWP) method and has been adapted for South African conditions by Dr. F. M. Chutter (1998). The assessment was undertaken according to the South African Scoring System (SASS) protocol as defined by Dickens and Graham (2001). All work was undertaken by an accredited South African Scoring System, version 5 (SASS5) practitioner.

Interpretation of the results of biological monitoring depends, to a certain extent, on interpretation of site-specific conditions (Thirion *et.al*, 1995). In the context of this investigation it would be best not to use SASS5 scores in isolation, but rather in comparison with relevant habitat scores. The reason for this is that some sites have a less desirable habitat or fewer biotopes than others do. In other words, a low SASS5 score is not necessarily regarded as poor in conjunction with a low habitat score. Also, a high SASS5 score in conjunction with a low habitat score can be regarded as better than a high SASS5 score in conjunction with a high habitat score. A low SASS5 score together with a high habitat score would be indicative of poor conditions. The IHAS Index is valuable in helping to interpret SASS5 scores and the effects of habitat variation on aquatic macro-invertebrate community integrity.

The perceived reference state for the local streams was determined in consideration of the ecoregion conditions as well as local habitat conditions. Local conditions are extremely poorly suited for supporting aquatic macro-invertebrates and very low diversities and abundances of aquatic macro-invertebrates can be expected. Only more tolerant taxa and those with specific adaptations to the unstable sandy habitat are deemed likely to occur in the area. Reference conditions are stated as a SASS score of 240 and an ASPT score of 6.8. Sites were classified according to the classification system for the (Upper) Highveld Ecoregion according to Dallas (2007), as well as the classification system of Dickens & Graham 2001.

Table 3: Definition of Present State Classes in terms of SASS and ASPT scores as presented in Dickens and Graham (2001)

Class	Description	SASS Score%	ASPT%
A	Unimpaired. High diversity of taxa with numerous sensitive taxa.	90-100 80-89	Variable >90
B	Slightly impaired. High diversity of taxa, but with fewer sensitive taxa.	80-89 70-79 70-89	<75 >90 76-90
C	Moderately impaired. Moderate diversity of taxa.	60-79 50-59 50-79	<60 >75 60-75
D	Largely impaired. Mostly tolerant taxa present.	50–59 40-49	<60 Variable
E	Severely impaired. Only tolerant taxa present.	20-39	Variable
F	Critically impaired. Very few tolerant taxa present.	0-19	Variable

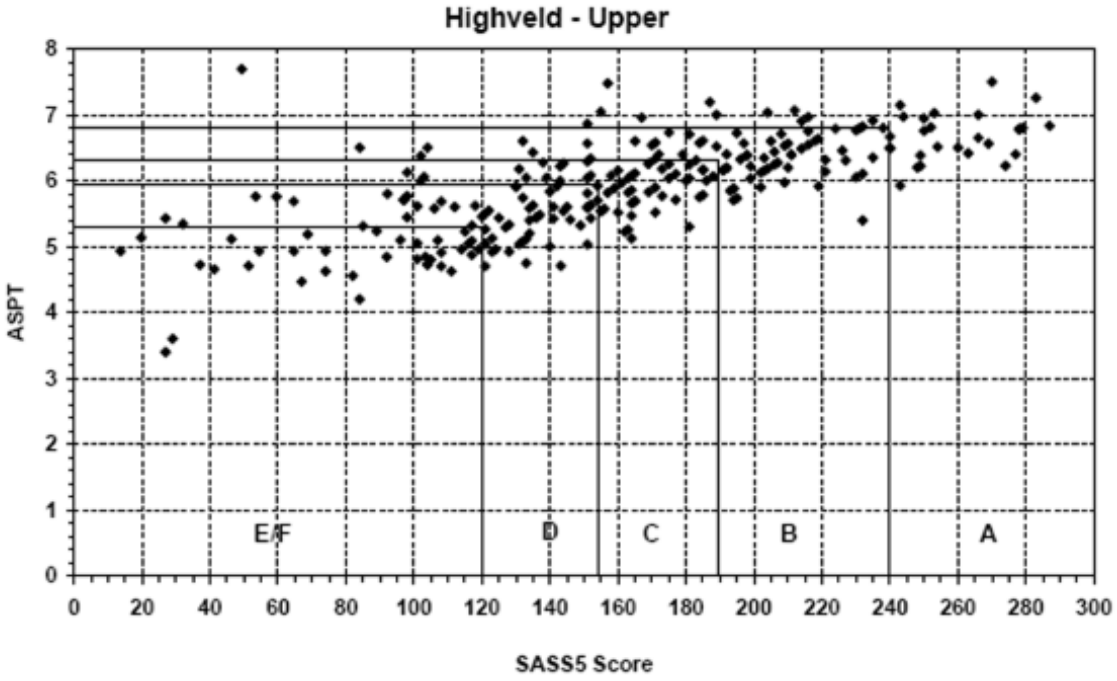

Figure 2: SASS5 Classification using biological bands calculated form percentiles for the Highveld ecoregion, Dallas, 2007

2.7 Aquatic Macro-Invertebrates: Macro-invertebrate Response Assessment Index (MIRAI)

The four major components of a stream system that determine productivity, with particular reference to aquatic organisms, are flow regime, physical habitat structure, water quality and energy inputs. An interplay between these factors (particularly habitat and availability of food sources) result in the discontinuous, patchy distribution pattern of aquatic macro-invertebrate populations. As such aquatic invertebrates shall respond to habitat changes (i.e. changes in driver conditions).

To relate drivers to such changes in habitat and aquatic invertebrate condition, two key elements are required. Firstly habitat preferences and requirements for each taxa present should be obtained. As such reference conditions can be established against which any response to drivers can be measured. Secondly habitat features should be evaluated in terms of suitability and the requirements mentioned in the first point. As a result expected and actual patterns can be evaluated to achieve an Ecostatus Category (EC) rating.

Based on the three key requirements, the MIRAI provides an approach to deriving and interpreting aquatic invertebrate response to driver changes. The index has been applied to sites GK1, GK2 and P. Stream following the methodology described by Thirion (2007). Aquatic macro-invertebrates expected at each point were derived both from previous studies of rivers near the area as well as habitat, flow and water parameters (Thirion 2007).

2.8 Fish biota: Habitat Cover Rating (HCR) and Fish Habitat Assessment (FHA)

This approach was developed to assess habitats according to different attributes that are surmised to satisfy the habitat requirements of various fish species. At each site, the following depth-flow (df) classes are identified, namely:

- Slow (<0.3m/s), shallow (<0.5m) - Shallow pools and backwaters.
- Slow, deep (>0.5m) - Deep pools and backwaters.
- Fast (>0.3m/s), shallow - Riffles, rapids and runs.
- Fast, deep - Usually rapids and runs.

The relative contribution of each of the above mentioned classes at a site was estimated and indicated as:

0 = Absent
1 = Rare (<5%)
2 = Sparse (5-25%)
3 = Moderate (25-75%)
4 = Extensive (>75%)

For each depth-flow class, the following cover features (cf) -considered to provide fish with the necessary cover to utilise a particular flow and depth class- were investigated:

- Overhanging vegetation
- Undercut banks and root wads
- Stream substrate
- Aquatic macrophytes

The amount of cover present at each of these cover features (cf) was noted as:

0 = absent

1 = Rare/very poor (<5%)

2 = Sparse/poor (5-25%)

3 = Moderate/good (25-75%)

4 = Extensive/excellent (>75%)

The fish habitat cover rating (HCR) was calculated as follows:

- The contribution of each depth-flow class at the site was calculated (df/Σdf).
- For each depth-flow class, the fish cover features (cf) were summed (Σcf).

HCR = df/Σdf x Σcf.

The amount and diversity of cover available for the fish community at the selected sites was graphically expressed as habitat cover ratings (HCR) for different flow-depth classes as a stacked bar chart.

2.9 Fish biota: Fish Response Assessment Index (FRAI)

The FRAI (Kleynhans 2008) is based on the premise that "drivers" (environmental conditions) may cause fish stress which shall then manifest as changes in fish species assemblage. The index employs preferences and intolerances of the reference fish assemblage, as well as the response of the actual (present) fish assemblage to particular drivers to indicate a change from reference conditions. Intolerances and preferences are divided into metric groups relating to preferences and requirements of individual species. This allows cause-effect relationships to be understood, i.e. between drivers and responses of the fish assemblage to changes in drivers. These metric groups are subsequently ranked, rated and finally integrated as a fish Ecological Category (EC). Fish expected to occur in the system is summarised in Table 4.

Table 4: Intolerance ratings for naturally occurring indigenous fish species with natural ranges included in the study area (Skelton, 2001 and Kleynhans, 2003).

SPECIES NAME	COMMON NAME	INTOLERANCE RATING	COMMENTS
Austroglanis sclateri	Rock catfish	2.7	Rare, endemic to the Orange-Vaal system
Barbus paludinosus	Straightfin barb	1.8	Widespread
Barbus anoplus	Chubbyhead barb	2.6	Widespread
Labeobarbus aeneus	Smallmouth yellowfish	2.5	Widespread in the Orange-Vaal system
Labeobarbus kimberleyensis	Largemouth yellowfish	2.5	Widespread in the Orange-Vaal system but is becoming scarce
Labeo capensis	Orange river mud fish	3.2	Widespread in the Orange-Vaal system
Labeo umbratus	Moggel	2.3	Widespread in the Orange-Vaal system

SPECIES NAME	COMMON NAME	INTOLERANCE RATING	COMMENTS
Pseudocrenilabrus philander	Southern mouthbrooder	1.3	Widely distributed in southern Africa
Tilapia Sparrmanii	Banded tilapia	1.3	Widely distributed in southern Africa
Clarias gariepinus	*Sharptooth catfish*	1.2	Most widely distributed fish in Africa.
Cyprinus carpio	Carp	1.4	Widespread alien species
Micropterus salmoides	Largemouth bass	2.2	Widespread alien species
Gambussia affinis	Mosquito fish	2	Widespread

Tolerant: 1-2 moderately tolerant :> 2-3 Moderately Intolerant: >3-4 Intolerant: >4

2.10 Riparian Vegetation Response Assessment Index (VEGRAI)

Riparian vegetation is described in the NWA (Act No 36 of 1998) as follows: 'riparian habitat' includes the physical structure and associated vegetation of the areas 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.

VEGRAI is designed for qualitative assessment of the response of riparian vegetation to impacts in such a way that qualitative ratings translate into quantitative and defensible results[1]. Results are defensible because their generation can be traced through an outlined process (a suite of rules that convert assessor estimates into ratings and convert multiple ratings into an Ecological Category).

Table 5: Descriptions of the A-F ecological categories.

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

2.11 Impact Assessment Methodology

In order for the EAP to allow for sufficient consideration of all environmental impacts, impacts were assessed using a common, defensible method of assessing significance that will enable comparisons to be made between risks/impacts and will enable authorities, stakeholders and the client to understand the process and rationale upon which

[1] Kleynhans et al, 2007

risks/impacts have been assessed. The method to be used for assessing risks/impacts is outlined in the sections below.

The first stage of risk/impact assessment is the identification of environmental activities, aspects and impacts. This is supported by the identification of receptors and resources, which allows for an understanding of the impact pathway and an assessment of the sensitivity to change. The definitions used in the impact assessment are presented below.

An **activity** is a distinct process or task undertaken by an organisation for which a responsibility can be assigned. Activities also include facilities or infrastructures that are possessed by an organisation.

An **environmental aspect** is an 'element of an organizations activities, products and services which can interact with the environment'[2]. The interaction of an aspect with the environment may result in an impact.

Environmental risks/impacts are the consequences of these aspects on environmental resources or receptors of particular value or sensitivity, for example, disturbance due to noise and health effects due to poorer air quality. In the case where the impact is on human health or wellbeing, this should be stated. Similarly, where the receptor is not anthropogenic, then it should, where possible, be stipulated what the receptor is.

Receptors can comprise, but are not limited to, people or human-made systems, such as local residents, communities and social infrastructure, as well as components of the biophysical environment such as wetlands, flora and riverine systems.

Resources include components of the biophysical environment.

Frequency of activity refers to how often the proposed activity will take place.

Frequency of impact refers to the frequency with which a stressor (aspect) will impact on the receptor.

Severity refers to the degree of change to the receptor status in terms of the reversibility of the impact; sensitivity of receptor to stressor; duration of impact (increasing or decreasing with time); controversy potential and precedent setting; threat to environmental and health standards.

Spatial extent refers to the geographical scale of the impact.

Duration refers to the length of time over which the stressor will cause a change in the resource or receptor.

The significance of the impact is then assessed by rating each variable numerically according to the defined criteria. Refer to the table below. The purpose of the rating is to develop a clear understanding of influences and processes associated with each impact.

[6] *The definition has been aligned with that used in the ISO 14001 Standard.*

The severity, spatial scope and duration of the impact together comprise the consequence of the impact and when summed can obtain a maximum value of 15. The frequency of the activity and the frequency of the impact together comprise the likelihood of the impact occurring and can obtain a maximum value of 10. The values for likelihood and consequence of the impact are then read off a significance rating matrix and are used to determine whether mitigation is necessary[3].

The assessment of significance is undertaken twice. Initial, significance is based on only natural and existing mitigation measures (including built-in engineering designs). The subsequent assessment takes into account the recommended management measures required to mitigate the impacts. Measures such as demolishing infrastructure, and reinstatement and rehabilitation of land, are considered post-mitigation.

The model outcome of the impacts was then assessed in terms of impact certainty and consideration of available information. The Precautionary Principle is applied in line with South Africa's National Environmental Management Act (No. 108 of 1997) in instances of uncertainty or lack of information, by increasing assigned ratings or adjusting final model outcomes. In certain instances where a variable or outcome requires rational adjustment due to model limitations, the model outcomes have been adjusted.

LIKELIHOOD DESCRIPTORS

Table 6: Criteria for assessing significance of impacts

Probability of impact	**RATING**
Highly unlikely	1
Possible	2
Likely	3
Highly likely	4
Definite	5
Sensitivity of receiving environment	**RATING**
Ecology not sensitive/important	1
Ecology with limited sensitivity/importance	2
Ecology moderately sensitive/ /important	3
Ecology highly sensitive /important	4
Ecology critically sensitive /important	5

CONSEQUENCE DESCRIPTORS

Severity of impact	**RATING**
Insignificant / ecosystem structure and function unchanged	1
Small / ecosystem structure and function largely unchanged	2

[3] *Some risks/impacts that have low significance will however still require mitigation*

Significant / ecosystem structure and function moderately altered	3
Great / harmful/ ecosystem structure and function largely altered	4
Disastrous / ecosystem structure and function seriously to critically altered	5
Spatial scope of impact	**RATING**
Activity specific/ < 5 ha impacted / Linear features affected < 100m	1
Development specific/ within the site boundary / < 100ha impacted / Linear features affected < 1000m	2
Local area/ within 1 km of the site boundary / < 2000ha impacted / Linear features affected < 3000m	3
Regional within 5 km of the site boundary / < 5000ha impacted / Linear features affected < 10 000m	4
Entire habitat unit / Entire system/ > 5000ha impacted / Linear features affected > 10 000m	5
Duration of impact	**RATING**
One day to one month	1
One month to one year	2
One year to five years	3
Life of operation or less than 20 years	4
Permanent	5

Table 7: Significance Rating Matrix.

	CONSEQUENCE (Severity + Spatial Scope + Duration)														
LIKELIHOOD (Frequency of activity + Frequency of impact)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

Table 8: Positive/Negative Mitigation Ratings.

Significance Rating	Value	Negative Impact Management Recommendation	Positive Impact Management Recommendation
Very high	126-150	Critically consider the viability of proposed projects Improve current management of existing projects significantly and immediately	Maintain current management
High	101-125	Comprehensively consider the viability of proposed projects Improve current management of existing projects significantly	Maintain current management
Medium-high	76-100	Consider the viability of proposed projects Improve current management of existing projects	Maintain current management
Medium-low	51-75	Actively seek mechanisms to minimise impacts in line with the mitigation hierarchy	Maintain current management and/or proposed project criteria and strive for continuous improvement
Low	26-50	Where deemed necessary seek mechanisms to minimise impacts in line with the mitigation hierarchy	Maintain current management and/or proposed project criteria and strive for continuous improvement

Significance Rating	Value	Negative Impact Management Recommendation	Positive Impact Management Recommendation
Very low	1-25	Maintain current management and/or proposed project criteria and strive for continuous improvement	Maintain current management and/or proposed project criteria and strive for continuous improvement

The following points were considered when undertaking the assessment:

- Risks and impacts were analysed in the context of the *project's area of influence* encompassing:
  - Primary project site and related facilities that the client and its contractors develop or controls;
  - Areas potentially impacted by cumulative impacts for further planned development of the project, any existing project or condition and other project-related developments; and
  - Areas potentially affected by impacts from unplanned but predictable developments caused by the project that may occur later or at a different location.
- Risks/Impacts were assessed for all stages of the project cycle including:
  - Pre-construction;
  - Construction;
  - Operation; and
  - Rehabilitation.
- If applicable, transboundary or global effects were assessed;
- Individuals or groups who may be differentially or disproportionately affected by the project because of their *disadvantaged* or *vulnerable* status were assessed.
- Particular attention was paid to describing any residual impacts that will occur after rehabilitation.

2.12 Mitigation measure development

The following points present the key concepts considered in the development of mitigation measures for the proposed development.

Mitigation and *performance improvement measures* and actions that address the risks and impacts[4] are identified and described in as much detail as possible.

Measures and actions to address negative impacts will favour avoidance and prevention over minimisation, mitigation or compensation.

[4] *Mitigation measures should address both positive and negative impacts*

Desired outcomes are defined, and have been developed in such a way as to be *measurable events with performance indicators, targets and acceptable criteria* that can be tracked over *defined periods*, with estimates of the *resources* (including human resource and training requirements) *and responsibilities for implementation.*

3 RESULTS OF LITERATURE REVIEW

3.1 Ecoregion

When assessing the ecology of any area (aquatic or terrestrial), it is important to know which ecoregion the study area is located within. This knowledge allows for improved interpretation of data to be made, since reference information and representative species lists are often available on this level of assessment, which aids in guiding the assessment.

The study area falls within the Upper Vaal Water Management Area (WMA) within the Highveld Aquatic Ecoregion, with the proposed project area residing in the upper Vaal River catchment (quaternary C11J). The Geelklipspruit, a tributary of the Upper Vaal River drains directly through the proposed project area; Figure 3 below indicates the aquatic ecoregion and quaternary catchment.

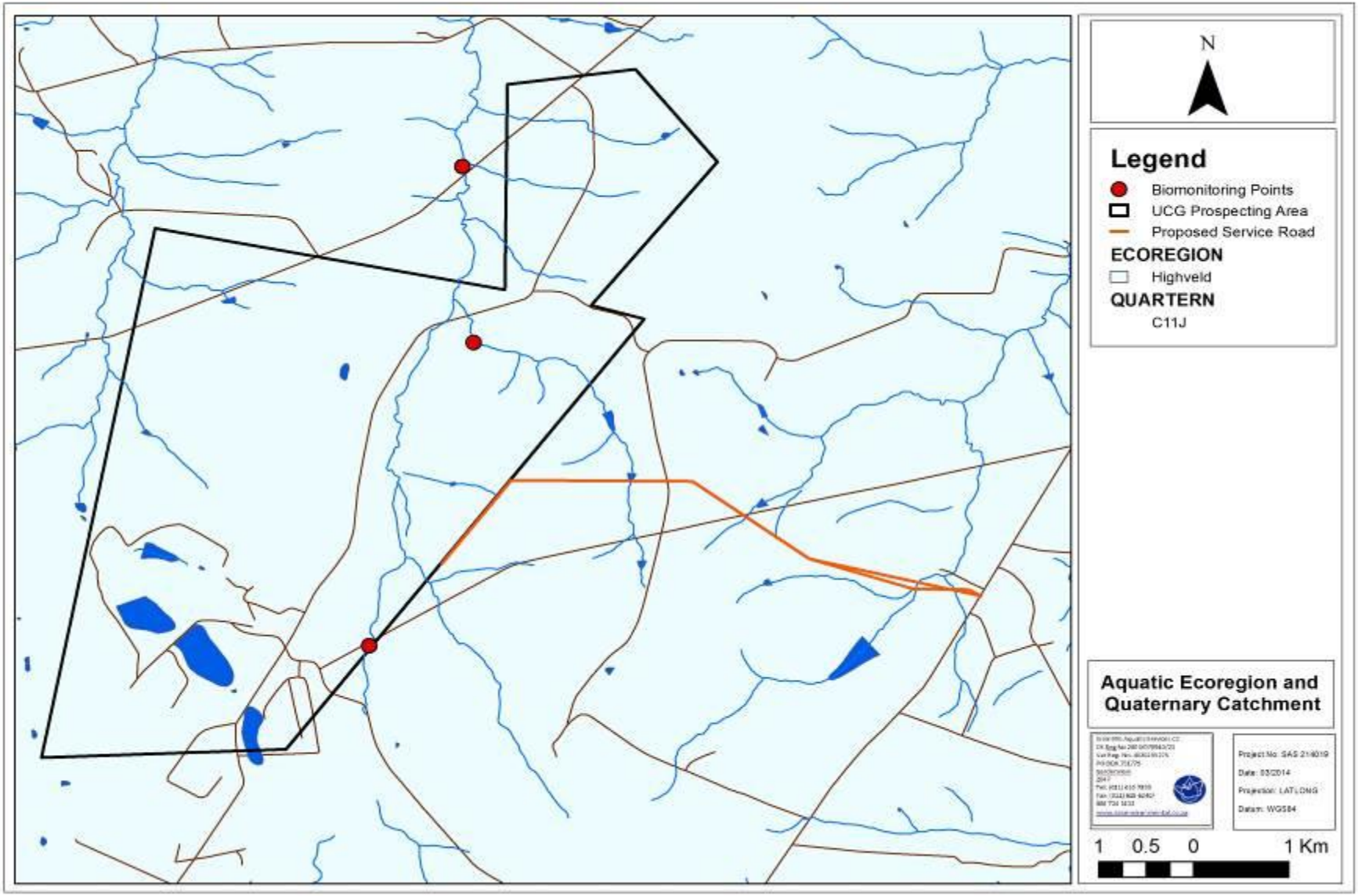

Figure 3: Quaternary catchment and aquatic ecoregions applicable to the study area.

3.2 Ecostatus Classification

Studies undertaken by the Institute for Water Quality Studies assessed all quaternary catchments as part of the Resource Directed Measures for Protection of Water Resources. In these assessments, the EIS, PEMC and DEMC were defined and serve as a useful guideline in determining the importance and sensitivity of aquatic ecosystems, prior to assessment or as part of a desktop assessment.

This database was searched for the catchment of concern in order to define the EIS, PEMC and DEMC. The results of the assessment are summarised in the table below.

Table 9: Summary of the ecological status of the C11J quaternary catchment based on Kleynhans (1999)

Catchment	Resource	EIS	PESC	DEMC
C11J	Vaal River	Moderate	Class B	C: Moderately modified

According to the ecological importance classification for the quaternary catchment, the system can be classified as a *Moderately modified* system which, in its present state, can be considered a Class B (largely natural) stream.

The points below summarise the impacts on the aquatic resources in the C11J quaternary catchment (Kleynhans 1999):

- The aquatic resources within this quaternary catchment have been moderately affected by bed modification as a result of farming and grazing within the catchment.
- Flow modification within the catchment is considered high.
- High levels of impact from inundation of the system have occurred.
- Riparian zones and stream bank conditions are considered to be moderately impacted by erosion and exotic willow trees (*Salix babylonica*).
- A moderate impact occurs as a result of the introduction of instream biota specifically from *Cyprinus carpio* species.
- Impacts on water quality in the system are considered moderately high due to agricultural runoff.

In terms of ecological functions, importance and sensitivity, the following points summarise the conditions in this catchment:

- The riverine systems in this catchment have a marginal diversity of habitat types.
- The site has a very low importance in terms of conservation.

- The riverine resources in this quaternary catchment have moderate intolerance to flow and flow related water quality changes.
- The aquatic resources in the area have a low importance in terms of migration of species.
- The system in this quaternary catchment is considered to be of high importance in terms of rare and endemic species conservation with regards to the *Austroglanis sclateri*.
- The aquatic resources in this catchment are marginally important in terms of the provision of refuge areas.
- The riverine resources in this quaternary catchment have a moderate sensitivity to changes in water quality and flow.
- The aquatic resources in this area are of moderate importance in terms of Species/Taxon richness.
- The quaternary catchment is of moderate importance with regards to unique or endemic species.

4 AQUATIC ECOLOGICAL ASSESSMENT RESULTS

A photographic record of each site was made in order to provide a visual record of the condition of each assessment site as observed during the field assessment. The photographs taken are presented, followed by a table summarising the observations for the various criteria made during the visual assessment undertaken at each point.

4.1 THE GEELKLIPSPRUIT (Points GK1 and GK2)

Figure 4: Upstream view of the GK1 site on the Geelklipspruit indicating the slow flows and bankside vegetation at this point.

Figure 5: Local view of the GK1 site indicating the rocky substrate and algal proliferation at this point.

Figure 6: Upstream view of the GK2 site on the Geelklipspruit indicating the low flows at this point.

Figure 7: Downstream view of the GK2 site on the Geelklipspruit indicating the bedrock present at the site.

Table 10: Description of the location of the assessment site GK1 and GK2

Characteristics	Site GK1 (Upstream)	Site GK2 (Downstream)
Significance of the point	This point is to be used as a reference point for the GK2 site. Any degradation from this point would serve as an indication of impacts in a downstream direction.	This point is situated just downstream of the Eskom Majuba Project. Any negative impacts as a result of the proposed development would be evident at this point.
Surrounding anthropogenic activities	The site is situated upstream of a road crossing which may affect the flows at this point. The site is situated upstream of the proposed service road and development area.	This site is situated in a large open area. The surrounding area is affected by activities from the rural community as well as adjacent farming activities. The proposed activities will also impact on the stream at this point.
Riparian zone characteristics	The riparian zone at this point is narrow and steep.	A mix of grasses and sedges. Bankside cover is good at this point.
Depth characteristics	The water at this point was flowing moderately at the present time.	The stream consists of moderately shallow runs and glides with some deeper pool areas.
Flow condition	The stream has moderately slow flow at this point.	There is a good diversity of flow at this point.
Water clarity	Water at this point was clear at the time of assessment.	Water was discolored at the time of the assessment.
Stones habitat characteristics	Excellent rocky substrate is present at this point with abundant cobble areas and small stones present.	The area is dominated by bedrock and there are no cobble substrates present at this point.
Vegetation habitat characteristics	Bankside vegetation consists mostly of grasses. There is little potential for erosion at this point.	Bankside vegetation consists mostly of grasses. There is little potential for erosion at this point.
Other habitat characteristics	There is some gravel substrate present in the backwaters.	There was no gravel, sand and muddy substrates present at the time of the assessment.
Erosion potential	Banks at this point are relatively stable and there is little potential for erosion.	Banks at this point are relatively stable and there is little potential for erosion.

4.2 Biota specific water quality

Table 11 below records the biota specific water quality of the GK1 and GK2 sites.

Table 11: Biota specific water quality variables

Site	Cond ms/m	PH	DO mg/l	Temp C
GK1	95.6	8.48	7.14	23.0
GK2	26.5	8.14	7.86	25.8

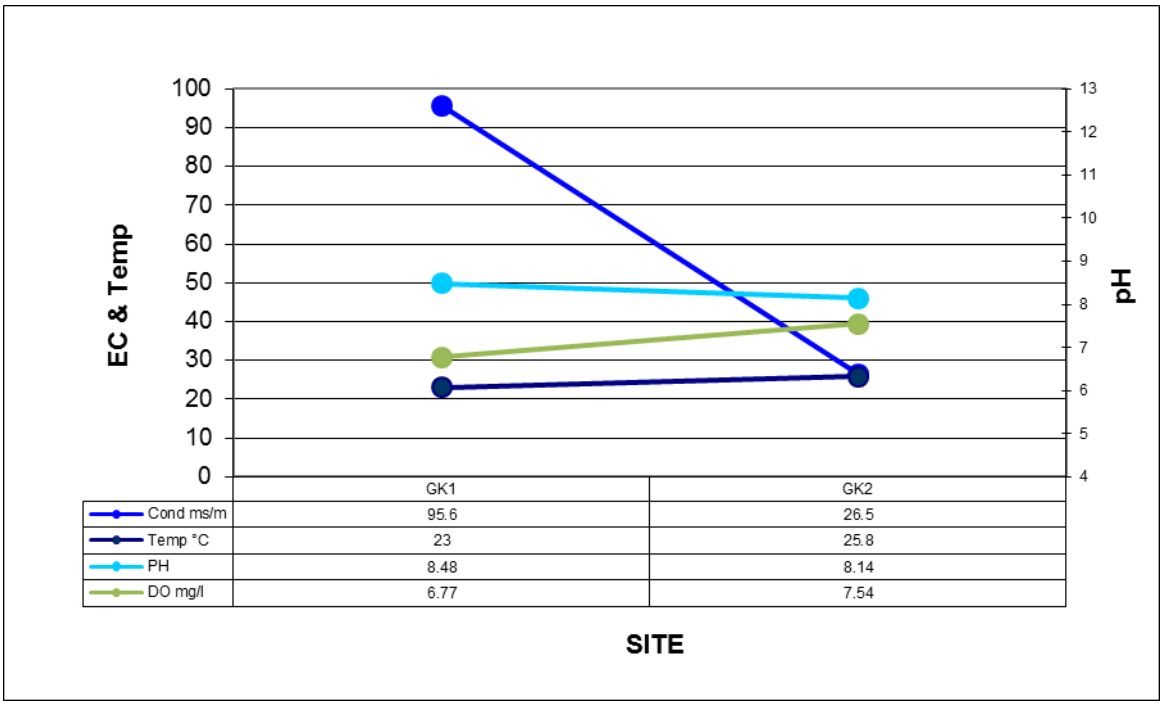

Figure 8: Biota specific water quality variation between the upstream GK1 and downstream GK2 sites

- At the time of the assessment, the dissolved salt concentrations can be seen as significantly elevated from natural conditions at the upstream site, while the downstream concentration is considerably lower in value.
- The EC value between the two sites decreases by 72.2%. The decrease in a downstream direction is seen as an improvement in the water quality;
- The decrease in EC in a downstream direction indicates that no contribution of salts as a result of the Eskom Majuba Plant is likely to be taking place at the current time;
- pH values are considered largely natural and slightly alkaline at both the upstream and downstream site.
- The pH at GK1 and GK2 may be considered to be largely natural with a 4.0% decrease between the upper and lower sampling points. This change falls within the DWA TWQR (DWAF, 1996) which advocates no change greater than 5% from reference or temporal data. Close monitoring of this trend should however continue;
- The water quality guideline for aquatic ecosystems (DWAF, 1996) states that dissolved oxygen concentrations should range between 80% and 120% of saturation;
- Saturation (i.e. maximum dissolved oxygen concentrations) shall in turn depend on the temperature of the water sampled (USA EPA website accessed 11 April 2014). The current readings were expressed as a percentage of the potential maximum (Table 12);

Table 12: Oxygen measured expressed as a percentage of maximum concentration at the temperature measured.

Site	Oxygen (mg/L)	Temperature when measured (°C)	Maximum oxygen at that temperature (mg/L)	Oxygen measured expressed as percentage of maximum
GK1	6.77	23.0	8.56	79.1
GK2	7.54	25.8	8.24	91.5

- The dissolved oxygen content at the GK2 site exceeded the 80% saturation while the dissolved oxygen content at the GK1 site falls below the DWA TQWR (DWAF, 1996). The upstream GK1 site is likely to limit the sensitivity and diversity of the aquatic communities present at this point in the system;
- The observed spatial variation in temperature can be ascribed to natural and diurnal variations between sampling times as well as the nature of the stream at each point.

4.3 Habitat Assessment

In stream Habitat Integrity

Weights	14	13	13	13	14	10	9	8	6		
REACH	Water abstraction	Flow modification	Bed modification	Channel modification	Water quality	Inundation	Exotic macrophytes	Exotic fauna	Solid waste disposal	Total Score (%)	Classification
GK1	7	11	6	5	12	8	3	4	2	67.8	C Moderately modified
GK2	11	11	3	5	8	7	3	4	2	69.9	C Moderately modified

None	Small	Moderate	Large	Serious	Critical

Riparian Zone Habitat Integrity

Weights	13	12	14	12	13	11	12	13		

REACH	Vegetation removal	Alien encroachment	Bank erosion	Water abstraction	Flow modification	Channel modification	Water quality	Inundation	Total Score (%)	Classification
GK1	3	12	7	5	5	5	8	8	71.7	C Moderately modified
GK2	6	12	5	5	5	4	4	8	73.6	C Moderately modified

None	small	Moderate	Large	Serious	Critical

REACH	*INSTREAM HABITAT*	*RIPARIAN ZONE*	*IHI SCORE*	*CLASS*
GK1	67.8	71.7	69.7	C Moderately modified
GK2	69.9	73.6	71.7	C Moderately modified

- From the results of the application of the IHIA to the GK1 assessment site, it is evident that there are some impacts at the present time.
- Instream impacts included a large impact from flow modifications, water quality, inundation as well as moderate bed modifications. Overall, the site achieved a 67.8% score for instream integrity.
- The largest riparian zone impacts include exotic vegetation encroachment, bank erosion, water quality and inundation. The site achieved a 71.7% score for riparian zone integrity.
- The site obtained an overall IHIA rating of 69.7%, which indicates moderately modified (Class C conditions). The site, therefore, falls within the DEMC for the quaternary catchment in terms of habitat integrity.
- From the results of the application of the IHIA to the GK2 assessment site, it was observed that instream impacts included a moderate impact from water abstraction, flow modifications, water quality and inundation. Overall, the site achieved a 69.9% score for instream integrity.
- The largest riparian zone impacts include exotic vegetation encroachment, vegetation removal and inundation. The site achieved a 73.6% score for riparian integrity.
- The site obtained an overall IHIA rating of 71.7%, which indicates moderately modified (Class C conditions). The site, therefore, falls within the DEMC for the quaternary catchment in terms of habitat integrity.

Table 13 provides a summary of the results obtained from the application of the IHAS Index to the two assessment sites on the Geelklipspruit. This index determines habitat suitability with particular

reference to the requirements of aquatic macro-invertebrates. The results obtained from this assessment will aid in interpreting the SASS data.

Table 13: A summary of the results obtained from the application of an IHAS index to the assessment sites

Type of Result	Site GK1 (Upstream)	Site GK2 (Downstream)
McMillan, 1998 IHAS description	Habitat structure and diversity was inadequate for supporting a diverse aquatic macro-invertebrate community.	Habitat structure and diversity was inadequate for supporting a diverse aquatic macro-invertebrate community.
IHAS stones biotopes results	There was an adequate availability of rocky substrate for supporting a diversity of aquatic macro-invertebrate communities.	Only bedrock present at the site.
IHAS vegetation biotopes results	Adequate marginal vegetation was present to provide habitat for aquatic macro-invertebrates.	Marginal vegetation was present to provide habitat for aquatic macro-invertebrates.
IHAS other biotopes results	Adequate gravel, sand and muddy deposits available at the time of the assessment.	Very limited mud and gravel deposits were present at this point as the riverbed at this point was dominated by bedrock.
IHAS general stream characteristics	A relatively narrow, moderately flowing stream with a low diversity of flows. The stream is discolored at this point and banks are relatively stable due to the abundant bankside vegetation at this point.	The stream consisted of little diversity of depth and flow profiles at the time of assessment, with clear water. Banks were considered relatively stable with abundant bankside vegetation present at the time of the assessment.
IHAS score	61	63
Current IHAS Adjustment score	+22	+26

- Habitat structure and diversity was inadequate for supporting a diverse aquatic macro-invertebrate community.
- Habitat conditions at both sites vary slightly with an increase of 3.3% in habitat conditions at the downstream site and as such, it is expected that a slight variation (increased diversity and sensitivity) in the aquatic communities can be expected at the downstream point.

4.4 Aquatic macro-invertebrate community assessment

Tables 14 and 15 provide a summary of the results obtained from the application of the SASS5 and IHAS indices to the Geelklipspruit sites.

Table 14: Biotope specific summary of the results obtained from the application of the SASS5 index to the Geelklipspruit sites

PARAMETER		STONES	VEGETATION	GRAVEL, SAND AND MUD	TOTAL
SASS5 Score	GK1	26	48	29	68
	GK2	35	46	0	63
Taxa	GK1	6	10	8	16
	GK2	4	10	0	12
ASPT	GK1	4.3	4.8	3.6	4.3
	GK2	8.8	4.6	0	5.3

Table 15: A summary of the results obtained from the application of the SASS5 and IHAS indices to the Geelklipspruit sites

Type of Result	Site GK1 (Upstream)	Site GK2 (Downstream)
Biotopes sampled	Stones in current, gravel, sand, mud and marginal vegetation in current.	Bedrock and marginal vegetation.
Sensitive taxa present	*Caenidae; Aeshnidae,*	*Caenidae;*
Sensitive taxa absent	*Platycnemidae; Chlorocyphidae; Ecnomidae; Hydroptilidae; Lepidostomatidae; Pisuliidae; Corduliidae; Platycnemidae; Protoneuridae; Unionidae; Limnichidae*	*Heptageniidae, Elmidae; Naucoridae; Ephemeridae; Psychomyiidae; Xiphocentronidae; Polycentropodidae; Ancylidae; Hydraenidae; Heptageniidae; Leptoceridae*
Adjusted SASS5 score	90	89
SASS% of upstream reference	NA	92.6%
ASPT% of upstream reference	NA	123.3%
SASS5 % of reference score	28.3%	26.3%
ASPT % of reference score	63.2%	77.9%
Dallas, 2007 classification	Class E/F	Class E/F
Dickens and Graham, 2001 SASS5 classification	Class E (Severely impaired)	Class E (Severely impaired)

- The streams at the GK1 and GK2 sites may be considered to be in a Class E (severely impaired) condition according to the Dickens & Graham (2001) classification system. Both sites can be classified as a Class E/F condition according to the Dallas (2007) classification system.
- Spatially, between the upstream and the downstream sites, the SASS5 score decreased by 7.4% while the ASPT score increased by 23.3%. This is likely due to the bedrock present at the downstream site and can be considered natural variation.
- From the results of the current assessment, it is thus unlikely that some impacts as a result of the Eskom Majuba Plant are taking place on this section of the stream although the system as a whole can be considered to be impaired.
- The construction of the proposed service road as well as the development of the UCG Project will have an effect on the sensitivity and diversity of the system. It is imperative that all mitigation measures be adhered to, to minimise the impact and prevent further degradation of the system due to the proposed project.

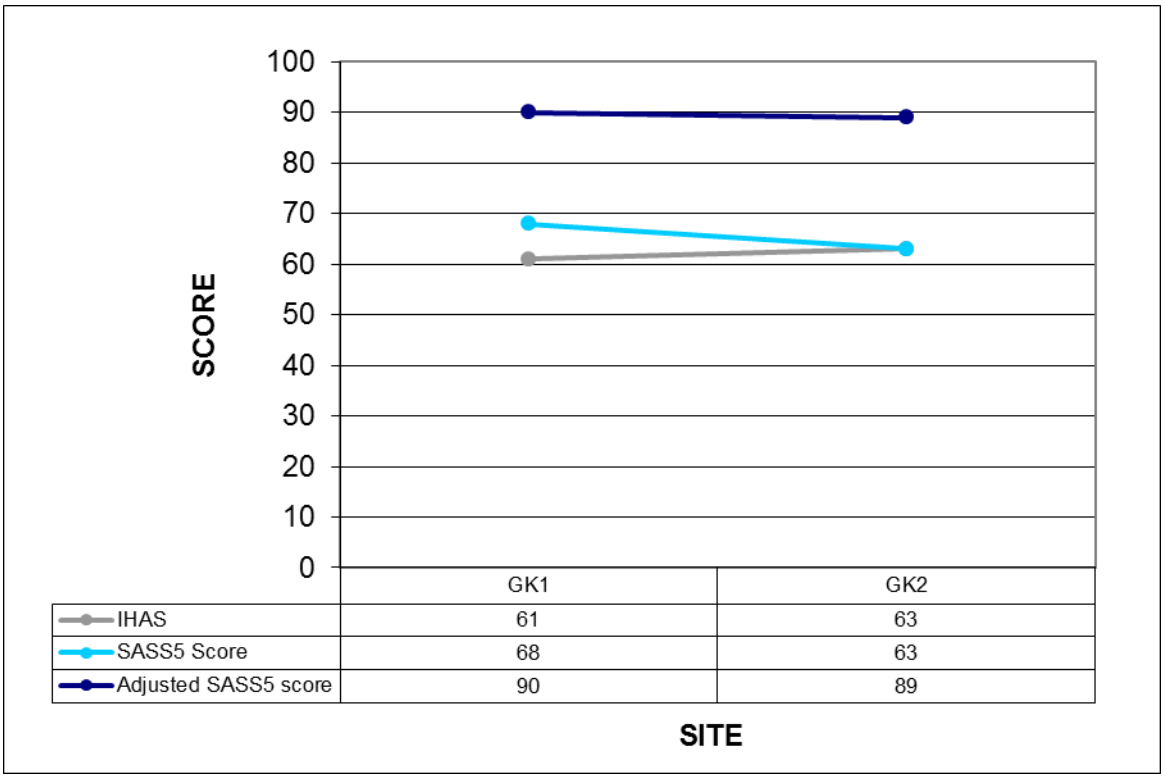

Figure 9: SASS and IHAS score variation between the upstream GK1 and downstream GK2 sites

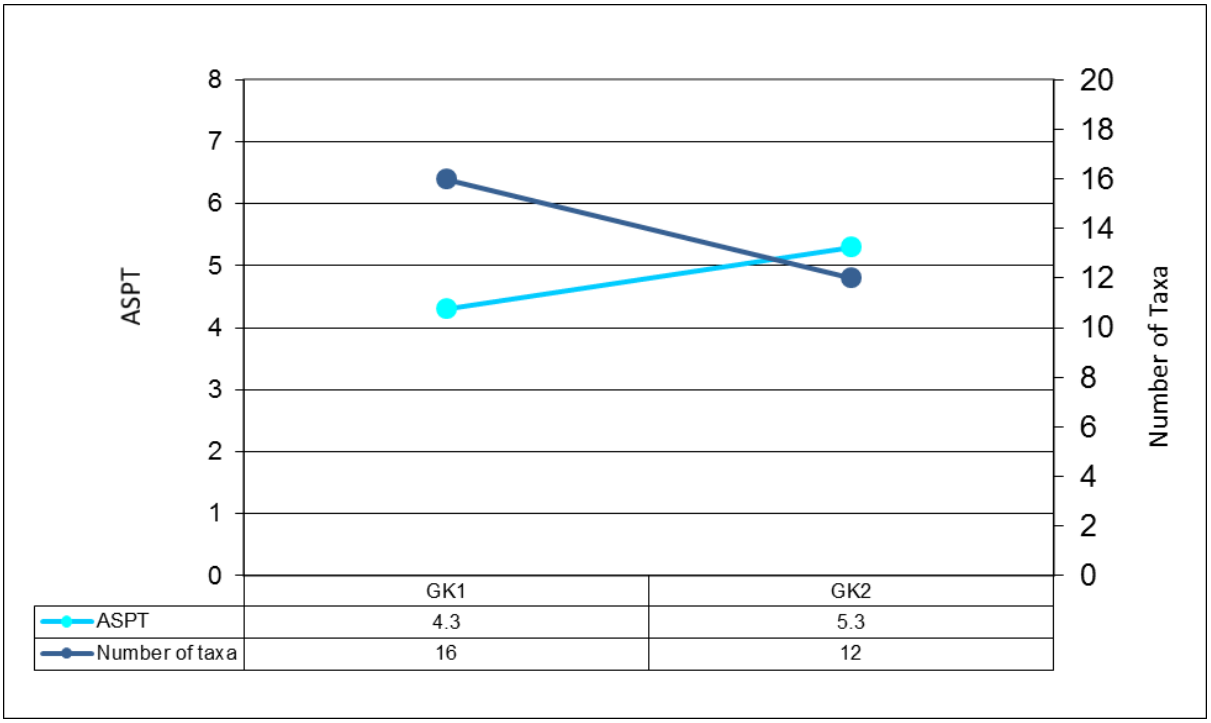

Figure 10: SASS and number of Taxa score variation between the upstream GK1 and downstream GK2 sites

4.5 Aquatic Macro-Invertebrates: MIRAI

The results obtained after employing the MIRAI are summarised below. For ease of comparison the classifications obtained using SASS5 are also presented in this section.

Table 16: Summary of the results (ecological categories) obtained from the application of the MIRAI to the two assessment sites, compared to classes awarded using SASS5.

Variable / Index	GK1	GK2
Ecological category (MIRAI)	D	D
Dickens and Graham (SASS5)	E	E
Dallas (SASS5)	E/F	E/F

From the table above it is clear that the MIRAI results in terms of (Ecological Category classification) correlate with the results obtained using the SASS class classifications. Both GK1 and GK2 can be classified as Class D (Largely modified) conditions with only tolerant taxa present at the time of the assessment. Any further impact on the system will lead to the critical loss of aquatic ecosystem diversity and sensitivity.

4.6 Fish Community Assessment

The HCR (Habitat Cover Rating) result for the site assessed is provided below:

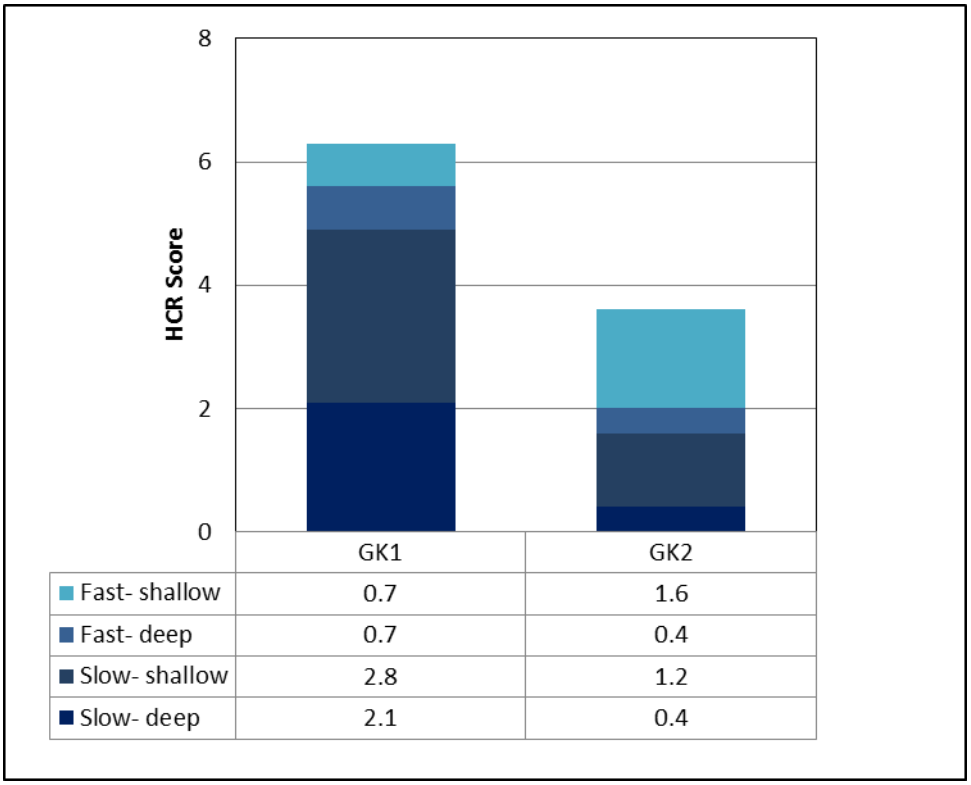

Figure 11: HCR score for the assessed sites

It is clear that slow-shallow and shallow-deep conditions predominate in the GK1 system, while fast-shallow and slow-shallow predominate the GK2 system. The fish expected in the GK1 system will therefore be limited to fish with high intolerance values for fast flowing water while the GK2 system will be expected to host species with a high intolerance value for deep habitats and water column cover. In general some significant limitations on the fish community can be expected with the degree of impact determined by the severity of the water quality and migration barriers on the system.

Table 17: Fish species collected at the various sites indicating abundance (i.e. numbers collected used for site score evaluation in the FRAI assessment) with natural ranges included in the Vaal River system (Skelton, 2001; Kleynhans, 2003; Kleynhans, Louw and Moolman, 2007).

SPECIES NAME	NUMBERS OF FISH COLLECTED AT THE VARIOUS SITES WITH ASSOCIATED ABUNDANCE SCORE (AS):				FROC[1] score (Vaal River segment)	
	GK1		GK2		TOTAL	
	No. fish	AS[4]	No. fish	AS[4]		
Barbus anoplus[2]	5	1	3	1	8	2
Labeobarbus aeneus[3]	0	0	6	2	6	2

[1] Fish species previously encountered in the Vaal River (catchment C11H) for which FROC (reference frequency of occurrence) values are listed (Kleynhans *et al.* 2007). Where fish species were collected that were not previously listed, the FROC scores employed were derived as described in the respective footnotes. Only these species (i.e. previously encountered plus actually encountered but not previously listed) were used for application of the FRAI assessment for the system (i.e. pooled for all four sites).
[2] FROC score from Vaal River catchment C11H (fish species FROC score not listed in catchment C11J).
[3] FROC score from Vaal River catchment C11H (fish species FROC score not listed in catchment C11J).
[4] AS = Abundance score. For site specific analyses abundance scores were determined for each site and used as FROC scores in the FRAI assessment. Abundance scores (AS) were classified as follows:
1 to 5 fish = 1
6 to 15 fish = 2
16 to 30 = 3
31 to 60 = 4
61 to 120 = 5

Table 18: Summary of the result (ecological categories) obtained from the application of the FRAI to the assessment site

Variable / Index	GK1	GK2
Refined EC (FRAI)	D	D
Dickens & Graham classification	E	E

EC = Ecological category

From the above it is clear that the EC calculated for the FRAI largely corresponds to that obtained for the macro-invertebrate classification which would be expected since the drivers affecting the two assemblages are largely similar. Both the GK1 and GK2 sites can be classified as largely modified (Class D) systems with regards to fish sensitivity and diversity.

4.7 Riparian Vegetation Response Assessment Index (VEGRAI)

Table 19: The overall VEGRAI score of the Geelklipspruit in the study area

LEVEL 3 ASSESSMENT					
METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**% WEIGHT**
MARGINAL	81.9	51.2	2.8	1.0	100.0
NON MARGINAL	74.3	27.9	0.0	2.0	60.0
2.0					160.0
LEVEL 3 VEGRAI (%)				79.0	
VEGRAI EC				**B/C**	
AVERAGE CONFIDENCE				1.4	

The score attained for the VEGRAI indicated that the riparian system falls into the category B/C. This indicates that the area has suffered a moderate loss of natural habitat, biota and basic ecosystem functions. There has been slight erosion of the study area. A small amount of alien invasive vegetation is also present, most notably within the riparian zones, and can be attributed to the anthropogenic disturbances of the area over the years.

4.8 THE PROCESS STREAM (P. Stream)

The Process Stream is a biomonitoring point which lies downstream of the proposed service road and development and upstream of the GK2 downstream site.

4.9 Visual Assessment

Figure 12: Upstream view of the P. Stream site indicating the large pool habitats present at this point at the time of the assessment.

Figure 13: Local view of the P.Stream site indicating the pool habitats and low flow conditions at this point.

Table 20: Description of the location of the assessment site Lm7

Characteristics	Site P. Stream
Significance of the point	This point is situated downstream of the proposed service road and upstream of the GK2 downstream site. Any negative impacts on the system as a result of the development activities would be evident at this point.
Surrounding anthropogenic activities	This point is situated in an open area close to the Eskom site offices.
Surrounding impacts	The surrounding catchment has been impacted upon by mining and agricultural activities.
Riparian zone characteristics	The riparian zone at this point is very narrow with a steep incised channel and large impacts from erosion.
Depth characteristics	The stream at this point consists of shallower runs and shallow pool areas.
Flow condition	Low, slow flowing water at the time of assessment with little variation.
Water clarity	Clear
Stones habitat characteristics	The river at this point has limited cobble and stone substrates present.
Vegetation habitat characteristics	Marginal vegetation as well as some aquatic vegetation present at the time of the assessment.
Other habitat characteristics	There were extensive muddy deposits present at this point for suitably adapted organisms at the time of the assessment.
Erosion potential	Extensive bank erosion potential under high flow conditions due to limited marginal vegetation cover. Banks are steep and incised and are prone to failure.

4.10 Biota specific water quality

Table 21 below records the biota specific water quality of the P.Stream site.

Table 21: Biota specific water quality variables recorded at the P. Stream site

Site	Cond ms/m	PH	DO mg/l	Temp °C
P. Stream	56.9	7.64	5.56	25.3

- Water quality based on the biota specific parameters may be considered poor for the P. Stream site;
- The EC at P. Stream may be considered to be significantly elevated from natural conditions;
- The pH at P. Stream may be considered as largely natural;
- Saturation (i.e. maximum dissolved oxygen concentrations) shall in turn depend on the temperature of the water sampled (USA EPA website accessed 11 April 2014). The current readings were expressed as a percentage of the potential maximum (Table 22);

Table 22: Oxygen measured expressed as a percentage of maximum concentration at the temperature measured.

Site	Oxygen (mg/L)	Temperature when measured (°C)	Maximum oxygen at that temperature (mg/L)	Oxygen measured expressed as percentage of maximum
P. Stream	5.56	25.3	8.24	67.5

- The dissolved oxygen content at the P.Stream site falls below the 80% saturation. The dissolved oxygen levels at the site is likely to limit the sensitivity and diversity of the aquatic communities present;
- The temperature was normal for the time of the year when sampling took place.

4.11 Habitat Assessment

In stream Habitat Integrity

Weights	14	13	13	13	14	10	9	8	6		
REACH	Water abstraction	Flow modification	Bed modification	Channel modification	Water quality	Inundation	Exotic macrophytes	Exotic fauna	Solid waste disposal	Total Score (%)	Classification

P. Stream	7	14	12	16	10	5	3	4	2	56.6	D Largely modified

None	Small	Moderate	Large	Serious	Critical

Riparian Zone Habitat Integrity

Weights	13	12	14	12	13	11	12	13		
REACH	Vegetation removal	Alien encroachment	Bank erosion	Water abstraction	Flow modification	Channel modification	Water quality	Inundation	Total Score (%)	Classification
P.Stream	6	12	14	5	6	6	6	8	61.7	C Moderately modified

None	small	Moderate	Large	Serious	Critical

REACH	*INSTREAM HABITAT*	*RIPARIAN ZONE*	*IHI SCORE*	*CLASS*
P.Stream	56.6	61.7	59.1	D Largely modified

- From the results of the application of the IHIA to the P. Stream assessment site, instream impacts were found to include large impacts from flow, bed and channel modifications as well as moderate water quality modifications. Overall, the site achieved a 56.6% score for instream integrity.
- The largest riparian zone impact was found to be from the effect of erosion at the site. The site achieved a 61.7% score for riparian integrity.
- The site obtained an overall IHIA rating of 59.1%, which indicates largely modified (Class D conditions). The site, therefore, falls below the DEMC for the quaternary catchment. Further degradation of this point should be prevented as far as possible.

Table 23 provides a summary of the results obtained from the application of the IHAS Index to the assessment site on the Process Stream. This index determines habitat suitability with particular reference to the requirements of aquatic macro-invertebrates. The results obtained from this assessment will aid in defining the habitat condition.

Table 23: A summary of the results obtained from the application of and IHAS indices to the assessment sites

Type of Result	Site P. Stream
McMillan, 1998 IHAS description	Habitat structure and diversity was inadequate for supporting a diverse aquatic macro-invertebrate community.
IHAS stones biotopes results	Limited rocky substrate was available at the time of the assessment.
IHAS vegetation biotopes results	Adequate marginal vegetation was present at the site. This will contribute to the diversity of the aquatic community at this point.
IHAS other biotopes results	Extensive mud deposits were present for colonisation by suitably adapted organisms.

Type of Result	Site P. Stream
IHAS general stream characteristics	A relatively narrow stream with little diversity of depth classes and clear water at the time of the assessment. The stream channel has been affected by erosion and the stream is incised with steep banks with further potential for erosion to take place.
IHAS score	57
IHAS Adjustment score	+21

- The P. Stream site indicated habitat structure and diversity that is inadequate for supporting diverse aquatic macro-invertebrate communities.

4.12 Aquatic macro-invertebrate community assessment

Tables 24 and 25 are a summary of the results obtained from the application of the SASS5 and IHAS indices to the P. Stream site.

Table 24: Biotope specific summary of the results obtained from the application of the SASS5 index to the Process Stream site

PARAMETER	SITE	STONES	VEGETATION	GRAVEL, SAND AND MUD	TOTAL
SASS5 Score	P.Stream	20	30	20	56
Taxa		6	6	4	12
ASPT		3.3	5.0	5.0	4.7

Table 25: A summary of the results obtained from the application of the SASS5 and IHAS indices to the Process Stream.

Type of Result	Site P. Stream
Biotopes sampled	Vegetation out of current, gravel, sand, mud, some stones in current.
Sensitive taxa present	*Aeshnidae; Caenidae*
Sensitive taxa absent	*Athericidae; Leptophlebiidae; Leptoceridae; Platycnemidae, Heptageniidae, Psephnidae; Philopotamidae, Dixidae; Tricorythidae; Chlorocyphidae; Perlidae; Chlorolestidae; Hydracarina; Gomphidae; Ancylidae; Atyidae;*
Adjusted SASS5 score	77
SASS5 % of reference score	23.3%
ASPT % of reference score	69.1%
Dallas 2007 SASS5 classification	Class E/F
Dickens & Graham, 2001 SASS5 classification	Class E (Severely impaired)

- The Process Stream may be considered to be in a Class E/F condition according to the Dallas (2007) classification system and in a Class E (severely impaired) condition according to the Dickens & Graham (2001) classification system.

4.13 Aquatic Macro-Invertebrates: MIRAI

The results obtained after employing the MIRAI are summarised below. For ease of comparison the classifications obtained using SASS5 are also presented in this section.

Table 26: Summary of the results (ecological categories) obtained from the application of the MIRAI to the four assessment sites, compared to classes awarded using SASS5.

Variable / Index	P. Stream
Ecological category (MIRAI)	D
Dickens and Graham (SASS5)	E
Dallas (SASS5)	E/F

From the table above it is clear that the MIRAI results in terms of (Ecological Category classification) correlate with the results obtained using the SASS class classifications. The P. Stream can be classified as largely modified (Class D) in terms of the macro-invertebrate sensitivity and diversity, and is likely due to the erosion and channel modification present at the site.

4.14 Fish Community Assessment

The HCR (Habitat Cover Rating) results for the Process Stream:

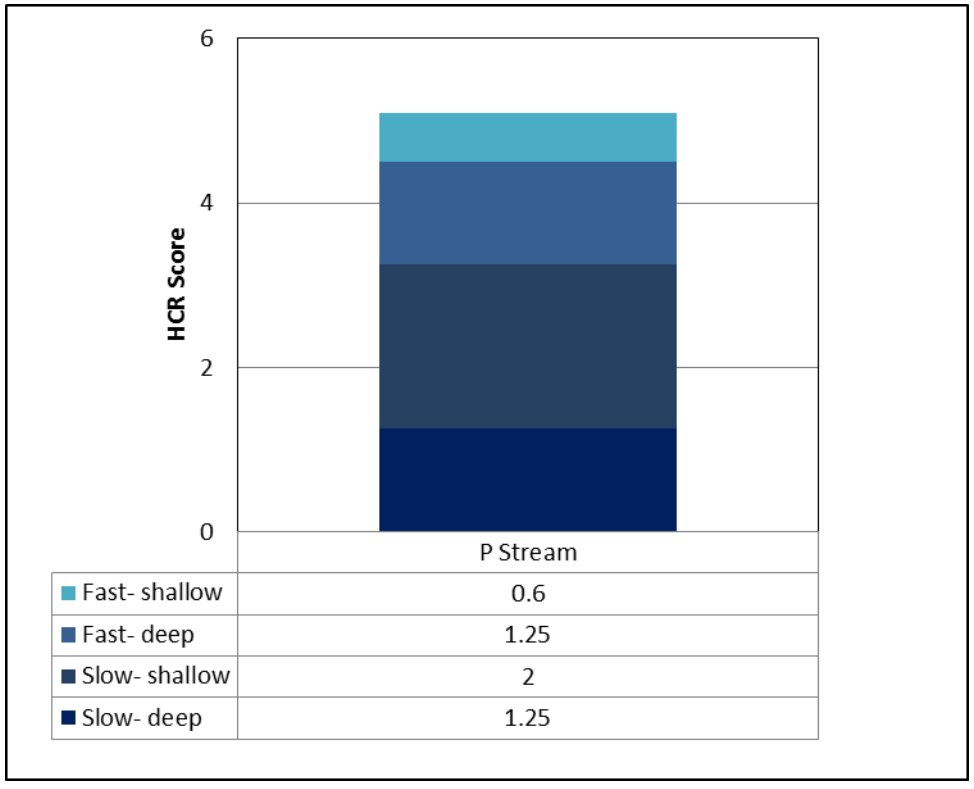

Figure 14: HCR scores for the four sites assessed

It is clear that slow-shallow conditions predominate in the system followed by slow-deep conditions. The fish expected in the area will therefore be limited to fish with high intolerance values for flowing water and to a lesser degree species with a high intolerance value for deep habitats and water column

cover. In general some significant limitations on the fish community can be expected with the degree of impact determined by the severity of the water stress on the system.

Table 27: Fish species collected at the various sites indicating abundance (i.e. numbers collected used for site score evaluation in the FRAI assessment) with natural ranges included in the Vaal River system (Skelton, 2001; Kleynhans, 2003; Kleynhans, Louw and Moolman, 2007).

SPECIES NAME	NUMBERS OF FISH COLLECTED AT THE VARIOUS SITES WITH ASSOCIATED ABUNDANCE SCORE (AS):		FROC[1] score (Vaal River segment)	
	P Stream		TOTAL	
	No. fish	AS[4]		
Barbus anoplus[2]	7	2	7	2

[1] Fish species previously encountered in the Vaal River (catchment C11H) for which FROC (reference frequency of occurrence) values are listed (Kleynhans *et al.* 2007). Where fish species were collected that were not previously listed, the FROC scores employed were derived as described in the respective footnotes. Only these species (i.e. previously encountered plus actually encountered but not previously listed) were used for application of the FRAI assessment for the system (i.e. pooled for all four sites).
[2] FROC score from Vaal River catchment C11H (fish species FROC score not listed in catchment C11J).
[4] AS = Abundance score. For site specific analyses abundance scores were determined for each site and used as FROC scores in the FRAI assessment. Abundance scores (AS) were classified as follows:
1 to 5 fish = 1
6 to 15 fish = 2
16 to 30 = 3
31 to 60 = 4
61 to 120 = 5

Table 28: Summary of the results (ecological categories) obtained from the application of the FRAI to the four assessment sites, compared to that obtained using MIRAI.

Variable / Index	P Stream
Refined EC (FRAI)	D
Ecological category (MIRAI)	E

EC = Ecological category

From the above it is clear that the EC calculated for the FRAI largely corresponds to that obtained for the MIRAI which would be expected since the drivers affecting the two assemblages are largely similar. Because the habitat flow and cover conditions (and hence potential drivers) were fairly homogenous between the sites (see section 4.12), the EC values between the sites were also similar. The P.Stream can be classified as largely modified in terms of fish sensitivity and diversity present at the site at the time of the assessment. Should the proposed development further impact on the system, the aquatic ecosystem will suffer a critical loss of biodiversity and sensitivity.

4.15 Riparian Vegetation Response Assessment Index (VEGRAI)

Table 29: The overall VEGRAI score of the Process Stream in the study area

LEVEL 3 ASSESSMENT					
METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**% WEIGHT**
MARGINAL	65.7	41.1	3.3	1.0	100.0
NON MARGINAL	74.3	27.9	0.0	2.0	60.0
2.0					160.0
LEVEL 3 VEGRAI (%)				68.9	
VEGRAI EC				**C**	
AVERAGE CONFIDENCE				1.7	

The score attained for the VEGRAI indicated that the riparian system falls into the category C. This indicates that the area has suffered a moderate loss of natural habitat, biota and basic ecosystem functions. This is in accordance with what was observed during the site visit and survey. There has been significant erosion of the study area and can be attributed to the anthropogenic disturbances of the area over the years. Development without proper mitigation can lead to the further loss of natural riparian vegetation.

5 IMPACT ASSESSMENT

5.1 Impact Identification and Assessment

The tables below serve to summarise the significance of potential impacts on the integrity of the aquatic resources affected by the proposed development of the UCG plant and service road. A summary of all potential construction, operational, rehabilitation and cumulative impacts is provided in Section 5.6. The sections below present the impact assessment according to the method described in Section 2.12 of the Method of Assessment. In addition, it also indicates the required mitigatory measures needed to minimise the impact and presents an assessment of the significance of the impacts taking into consideration the available mitigatory measures assuming that they are fully implemented at an acceptable cost. Mitigatory measures have been presented for both construction and operational phase impacts. In addition the mitigatory measures have been defined as both essential mitigation measures and recommended mitigation measures.

5.2 IMPACT 1: Impacts as a result of Groundwater Contamination

Introductory discussion and Rationale

Groundwater contamination is considered "the most significant environmental risk related to UCG" (LLNL, 2011). The gasification process creates a number of compounds in the coal seam, including phenols and polycyclic aromatic hydrocarbons, benzene, carbon dioxide, ammonia and sulphide. These compounds can migrate from the gasification zone and contaminate surrounding ground water.

Whilst some of these factors can be influenced to a certain extent, most of the risk of wider groundwater pollution is governed by the natural characteristics of the site, namely the permeability of in-situ rocks and geological structures, hydrogeological conditions and the impact of the reactor caving on local ground conditions. Site selection is therefore key to addressing concerns over groundwater pollution.

Poor Quality Groundwater:

It should be noted that the pre-existing groundwater that are present in and around the coal seam may be of very poor quality, with high TDS and high concentrations of certain ions associated with the leaching of minerals over long periods of time. This groundwater can represent a risk if the changes to underground strata and hydrogeology caused by the UCG operations causes them to flow to 'economically or environmentally significant' aquifers in the overburden. This is known as 'cross-contamination' of aquifer horizons.

Activities potentially leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to the placement of infrastructure close to water courses and underground aquifers	Groundwater influx during construction	Clean and dirty water systems not being managed to the required specifications to prevent contamination of clean water areas.	Poor closure measures followed
		Groundwater influx during operational phase	Generation of wastewater during cavity flushing/venting or remediation.
		Groundwater plume surrounding the reactor not maintained	

Aspects of Aquatic ecology affected

Construction	Operational	Decommissioning & Closure
Impacts on groundwater quality which could manifest in surface water sources	Impacts on groundwater quality which could manifest in surface water sources	Impacts on groundwater quality which could manifest in surface water sources

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Unmanaged	**5**	**3**	**4**	**3**	**5**	**8**	**12**	**96 (Medium-High)**

Essential mitigation measures:

- Appropriate site selection and investigation. Ensure that UCG has limited connectivity with other water resources;
- Shutdown procedures must be followed. The gasification zone must be allowed to cool slowly, while continued gas extraction takes place until the gasification process stops completely.
- Post gasification reactor flushing - It may be advantageous to pump water from the reactor post gasification for two reasons; firstly it ensures that groundwater flow is maintained towards the reactor by lowering the local hydrostatic pressure and secondly, it removes contaminants from the reactor so that they may be treated and disposed of at the surface;
- Monitoring borehole design and construction as well as continued groundwater monitoring after closure.

Recommended mitigation measures

- No infrastructure should encroach into any major drainage lines;
- Restrict construction activities to the drier winter months, if possible, to avoid sedimentation and siltation of riparian features in the vicinity of the proposed development;
- Maintain the groundwater plume around the reactor to avoid aqueous phase contamination.

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Managed	**2**	**3**	**3**	**2**	**4**	**5**	**9**	**45 (Low)**

Probable latent impacts

- Ongoing contamination of groundwater resources.

5.3 IMPACT 2: Impacts due to Subsidence

Introductory discussion and Rationale

Subsidence is the sinking or lowering of a surface region relative to the surrounding region. It occurs as a result of the removal of material from the underground coal formation.

In general, UCG subsidence results in height decrease equivalent to one-third of the vertical thickness of the coal seam and would only affect land directly above the gasified coal seam. The

magnitude and characteristics of subsidence depends on many factors including the seam depth, rock stiffness and yield strength, disposition of seam, the stress resulting from the gasification, and other geological properties. Subsidence typically results in a uniform lowering of the region as opposed to abrupt potholes.

The primary concern with subsidence is the effect it can have on re-routing surface waters and local impacts on shallow aquifers and infrastructure likes roads and pipelines.

Activities potentially leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to the underground mining of surface infrastructure and rivers.	Due to improper site selection, rivers and surface infrastructure deliberately undermined.	Due to improper site selection, rivers and surface infrastructure deliberately undermined.	Poor planning leading to the underground mining of surface infrastructure and rivers.

Aspects of Aquatic ecology affected

Construction	Operational	Decommissioning & Closure
Root shear and vegetation death at the tensile strains of the curvature of the subsidence surface	Root shear and vegetation death at the tensile strains of the curvature of the subsidence surface	Changes in drainage features and surface water flow
Changes in drainage features and surface water flow	Changes in drainage features and surface water flow	Visual amenity changes
Visual amenity changes	Provide a passage for gas loss	Loss of flow sensitive macroinvertebrates and fish
Loss of flow sensitive macroinvertebrates and fish	Create a connection between the cavity and overlying aquifers such that water ingress into the cavity increases	Alien vegetation encroachment
Loss of aquatic habitats for aquatic macroinvertebrates and fish	Visual amenity changes	
Alien vegetation encroachment	Loss of flow sensitive macroinvertebrates and fish	
	Alien vegetation encroachment	
	Loss of aquatic habitats for aquatic macroinvertebrates and fish	

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Unmanaged	**5**	**3**	**3**	**2**	**5**	**8**	**10**	**80 (Medium-High)**

Essential mitigation measures:

- Appropriate site selection and investigation. Ensure that UCG has limited connectivity with other water resources and surface infrastructure;
- Buffer areas should be allocated to all wetland, riparian and surface infrastructure to avoid deliberate undermining as far as possible;
- Sites should be actively monitored to determine the rate and extent of surface subsidence.

Recommended mitigation measures

- No infrastructure should encroach into any major drainage lines.

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Managed	2	3	2	1	4	5	7	35 (Low)

Probable latent impacts

- Ongoing contamination of underground resources;
- Ongoing impact on stream flow.

5.4 IMPACT 3: Impacts on Aquatic Ecology due to Wastewater generation

Impaired water quality due to pollutants discharged from UCG Plant

The gas solution produced by UCG contains a component of liquid or vaporized water (produced water) which is removed from the gas before the gas is combusted in a power plant. This water contains residual hydrocarbons, benzenes and possibly phenols and polycyclic aromatic hydrocarbons, but it is expected to be fully treatable.

A further consideration is the run-off of pollutants from the UCG Plant area following rainfall, due to the activities within that area.

Impaired water quality due to petrochemical spills

Fuel or oil spills from vehicles could contaminate surface water resources. Leakages, spills or run-off from vehicle wash bays, workshop facilities, fuel depots or storage facilities of potentially polluting substances could contaminate surface water resources.

Activities potentially leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to the placement of infrastructure near to water courses as well as road crossings and bridges	Mining to open the facility	Clean and dirty water systems not being managed to the required specifications to prevent contamination of clean water areas.	Generation of wastewater during cavity flushing, venting and remediation of site.
Inadequate design of infrastructure, with special mention of clean and dirty water systems, gas treatment, wastewater and cavity flushing/pumping water areas.	Clean and dirty water systems not being constructed to the required specifications to prevent contamination of clean water areas.	Disturbance of soils leading to increased erosion	
Inadequate separation of clean and dirty water areas	Site clearing and the removal of vegetation leading to increased runoff and erosion	Potential contamination from fuel and hazardous chemicals	
	Disturbance of soils leading to increased erosion	Contamination of groundwater	
	Potential contamination from fuel and hazardous chemicals		
	Contamination of groundwater		

Aspects of Aquatic ecology affected

Construction	Operational	Decommissioning & Closure
Loss of water quality sensitive macro-invertebrates and fish	Loss of water quality sensitive macro-invertebrates and fish	Latent release of contaminants in sediments leading to the formation of an on-going source of potential water contamination
Impact on riparian vegetation structures due to impaired water quality	Impact on riparian vegetation structures due to impaired water quality	Impacts on groundwater quality which could manifest in surface water sources
Build-up of contaminants in sediments leading to the creation of a sediment sink and chronic source of potential water contamination	Build-up of contaminants in sediments leading to the creation of a sediment sink and chronic source of potential water contamination	
Increased turbidity of water	Impacts on groundwater quality which could manifest in surface water sources	
	Increased turbidity of water	

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Unmanaged	**4**	**3**	**3**	**3**	**3**	**7**	**9**	**63 (Medium-Low)**
Essential mitigation measures:								

- Very clear and well managed clean and dirty water separation must take place;
- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise the loss of clean water runoff areas and the concomitant recharge of streams in the area.
- Keep all demarcated sensitive zones outside of the construction area off limits during the construction phase of the project;
- All hazardous chemicals must be stored on bunded surfaces;
- Ensure that all spills are immediately cleaned up;
- Monitor groundwater to identify any problematic plumes of contamination;
- On-going aquatic ecological monitoring must take place on a 6 monthly basis by a suitably qualified assessor.

Recommended mitigation measures

- Permit only essential construction personnel within 32m of all riparian systems;
- No infrastructure should encroach into any major drainage lines;
- Restrict construction activities to the drier winter months, if possible, to avoid sedimentation and siltation of riparian features in the vicinity of the proposed development and aim for completion in early spring at which time revegetation should take place allowing for a full summer growing season to become established.

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Managed	2	3	2	2	2	5	6	30 (Low)

Probable latent impacts

- Ongoing salinisation of the water courses in the area;
- Impacts on pH
- Impacts on dissolved oxygen concentration and saturation
- Loss of aquatic taxa intolerant to poor quality water;
- Altered riparian vegetation structures.

5.5 IMPACT 4: Loss of Aquatic Habitat

Habitat destruction is the alteration of a natural habitat to the point that it is rendered unfit to support the species dependent upon it as their home territory. Many organisms previously using the area are displaced or destroyed, reducing biodiversity. Globally modification of habitats for agriculture is the chief cause of such habitat loss. Other causes of habitat destruction include surface mining, deforestation, slash-and-burn practices and urban development. Habitat destruction is presently ranked as the most significant cause of species extinction worldwide. Additional causes of habitat destruction include water pollution, introduction of alien species, overgrazing and overfishing.

Riverine systems and particularly ephemeral riverine systems or river systems that have very low flows as part of their annual hydrological cycles are particularly susceptible to changes in habitat

condition. The proposed development project has the potential to lead to habitat loss and/or alteration of the aquatic and riparian resources on the study area.

It is however important to note that the aquatic ecology, and especially aquatic habitats of most of the systems has been seriously to critically impaired and as such the risk to the receiving environment as a result of the proposed project is reduced to some degree.

Activities leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to the placement of infrastructure near to water courses as well as road crossings and bridges	Site clearing and the removal of vegetation leading to increased runoff and erosion	On-going disturbance of soils with general operational activities	Alien vegetation encroachment
Inadequate design of infrastructure, with special mention of the service road leading to changes to systems leading to altered hydrology	Site clearing and road construction and the disturbance of soils leading to increased erosion	Alien vegetation encroachment	
	Earthworks in the vicinity of drainage systems leading to increased runoff and erosion and altered runoff patterns		
	Construction of the service road altering stream flow patterns and water velocities		
	Alien vegetation encroachment		

Aspects of instream habitat affected

Construction	Operational	Decommissioning & Closure
Erosion and incision of riparian zone	Erosion and incision of riparian zone	Erosion and incision of riparian zone
Loss of aquatic refugia	Loss of aquatic refugia	Loss of aquatic refugia
Altered substrate conditions due to the deposition of silt	Altered substrate conditions due to the deposition of silt	Altered substrate conditions due to the deposition of silt
Altered depth and flow regimes in the major drainage systems	Altered depth and flow regimes in the major drainage systems	Alien vegetation proliferation
Alien vegetation proliferation	Alien vegetation proliferation	

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Unmanaged	**4**	**3**	**3**	**3**	**3**	**7**	**9**	**63 (Medium-Low)**

Essential mitigation measures:

- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise the loss of aquatic habitats in the area.
- Keep all demarcated sensitive zones outside of the construction area off limits during the construction phase of the project;
- On-going aquatic ecological monitoring must take place on a 6 monthly basis by a suitably qualified assessor.

Recommended mitigation measures

- Permit only essential construction personnel within 32m of all riparian systems;
- No infrastructure should encroach into any major drainage lines;
- Restrict construction activities to the drier winter months, if possible, to avoid sedimentation and siltation of riparian features in the vicinity of the proposed development and aim for completion in early spring at which time revegetation should take place allowing for a full summer growing season to become established.

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Managed	2	3	2	2	2	5	6	30 (Low)

Probable latent impacts

- Sedimentation of the systems may occur for long after the project is completed;
- Eroded and incised streams are unlikely to be rehabilitated.
- Silted up refuge pools are unlikely to be naturally rehabilitated.

5.6 IMPACT 5: Loss of Aquatic Biodiversity and Sensitive Taxa

Aquatic resources in the area can be considered abundant; however they are generally exposed to significant water stress. The aquatic resources in the area do however support, or potentially support, an aquatic community of significant diversity and sensitivity. The aquatic resources in the area have mostly been affected severely by agricultural practices with special mention of the following impacts:

- Impacts on stream bed structure and instream habitat;
- Bankside vegetation cover and riparian zone integrity; and
- Water quality with special mention of increased salt loads.

The aquatic ecology of the area can potentially be impacted by further reductions in instream flow, altered water quality and habitat loss. Additional impacts can be expected to occur during construction due to the clearing of footprint areas and increased runoff of silt rich water. During the operational phase of the project impacts on water quality are considered to be particularly likely. Post closure impacts on water quality may continue due to seepage from the UCG Plant.

Activities leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to the placement of infrastructure within riverine features with special mention of road crossings and bridges	Site clearing and the removal of vegetation during road construction	On-going disturbance of soils with general operational activities	Inadequate closure leading to post closure impacts on water quality
Inadequate design of infrastructure leading to contamination of water and sediments in the streams	Construction of bridge crossings altering stream flow patterns and water velocities	Inadequate separation of clean and dirty water areas	On-going erosion of disturbed areas that have not been adequately rehabilitated
	Placement of infrastructure within riverine features with special mention of road crossings and bridges	Potential contamination from fuel and hazardous chemicals	
	Inadequate separation of clean and dirty water areas	Contamination of groundwater	
	Potential contamination from fuel and hazardous chemicals		

Aspects of biotic integrity affected

Construction	Operational	Decommissioning & Closure
Sedimentation and loss of natural substrates	Sedimentation and loss of natural substrates	Sedimentation and loss of natural substrates
Altered stream channel forms	Altered stream channel forms	Altered stream channel forms
Increased turbidity of water	Increased turbidity of water	Loss of refugia
Loss of refugia	Loss of refugia	Loss of flow sensitive macro-invertebrates and fish
Deterioration in water quality	Deterioration in water quality	Loss of water quality sensitive macro-invertebrates and fish
Loss of flow sensitive macroinvertebrates and fish	Loss of flow sensitive macroinvertebrates and fish	Loss of riparian vegetation species
Loss of water quality sensitive macroinvertebrates and fish	Loss of water quality sensitive macroinvertebrates and fish	
Loss of riparian vegetation species	Loss of riparian vegetation species	

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Unmanaged	**4**	**3**	**3**	**3**	**2**	**7**	**8**	**56 (Medium-Low)**

Essential mitigation measures:

- Very clear and well managed clean and dirty water separation must take place;
- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise the loss of clean water runoff

areas and the concomitant recharge of streams in the area.
- Keep all demarcated sensitive zones outside of the construction area off limits during the construction phase of the project;
- All hazardous chemicals must be stored on bunded surfaces;
- Ensure that all spills are immediately cleaned up;
- Monitor groundwater to identify any problematic plumes of contamination;
- On-going aquatic ecological monitoring must take place on a 6 monthly basis by a suitably qualified assessor.

Recommended mitigation measures

- Permit only essential construction personnel within 32m of all riparian systems;
- No infrastructure should encroach into any major drainage lines;
- Restrict construction activities to the drier winter months, if possible, to avoid sedimentation and siltation of riparian features in the vicinity of the proposed development.

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Managed	2	3	2	1	2	5	5	25 (Very Low)

Probable latent impacts

- Ongoing salinisation of the water courses in the area;
- Impacts on pH
- Impacts on dissolved oxygen concentration and saturation
- Loss of aquatic taxa intolerant to poor quality water;
- Altered riparian vegetation structures.

5.7 IMPACT 6: Loss of Instream Flow, Aquatic Refugia and Flow Dependent Taxa

The drainage features in the area are generally relatively small drainage systems. Any impact on instream flow will therefore be significant and has the potential to have a significant impact on the ecology of these riverine systems.

A substantial increase to the peak flow of flood events in the drainage systems of the area could cause erosion and change in channel character and dimensions, destroy riverine vegetation, alter bed roughness and cause eroded sediment to be deposited downstream.

It is expected that Project activities will cause a change to peak flows in the river systems downstream of the Project site, due to the following factors:

- Change in surface coverage. Development of the Project area will change the surface coverage in some areas from vegetated soil to buildings, hardened gravel roads, paved areas

(parking), and compacted earth. These new surface types will allow considerably less infiltration into the ground (typically 0-20%) as compared to the natural surface (typically 60-70%), resulting in more surface run-off following storms and consequently higher peak flow rates.

- Capture of run-off and capture of rainfall in the 'dirty' area would lower instream flow in the receiving environment.
- Canalisation of run-off.

In technical terms, the time of concentration would be reduced, reducing the time of concentration results in higher peak flow rates. This effect is dependent on the design of the canalisation system, as increasing the length of flow paths, and implementing other detention measures, could negate this effect.

Furthermore, if the canals only extend as far as to route water around the outer edge of operational areas, then concentrated volumes of water will be discharged at point locations leading to altered surface and subterranean hydrology.

Subsidence is the sinking or lowering of a surface region relative to the surrounding region. It occurs as a result of the removal of material from the underground coal formation. The primary concern with subsidence is the effect it can have on re-routing surface waters and local impacts on shallow aquifers and infrastructure likes roads and pipelines.

All the above factors are likely to lead to altered riverine recharge flood peaks and a general loss of runoff volumes successfully reaching the water courses in the area as well as the other major drainage systems in the area which in turn lead to the loss of aquatic biota such as fish and aquatic macro-invertebrates which rely on the presence of surface water as well as the riparian zone which relies on base flows as well as recharge by larger rainfall events.

Activities potentially leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading extensive dirty water areas which need to be managed and reducing the runoff to the drainage systems in the area	Construction of clean and dirty water separation structures for pollution control purposes.	Impact on natural stream flow regulation and stream recharge due to altered hydrology in the area	Loss of water to inadequately rehabilitated areas such as clean and dirty water separation systems

Inadequate design of clean and dirty water separation systems leading to loss of recharge of the larger systems	Site clearing and the removal of vegetation leading to increased runoff and erosion	Loss of water through clean and dirty water separation as well as stream diversion systems	Impact on natural stream flow regulation and stream recharge due to altered hydrology in the area
Design of canals leading to rapid release of water which in turn will lead to a loss of stream flow regulation capabilities in the area	Construction of bridge crossings altering stream flow patterns and water velocities		

Aspects of instream habitat and flow affected

Construction	Operational	Decommissioning & Closure
Loss of instream surface and base flow	Loss of instream surface and base flow	Loss of instream surface and base flow
The drying out of aquatic refugia	The drying out of aquatic refugia	The drying out of aquatic refugia
Loss of streamflow regulation and stream recharge	Loss of streamflow regulation and stream recharge	Loss of streamflow regulation and stream recharge
Loss of aquatic habitats for aquatic macro-invertebrates and fish	Loss of aquatic habitats for aquatic macro-invertebrates and fish	Loss of aquatic habitats for aquatic macro-invertebrates and fish
Increased moisture stress on riparian vegetation	Increased moisture stress on riparian vegetation	Increased moisture stress on riparian vegetation

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Unmanaged	**4**	**3**	**3**	**4**	**4**	**7**	**11**	**77 (Medium-High)**

Essential mitigation measures:

- Very clear and well managed clean and dirty water separation must take place;
- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise the loss of clean water runoff areas and the concomitant recharge of streams in the area.
- Keep all demarcated sensitive zones outside of the construction area off limits during the construction phase of the project.

Recommended mitigation measures

- Permit only essential construction personnel within 32m of all riparian systems;
- No infrastructure should encroach into any major drainage lines;
- Restrict construction activities to the drier winter months, if possible, to avoid sedimentation and siltation of riparian features in the vicinity of the proposed development and aim for completion in early spring at which time revegetation should take place allowing for a full summer growing season to become established.

	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Managed	**2**	**3**	**2**	**2**	**1**	**5**	**5**	**25 (Very Low)**

Probable latent impacts

- Reduced recharge of the drainage systems of the area affected by upstream and adjacent usage;
- Reduced availability of refugia for aquatic biota;
- Altered riparian vegetation structures.
- Impacts due to subsidence are possible.

5.8 Impact assessment conclusion

Based on the above assessment it is evident that there are six possible impacts on the aquatic ecology of the area observed. In considering the impacts and mitigation, it is assumed that a high level of mitigation will take place without high prohibitive costs. From the table it is evident that prior to mitigation, the impacts on groundwater, subsidence, and instream flow and refuge are medium- high level impacts, which can be mitigated and will be reduced to low and very- low level impacts. The impacts from wastewater generation, loss of aquatic habitat and loss of aquatic biodiversity and sensitivity are medium-low level impacts, when mitigation takes place, these impacts on aquatic ecology in the area will be reduced to low and very low level impacts.

Table 30: Summary of impact significance

No	Impact	Prior to mitigation	Post mitigation
1	Impacts on Groundwater	Medium- High	Low
2	Impacts due to Subsidence	Medium- High	Low
3	Impacts due to Wastewater Generation	Medium- Low	Low
4	Loss of Aquatic Habitat	Medium- Low	Low
5	Loss of Aquatic Biodiversity and Sensitivity	Medium- Low	Very- Low
6	Loss of Instream Flow and Aquatic Refugia	Medium- High	Very- Low

6 CONCLUSION

Scientific Aquatic Services (SAS) and Royal HaskoningDHV (RHDHV) were appointed by Eskom UCG to undertake a Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) analysis of the aquatic and riparian resources as part of the environmental assessment and authorisation process for the Eskom Underground Coal Gasification (UCG) Project's required water use licenses. The project area identified for UCG is located opposite the Majuba Power Station,

Amersfoort, Mpumalanga (hereafter referred to as “the proposed project”). The proposed project forms part of a feasibility implementation pilot project with the goal of determining the commercial viability of using UCG as a primary source of fuel to generate electricity.

The following summarizes the results of the aquatic assessment of the Geelklipspruit:

Biota specific water quality

- The EC value between the two sites decreases by 72.2%. The decrease in a downstream direction is seen as an improvement in the water quality.
- The decrease in EC in a downstream direction indicates that no contribution of salts as a result of the Eskom Majuba Plant is likely to be taking place at the current time.
- The pH at GK1 and GK2 may be considered to be largely natural with a 4.0% decrease between the upper and lower sampling points. This change falls within the DWA TWQR (DWAF, 1996) which advocates no change greater than 5% from reference or temporal data. Close monitoring of this trend should however need to continue.
- The dissolved oxygen content at the GK2 site exceeded the 80% saturation while the dissolved oxygen content at the GK1 site falls below the DWA TQWR (DWAF, 1996). The upstream GK1 site is likely to limit the sensitivity and diversity of the aquatic communities present at this point in the system;
- The observed spatial variation in temperature can be ascribed to natural and diurnal variations between sampling times as well as the nature of the stream at each point.

Habitat Assessment

- From the results of the application of the IHIA to the GK1 assessment site, it is evident that there are some impacts at the present time.
- Instream impacts included a large impact from flow modifications, water quality, inundation as well as moderate bed modifications. Overall, the site achieved a 67.8% score for instream integrity.
- The largest riparian zone impacts include exotic vegetation encroachment, bank erosion, water quality and inundation. The site achieved a 71.7% score for riparian zone integrity.
- The site obtained an overall IHIA rating of 69.7%, which indicates moderately modified (Class C conditions). The site, therefore, falls within the DEMC for the quaternary catchment in terms of habitat integrity.
- From the results of the application of the IHIA to the GK2 assessment site, it was observed that instream impacts included a moderate impact from water abstraction, flow modifications, water quality and inundation. Overall, the site achieved a 69.9% score for instream integrity.

- The largest riparian zone impacts include exotic vegetation encroachment, vegetation removal and inundation. The site achieved a 73.6% score for riparian zone integrity.
- The site obtained an overall IHIA rating of 71.7%, which indicates moderately modified (Class C conditions). The site, therefore, falls within the DEMC for the quaternary catchment in terms of habitat integrity.
- Habitat structure and diversity was inadequate for supporting a diverse aquatic macro-invertebrate community.
- Habitat conditions at both sites vary slightly with an increase of 3.3% in habitat conditions at the downstream site and as such, it is expected that a slight variation (increased diversity and sensitivity) in the aquatic communities can be expected at the downstream point.

Aquatic macro-invertebrate community assessment

- The streams at the GK1 and GK2 sites may be considered to be in a Class E (severely impaired) condition according to the Dickens & Graham (2001) classification system. Both sites can be classified as a Class E/F condition according to the Dallas (2007) classification system.
- Spatially, between the upstream and the downstream sites, the SASS5 score decreased by 7.4% while the ASPT score increased by 23.3%. This is likely due to the bedrock present at the downstream site and can be considered natural variation.
- It is clear that the MIRAI results in terms of (Ecological Category classification) correlate with the results obtained using the SASS class classifications. Both GK1 and GK2 can be classified as Class D (Largely modified) conditions with only tolerant taxa present at the time of the assessment.
- From the results of the current assessment, it is thus unlikely that some impacts as a result of the Eskom Majuba Plant are taking place on this section of the stream although the system as a whole can be considered to be impaired.
- The construction of the proposed service road as well as the development of the UCG Project will have an effect on the sensitivity and diversity of the system. It is imperative that all mitigation measures be adhered to, to minimise the impact and prevent further degradation of the system due to the proposed project.

Fish community assessment

- It is clear that slow-shallow and shallow-deep conditions predominate in the GK1 system, while fast-shallow and slow-shallow predominate the GK2 system.

- The fish expected in the GK1 system will therefore be limited to fish with high intolerance values for fast flowing water while the GK2 system will be expected to host species with a high intolerance value for deep habitats and water column cover.
- In general some significant limitations on the fish community can be expected with the degree of impact determined by the severity of the water quality and migration barriers on the system.
- It is clear that the EC calculated for the FRAI largely corresponds to that obtained for the macro-invertebrate classification which would be expected since the drivers affecting the two assemblages are largely similar. Both the GK1 and GK2 sites can be classified as largely modified (Class D) systems with regards to fish sensitivity and diversity.

Riparian Vegetation Response Assessment

- The score attained for the VEGRAI indicated that the riparian system falls into the category B/C.
- This indicates that the area has suffered a moderate loss of natural habitat, biota and basic ecosystem functions.
- There has been slight erosion of the study area.
- A small amount of alien invasive vegetation is also present, most notably within the riparian zones, and can be attributed to the anthropogenic disturbances of the area over the years.

The following summarizes the Process Stream results:

Biota specific water quality

- Water quality based on the biota specific parameters may be considered poor for the P. Stream site;
- The EC at P. Stream may be considered to be significantly elevated from natural conditions;
- The pH at P. Stream may be considered as largely natural;
- The dissolved oxygen content at the P.Stream site falls below the 80% saturation. The water in this system is likely to limit the sensitivity and diversity of the aquatic communities present or exposed to this water;
- DO can be considered as unsuitable for sustaining an aquatic community; and
- The temperature was normal for the time of the year when sampling took place.

Habitat Assessment

- From the results of the application of the IHIA to the P. Stream assessment site, instream impacts were found to include large impacts from flow, bed and channel modifications as well

as moderate water quality modifications. Overall, the site achieved a 56.6% score for instream integrity.

- The largest riparian zone impact was found to be from the effect of erosion at the site. The site achieved a 61.7% score for riparian integrity.
- The site obtained an overall IHIA rating of 59.1%, which indicates largely modified (Class D conditions). The site, therefore, falls below the DEMC for the quaternary catchment. Further degradation of this point should be prevented as far as possible.
- The P. Stream site indicated habitat structure and diversity that is inadequate for supporting diverse aquatic macro-invertebrate communities.

Aquatic macro-invertebrate community assessment

- The Process Stream may be considered to be in a Class E/F condition according to the Dallas (2007) classification system and in a Class E (severely impaired) condition according to the Dickens & Graham (2001) classification system.
- From the table above it is clear that the MIRAI results in terms of (Ecological Category classification) correlate with the results obtained using the SASS class classifications. The P. Stream can be classified as largely modified (Class D) in terms of the macro-invertebrate sensitivity and diversity, and is likely due to the erosion and channel modification present at the site.

Fish community assessment

- It is clear that slow-shallow conditions predominate in the system followed by slow-deep conditions.
- The fish expected in the area will therefore be limited to fish with high intolerance values for flowing water and to a lesser degree species with a high intolerance value for deep habitats and water column cover.
- In general some significant limitations on the fish community can be expected with the degree of impact determined by the severity of the water stress on the system.
- From the above it is clear that the EC calculated for the FRAI largely corresponds to that obtained for the MIRAI which would be expected since the drivers affecting the two assemblages are largely similar. Because the habitat flow and cover conditions (and hence potential drivers) were fairly homogenous between the sites (see section 4.12), the EC values between the sites were also similar. The P.Stream can be classified as largely modified in terms of fish sensitivity and diversity present at the site at the time of the assessment.

Riparian Vegetation Response Assessment

- The score attained for the VEGRAI indicated that the riparian system falls into the category C.
- This indicates that the area has suffered a moderate loss of natural habitat, biota and basic ecosystem functions.
- There has been significant erosion of the study area and can be attributed to the anthropogenic disturbances of the area over the years.

Based on the impact assessment it is evident that there are six possible impacts on the aquatic ecology of the area observed. In considering the impacts and mitigation, it is assumed that a high level of mitigation will take place without high prohibitive costs. From the table it is evident that prior to mitigation, the impacts on groundwater, subsidence, and instream flow and refuge are medium- high level impacts, which can be mitigated and will be reduced to low and very- low level impacts. The impacts from wastewater generation, loss of aquatic habitat and loss of aquatic biodiversity and sensitivity are medium-low level impacts, when mitigation takes place, these impacts on aquatic ecology in the area will be reduced to very low level impacts.

Based on the findings of this study it is the opinion of the aquatic ecologists that the proposed UCG project be considered favourably, from an aquatic ecological point of view, provided that the mitigatory measures presented in this report are strictly adhered to.

7 REFERENCES

Bromilow, C. 2010. Second Edition, Second Impression. *Problem Plants of South Africa.* Briza Publications, Pretoria, RSA.

Dada R., Kotze D., Ellery W. and Uys M. 2007. WET-RoadMap: *A Guide to the Wetland Management Series*. WRC Report No. TT 321/07. Water Research Commission, Pretoria.

DWA, South Africa *Version 1.0 of Resource Directed Measures for Protection of Water Resources,* 1999. [Appendix W3].

De Villiers, C., Driver, A., Clark, B., Euston-Brown, D., Day, L., Job, N., Helme, N., Van Ginkel, CE., Glen, RP., Gordon-Gray, KD., Cilliers, CJ., Muasya, M and van Deventer, PP. 2011. *Easy identification of some South African Wetland Plants*. WRC Report No TT 479/10.

DWA and Forestry (2005). A practical field procedure of identification and delineation of wetlands and riparian areas**. DWA, Pretoria.**

DWAF. 2007. *Manual for the assessment of a Wetland Index of Habitat Integrity for South African floodplain and channelled valley bottom wetland types* by M. Rountree (ed); C.P. Todd, C. J. Kleynhans, A. L. Batchelor, M. D. Louw, D. Kotze, D. Walters, S. Schroeder, P. Illgner, M. Uys. and G.C. Marneweck. Report no. N/0000/00/WEI/0407. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Du Preez, L and Carruthers, V. 2008. A complete guide to the frogs of Southern Africa. Stuiker Nature, Random house, Cape Town, South Africa

Kleynhans C.J. 1999. *A procedure for the determination of the ecological reserve for the purposes of the national water balance model for South African River*. Institute of Water Quality Studies, Department of Water Affairs & Forestry, Pretoria.

Kleynhans CJ, Mackenzie J, Louw MD. 2007. Module F: *Riparian Vegetation Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination* (version 2). Joint Water Research Commission and DWA and Forestry report. WRC Report No.

Kleynhans C.J., Thirion C. and Moolman J. 2005. *A Level 1 Ecoregion Classification System for South Africa, Lesotho and Swaziland*. Report No. N/0000/00/REQ0104. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria

Kotze D.C., Marneweck G.C., Batchelor A.L., Lindley D.S., Collins. N.B., 2005 *Wet Eco-services. A technique for rapidly assessing ecosystem services supplied by wetlands.*

Lawrence Livermore National Laboratory, 2011. Presentation on LLNL underground coal gasification program to DOI, Office of Surface Mining. September 20, 2011.

Macfarlane D.M., Kotze D.C., Ellery W.N., Walters D., Koopman V., Goodman P. and Goge C. 2008. *WET-Health: A technique for rapidly assessing wetland health.* WRC Report No. TT 340/08. Water Research Commission, Pretoria.

Mucina, L. & Rutherford, M.C. (Eds). 2006. *The Vegetation of South Africa, Lesotho and Swaziland.* Strelitzia 19. South African National Biodiversity Institute, Pretoria, RSA.

Nel, JL, Driver, A., Strydom W.F., Maherry, A., Petersen, C., Hill, L., Roux, D.J, Nienaber, S., Van Deventer, H., Swartz, E. & Smith-Adao, L.B. 2011a*. Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources*. Water Research Commission Report No. TT 500/11, Water Research Commission, Pretoria.

Ollis, DJ; Snaddon, CD; Job, NM & Mbona, N. 2013. *Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems*. SANBI Biodiversity Series 22. South African Biodiversity Institute, Pretoria.

Onderstall, Jo. 1984. *Transvaalse Laeveld en Platorand insluitende Die Nationale Krugerwildtuin. Veldblomgids van Suid-Africa*. Botaniese Vereniging van Suid-Afrika, Kaapstad, RSA.

Rowntree K.M. and Wadeson R.A. 2000. An Index of Stream Geomorphology for the Assessment of River Health. *Field Manual for Channel Classification and Condition Assessment*. NAEBP Report Series No. 13, Institute of Water Quality Studies, Department of Water Affairs and Forestry, Pretoria. Available: http://www.csir.co.za/rhp/reports/reportseries13.html.

Sinclair, I. and Ryan, P. 2010. *Birds of Africa south of the Sahara*. Struik Nature, Cape town, RSA.

Smit, N. 2008. *Field Guide to the Acacias of South Africa*. Briza Publications, Pretoria, RSA.

The South African National Biodiversity Institute - Biodiversity GIS (BGIS) *[online].* URL: http://bgis.sanbi.org

SRK Consulting & Natural Scientific Services cc 2010 Faunal Assessment for the proposed Chapudi Coal Project near Waterpoort, Limpopo Province

The South African National Biodiversity Institute - Biodiversity GIS (BGIS) *[online].* Retrieved 2011/12/21 URL: http://bgis.sanbi.org

Van Ginkel CE., Glen RP., Gordon-Gray KD., Cilliers CJ., Muasya M., Van Deventer PP. 2011. Wetland Plants. WRC Report No TT 479/10.

Van Oudtshoorn, F. 2004. Second Edition, Third Print. *Guide to Grasses of South Africa.* Briza Publications, Pretoria, RSA.

Van Rooyen, N. 2001. Flowering plants of the Kalahari Dunes. Ecotrust cc, RSA.

Zietsman PC & Zietsman, LE. 2010. Department of Botany, National Museum. Bloemfontein Centre for Environmental Management, University of the Free State, Bloemfontein.

Van Wyk, B. and van Wyk, P. 1997. *Field Guide to Trees of Southern Africa*. Struik Publishers, Cape Town, RSA.

Van Wyk, B., van Wyk, P. and van Wyk B.E. 2011. *Photo Guide to Trees of Southern Africa*. Briza Publications, Pretoria, RSA.

Appendix 1: IHAS Score sheets March 2014

INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

River Name: Geelklipspruit
Site Name: GK1
Date: 24/03/2014

SAMPLING HABITAT	0	1	2	3	4	5
STONES IN CURRENT (SIC)						
Total length of white water rapids (i.e.: bubbling water) (in meters)	none	0-1	>1-2	>2-3	>3-5	>5
Total length of submerged stones in current (run) (in meters)	none	0-2	>2-5	>5-10	>10	
Number of separate SIC area's kicked (not individual stones)	0	1	2-3	4-5	6+	
Average stone size's kicked (cm's) (gravel is <2, bedrock is >20)	none	<2>20	2-10	11-20	2-20	
Amount of stone surface clear (of algae, sediment, etc) (in %)*	n/a	0-25	26-50	51-75	>75	
PROTOCOL: time spent actually kicking stones (in minutes) (gravel/bedrock = 0 min)	0	<1	>1-2	2	>2-3	>3
(* NOTE: up to 25% of stone is usually embedded in the stream bottom)						
SIC Score (max 20):				**12**		
VEGETATION	**0**	**1**	**2**	**3**	**4**	**5**
Length of fringing vegetation sampled (river banks) (PROTOCOL - in meters)	none	0-½	>½-1	>1-2	2	>2
Amount of aquatic vegetation sampled (underwater) (in square meters)	none	0-½	>½-1	>1		
Fringing vegetation sampled in: ('still' = pool/still water only; 'run' = run only)	none		run	pool		mix
Type of vegetation (% leafy veg. As opposed to stems/shoots) (aq. Veg. Only = 49%)	none	0	1-25	26-50	51-75	>75
Vegetation Score (max 15):					**9**	
OTHER HABITAT/GENERAL	**0**	**1**	**2**	**3**	**4**	**5**
Stones out of current (SOOC) sampled: (PROTOCOL - in square meters)	none	0-½	>½-1	1	>1	
Sand sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones)	none	under	0-½	>½-1	1	>1
Mud sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones)	none	under	0-½	½	>½	
Gravel sampled: (PROTOCOL - in minutes) (if all gravel, SIC stone size = <2)**	none	0-½	½	>½**		
Bedrock sampled: ('all' = no SIC, sand, or gravel then SIC stone size = >20)**	none	some			all**	
Algae present: ('1-2m² = algal bed; 'rocks' = on rocks; 'isol' = isolated clumps)***	>2m²	rocks	1-2m²	<1m²	isol	none
Tray identification: (PROTOCOL - using time: 'coor' = correct time)		under		corr		over
(** NOTE: you must still fill in the SIC section)						
Other Habitat Score (max 20):					**12**	
HABITAT TOTAL (MAX 55):					**33**	
STREAM CONDITION	**0**	**1**	**2**	**3**	**4**	**5**
PHYSICAL						
River make up: ('pool' = pool/still/dam only; 'run' only; etc)	pool		run	rapid	2mix	3mix
Average width of stream: (in meters)		>10	>5-10	<1	1-2	>2-5
Average depth of stream: (in meters)	>2	>1-2	1	>½-1	½	<½
Approximate velocity of stream: ('slow' = <¼m/s; 'fast' = >1m/s) (use twig to test)	still	slow	fast	med		mix
Water colour: ('disc' = discoloured with visible colour but still transparent)	silty	opaque		disc		clear
Recent disturbance due to: ('const.' = construction; 'fl/dr' = flood or drought)***	flood	fire	constr	other		none
Bank/riparian vegetation is: ('grass' = includes reeds; 'shrubs' = include trees)	none		grass	shrubs	mix	
Surrounding impacts: ('erosn' = erosion/shear bank; 'farm' = farmland/settlement)***	erosn	farm	trees	other		open
Left bank cover: (rocks and vegetation) (in %)	0-50	51-80	81-95	>95		
Right bank cover: (rocks and vegetation) (in %)	0-50	51-80	81-95	>95		
(*** NOTE: if more than one option, choose the lowest)						
STREAM CONDITIONS TOTAL (MAX 28						
TOTAL IHAS SCORE (%):					**61**	

INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

River Name: Geelklipspruit
Site Name: GK2 **Date**: 24/03/2014

SAMPLING HABITAT	0	1	2	3	4	5
STONES IN CURRENT (SIC)						
Total length of white water rapids (i.e.: bubbling water) (in meters)	none	0-1	>1-2	>2-3	>3-5	>5
Total length of submerged stones in current (run) (in meters)	none	0-2	>2-5	>5-10	>10	
Number of separate SIC area's kicked (not individual stones)	0	1	2-3	4-5	6+	
Average stone size's kicked (cm's) (gravel is <2, bedrock is >20)	none	<2>20	2-10	11-20	2-20	
Amount of stone surface clear (of algae, sediment, etc) (in %)*	n/a	0-25	26-50	51-75	>75	
PROTOCOL: time spent actually kicking stones (in minutes) (gravel/bedrock = 0 min)	0	<1	>1-2	2	>2-3	>3
(* NOTE: up to 25% of stone is usually embedded in the stream bottom)						
SIC Score (max 20):				**7**		
VEGETATION	**0**	**1**	**2**	**3**	**4**	**5**
Length of fringing vegetation sampled (river banks) (PROTOCOL - in meters)	none	0-½	>½-1	>1-2	2	>2
Amount of aquatic vegetation sampled (underwater) (in square meters)	none	0-½	>½-1	>1		
Fringing vegetation sampled in: ('still' = pool/still water only; 'run' = run only)	none		run	pool		mix
Type of vegetation (%leafy veg. As opposed to stems/shoots) (aq. Veg. Only = 49%)	none	0	1-25	26-50	51-75	>75
Vegetation Score (max 15):					**11**	
OTHER HABITAT/GENERAL	**0**	**1**	**2**	**3**	**4**	**5**
Stones out of current (SOOC) sampled: (PROTOCOL - in square meters)	none	0-½	>½-1	1	>1	
Sand sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones)	none	under	0-½	>½-1	1	>1
Mud sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones)	none	under	0-½	½	>½	
Gravel sampled: (PROTOCOL - in minutes) (if all gravel, SIC stone size = <2)**	none	0-½	½	>½**		
Bedrock sampled: ('all' = no SIC, sand, or gravel then SIC stone size = >20)**	none	some			all**	
Algae present: ('1-2m² = algal bed; 'rocks' = on rocks; 'isol' = isolated clumps)***	>2m²	rocks	1-2m²	<1m²	isol	none
Tray identification: (PROTOCOL - using time: 'coor' = correct time)		under		corr		over
(** NOTE: you must still fill in the SIC section)						
Other Habitat Score (max 20):					**11**	
HABITAT TOTAL (MAX 55):					**29**	
STREAM CONDITION	**0**	**1**	**2**	**3**	**4**	**5**
PHYSICAL						
River make up: ('pool' = pool/still/dam only; 'run' only; etc)	pool		run	rapid	2mix	3mix
Average width of stream: (in meters)		>10	>5-10	<1	1-2	>2-5
Average depth of stream: (in meters)	>2	>1-2	1	>½-1	½	<½
Approximate velocity of stream: ('slow' = <¼m/s; 'fast' = >1m/s) (use twig to test)	still	slow	fast	med		mix
Water colour: ('disc' = discoloured with visible colour but still transparent)	silty	opaque		disc		clear
Recent disturbance due to: ('const.' = construction; 'fl/dr' = flood or drought)***	flood	fire	constr	other		none
Bank/riparian vegetation is: ('grass' = includes reeds; 'shrubs' = include trees)	none		grass	shrubs	mix	
Surrounding impacts: ('erosn' = erosion/shear bank; 'farm' = farmland/settlement)***	erosn	farm	trees	other		open
Left bank cover: (rocks and vegetation) (in %)	0-50	51-80	81-95	>95		
Right bank cover: (rocks and vegetation) (in %)	0-50	51-80	81-95	>95		
(*** NOTE: if more than one option, choose the lowest)						
STREAM CONDITIONS TOTAL (MAX 34						
TOTAL IHAS SCORE (%):					**63**	

INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

River Name: PROCESS STREAM
Site Name: PSTREAM 1 **Date**: 24/03/2014

SAMPLING HABITAT	0	1	2	3	4	5
STONES IN CURRENT (SIC)						
Total length of white water rapids (i.e.: bubbling water) (in meters)	none	0-1	>1-2	>2-3	>3-5	>5
Total length of submerged stones in current (run) (in meters)	none	0-2	>2-5	>5-10	>10	
Number of separate SIC area's kicked (not individual stones)	0	1	2-3	4-5	6+	
Average stone size's kicked (cm's) (gravel is <2, bedrock is >20)	none	<2>20	2-10	11-20	2-20	
Amount of stone surface clear (of algae, sediment, etc) (in %)*	n/a	0-25	26-50	51-75	>75	
PROTOCOL: time spent actually kicking stones (in minutes) (gravel/bedrock = 0 min)	0	<1	>1-2	2	>2-3	>3
(* NOTE: up to 25% of stone is usually embedded in the stream bottom)						
SIC Score (max 20):				**12**		
VEGETATION	**0**	**1**	**2**	**3**	**4**	**5**
Length of fringing vegetation sampled (river banks) (PROTOCOL - in meters)	none	0-½	>½-1	>1-2	2	>2
Amount of aquatic vegetation sampled (underwater) (in square meters)	none	0-½	>½-1	>1		
Fringing vegetation sampled in: ('still' = pool/still water only; 'run' = run only)	none		run	pool		mix
Type of vegetation (% leafy veg. As opposed to stems/shoots) (aq. Veg. Only = 49%)	none	0	1-25	26-50	51-75	>75
Vegetation Score (max 15):					**8**	
OTHER HABITAT/GENERAL	**0**	**1**	**2**	**3**	**4**	**5**
Stones out of current (SOOC) sampled: (PROTOCOL - in square meters)	none	0-½	>½-1	1	>1	
Sand sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones)	none	under	0-½	>½-1	1	>1
Mud sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones)	none	under	0-½	½	>½	
Gravel sampled: (PROTOCOL - in minutes) (if all gravel, SIC stone size = <2)**	none	0-½	½	>½**		
Bedrock sampled: ('all' = no SIC, sand, or gravel then SIC stone size = >20)**	none	some			all**	
Algae present: ('1-2m² = algal bed; 'rocks' = on rocks; 'isol' = isolated clumps)***	>2m²	rocks	1-2m²	<1m²	isol	none
Tray identification: (PROTOCOL - using time: 'coor' = correct time)		under		corr		over
(** NOTE: you must still fill in the SIC section)						
Other Habitat Score (max 20):					**14**	
HABITAT TOTAL (MAX 55):					**34**	
STREAM CONDITION	**0**	**1**	**2**	**3**	**4**	**5**
PHYSICAL						
River make up: ('pool' = pool/still/dam only; 'run' only; etc)	pool		run	rapid	2mix	3mix
Average width of stream: (in meters)		>10	>5-10	<1	1-2	>2-5
Average depth of stream: (in meters)	>2	>1-2	1	>½-1	½	<½
Approximate velocity of stream: ('slow' = <½m/s; 'fast' = >1m/s) (use twig to test)	still	slow	fast	med		mix
Water colour: ('disc' = discoloured with visible colour but still transparent)	silty	opaque		disc		clear
Recent disturbance due to: ('const.' = construction; 'fl/dr' = flood or drought)***	flood	fire	constr	other		none
Bank/riparian vegetation is: ('grass' = includes reeds; 'shrubs' = include trees)	none		grass	shrubs	mix	
Surrounding impacts: ('erosn' = erosion/shear bank; 'farm' = farmland/settlement)***	erosn	farm	trees	other		open
Left bank cover: (rocks and vegetation) (in %)	0-50	51-80	81-95	>95		
Right bank cover: (rocks and vegetation) (in %)	0-50	51-80	81-95	>95		
(*** NOTE: if more than one option, choose the lowest)						
STREAM CONDITIONS TOTAL (MAX 23						
TOTAL IHAS SCORE (%):					**57**	

Appendix 2: SASS5 Score sheets March 2014

RIVER HEALTH PROGRAMME - SASS 5 SCORE SHEET

DATE: 24/03/2014	TAXON		S	VG	GSM	TOT	TAXON		S	VG	GSM	TOT	TAXON		S	VG	GSM	TOT
GRID REFERENCE:	**PORIFERA**	5					**HEMIPTERA:**						**DIPTERA:**					
S:°	**COELENTERATA**	1					Belostomatidae*	3			**1**	**1**	Athericidae	10				
E:°	**TURBELLARIA**	3					Corixidae*	3	**A**		**A**	**B**	Blepharoceridae	15				
SITE CODE: GK1	**ANNELIDA:**						Gerridae*	5					Ceratopogonidae	5			**1**	**1**
RIVER: GEELKLIPSPRUIT	Oligochaeta	1	**A**		**1**	**A**	Hydrometridae*	6					Chironomidae	2				
SITE DESCRIPTION:	Leeches	3					Naucoridae*	7					Culicidae*	1	**1**	**1**		**A**
WEATHER CONDITION: HOT AND CLEAR	**CRUSTACEA:**						Nepidae*	3					Dixidae*	10				
TEMP: 23.0 °C	Amphipoda	13					Notonectidae*	3	**B**	**B**	**1**	**B**	Empididae	6				
Ph: 8.48	Potamonautidae*	3		**A**		**A**	Pleidae*	4					Ephydridae	3				
DO: 7.14 mg/l	Atyidae	8					Veliidae/M..veliidae*	5					Muscidae	1				
Cond: 95.6 mS/m	Palaemonidae	10					**MEGALOPTERA:**						Psychodidae	1				
BIOTOPES SAMPLED:	**HYDRACARINA**	8					Cordalidae	8					Simuliidae	5				
SIC: TIME: minutes	**PLECOPTERA:**						Sialidae	6					Syrphidae*	1				
SOOC:	Notonemouridae	14					**TRICHOPTERA**						Tabanidae	5				
BEDROCK:	Perlidae	12					Dipseudopsidae	10					Tipulidae	5				
AQUATIC VEG: DOM SP:	**EPHEMEROPTERA**						Ecnomidae	8					**GASTROPODA**					
M VEGIC: DOM SP:	Baetidae 1sp	4			**A**	**A**	Hydropsychidae 1sp	4					Ancylidae	6				
M VEGOOC: DOM SP:	Baetidae 2 sp	6					Hydropsychidae 2 sp	6					Bulininae*	3				
GRAVEL:	Baetidae >2 sp	12	**B**	**B**		**B**	Hydropsychidae >2 sp	12					Hydrobiidae*	3				
SAND:	Caenidae	6	**A**	**A**	**A**	**B**	Philopotamidae	10					Lymnaeidae*	3				
MUD:	Ephemeridae	15					Polycentropodidae	12					Physidae*	3		**B**		**B**
HAND PICKING/VISUAL OBS:	Heptageniidae	13					Psychomyiidae/Xiphocen.	8					Planorbidae*	3		**A**		**A**
FLOW:	Leptophlebiidae	9					**CASED CADDIS:**						Thiaridae*	3				
TURBIDITY:	Oligoneuridae	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
RIPARIAN LAND USE:	Polymitarcyidae	10					Calamoceratidae ST	11					**PELECYPODA**					
	Prosopistomatidae	15					Glossosomatidae SWC	11					Corbiculidae	5				
	Teloganodidae SWC	12					Hydroptilidae	6					Sphaeriidae	3				
	Tricorythidae	9					Hydrosalpingidae SWC	15					Unionidae	6				
	ODONATA:						Lepidostomatidae	10					**SASS SCORE:**		26	48	29	68
DISTURBANCE IN RIVER:	Calopterygidae ST,T	10					Leptoceridae	6					**NO OF TAXA:**		6	10	8	16
	Chlorocyphidae	10					Petrothrincidae SWC	11					**ASPT:**		4.33	4.80	3.63	4.25
	Chlorolestidae	8					Pisuliidae	10					**IHAS**:		61%			
	Coenagrionidae	4		**A**		**A**	Sericostomatidae SWC	13					**OTHER BIOTA**:					
	Lestidae	8					**COLEOPTERA:**											
SIGNS OF POLLUTION:	Platycnemidae	10					Dytiscidae*	5					**COMMENTS**:					
	Protoneuridae	8					Elmidae/Dryopidae*	8					* = airbreathers					
	Zygoptera juvs.	6					Gyrinidae*	5					SWC = South Western Cape					
	Aeshnidae	8		**1**		**1**	Halipidae*	5					T = Tropical					
	Corduliidae	8					Helodidae	12					ST = Sub-tropical					
OTHER OBSERVATIONS:	Gomphidae	6					Hydraenidae*	8					S = Stone & rock					
	Libellulidae	4			**A**	**A**	Hydrophilidae*	5		**A**		**A**	VG = all vegetation					
	LEPIDOPTERA:						Limnichidae	10					GSM = gravel, sand & mud					
	Pyralidae	12					Psephenidae	10					1=1, A=2-10, B=10-100, C=100-1000, D=>1000					

RIVER HEALTH PROGRAMME - SASS 5 SCORE SHEET

DATE: 24/03/2014	TAXON		S	VG	GSM	TOT	TAXON		S	VG	GSM	TOT	TAXON		S	VG	GSM	TOT
GRID REFERENCE:	**PORIFERA**	5					**HEMIPTERA:**						**DIPTERA:**					
S:°	**COELENTERATA**	1					Belostomatidae*	3		**A**		**A**	Athericidae	10				
E:°	**TURBELLARIA**	3					Corixidae*	3		**B**		**B**	Blepharoceridae	15				
SITE CODE: GK2	**ANNELIDA:**						Gerridae*	5		**A**		**A**	Ceratopogonidae	5				
RIVER: GEELKLIPSPRUIT	Oligochaeta	1					Hydrometridae*	6					Chironomidae	2		**A**		**A**
SITE DESCRIPTION:	Leeches	3					Naucoridae*	7					Culicidae*	1		**1**		**1**
WEATHER CONDITION: HOT AND CLEAR	**CRUSTACEA:**						Nepidae*	3					Dixidae*	10				
TEMP: 25.8 °C	Amphipoda	13					Notonectidae*	3					Empididae	6				
Ph: 8.14	Potamonautidae*	3					Pleidae*	4					Ephydridae	3				
DO: 7.86 mg/l	Atyidae	8					Veliidae/M..veliidae*	5		**A**		**A**	Muscidae	1				
Cond: 26.5 mS/m	Palaemonidae	10					**MEGALOPTERA:**						Psychodidae	1				
BIOTOPES SAMPLED:	**HYDRACARINA**	8					Cordalidae	8					Simuliidae	5	**A**			**A**
SIC: TIME: minutes	**PLECOPTERA:**						Sialidae	6					Syrphidae*	1				
SOOC:	Notonemouridae	14					**TRICHOPTERA**						Tabanidae	5				
BEDROCK:	Perlidae	12					Dipseudopsidae	10					Tipulidae	5				
AQUATIC VEG: DOM SP:	**EPHEMEROPTERA**						Ecnomidae	8					**GASTROPODA**					
M VEGIC: DOM SP:	Baetidae 1sp	4					Hydropsychidae 1sp	4					Ancylidae	6				
M VEGOOC: DOM SP:	Baetidae 2 sp	6					Hydropsychidae 2 sp	6					Bulininae*	3				
GRAVEL:	Baetidae >2 sp	12	**B**	**B**		**B**	Hydropsychidae >2 sp	12	**B**			**B**	Hydrobiidae*	3				
SAND:	Caenidae	6	**A**	**A**		**B**	Philopotamidae	10					Lymnaeidae*	3				
MUD:	Ephemeridae	15					Polycentropodidae	12					Physidae*	3				
HAND PICKING/VISUAL OBS:	Heptageniidae	13					Psychomyiidae/Xiphocen.	8					Planorbidae*	3				
FLOW:	Leptophlebiidae	9					**CASED CADDIS:**						Thiaridae*	3				
TURBIDITY:	Oligoneuridae	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
RIPARIAN LAND USE:	Polymitarcyidae	10					Calamoceratidae ST	11					**PELECYPODA**					
	Prosopistomatidae	15					Glossosomatidae SWC	11					Corbiculidae	5				
	Teloganodidae SWC	12					Hydroptilidae	6					Sphaeriidae	3				
	Tricorythidae	9					Hydrosalpingidae SWC	15					Unionidae	6				
	ODONATA:						Lepidostomatidae	10					**SASS SCORE:**		35	46	0	63
DISTURBANCE IN RIVER:	Calopterygidae ST,T	10					Leptoceridae	6					**NO OF TAXA:**		4	10	0	12
	Chlorocyphidae	10					Petrothrincidae SWC	11					**ASPT:**		8.75	4.60	0.00	5.25
	Chlorolestidae	8					Pisuliidae	10					**IHAS**:		63%			
	Coenagrionidae	4		**A**		**A**	Sericostomatidae SWC	13					**OTHER BIOTA**:					
	Lestidae	8					**COLEOPTERA:**											
SIGNS OF POLLUTION:	Platycnemidae	10					Dytiscidae*	5					**COMMENTS**:					
	Protoneuridae	8					Elmidae/Dryopidae*	8					* = airbreathers					
	Zygoptera juvs.	6					Gyrinidae*	5					SWC = South Western Cape					
	Aeshnidae	8					Halipidae*	5					T = Tropical					
	Corduliidae	8					Helodidae	12					ST = Sub-tropical					
OTHER OBSERVATIONS:	Gomphidae	6					Hydraenidae*	8					S = Stone & rock					
	Libellulidae	4					Hydrophilidae*	5		**1**		**1**	VG = all vegetation					
	LEPIDOPTERA:						Limnichidae	10					GSM = gravel, sand & mud					
	Pyralidae	12					Psephenidae	10					1=1, A=2-10, B=10-100, C=100-1000, D=>1000					

RIVER HEALTH PROGRAMME - SASS 5 SCORE SHEET

DATE: 24/03/2014	TAXON		S	VG	GSM	TOT	TAXON		S	VG	GSM	TOT	TAXON		S	VG	GSM	TOT
GRID REFERENCE:	**PORIFERA**	5					**HEMIPTERA:**						**DIPTERA:**					
S:°	**COELENTERATA**	1					Belostomatidae*	3		**1**		**1**	Athericidae	10				
E:°	**TURBELLARIA**	3					Corixidae*	3	**A**		**B**	**B**	Blepharoceridae	15				
SITE CODE: PSTREAM 1	**ANNELIDA:**						Gerridae*	5					Ceratopogonidae	5				
RIVER: PROCESS STREAM	Oligochaeta	1	**A**			**A**	Hydrometridae*	6					Chironomidae	2				
SITE DESCRIPTION:	Leeches	3					Naucoridae*	7					Culicidae*	1				
WEATHER CONDITION: HOT AND CLEAR	**CRUSTACEA:**						Nepidae*	3					Dixidae*	10				
TEMP: 27.8 °C	Amphipoda	13					Notonectidae*	3	**1**			**1**	Empididae	6				
Ph: 7.64	Potamonautidae*	3	**1**			**1**	Pleidae*	4					Ephydridae	3				
DO: 5.56 mg/l	Atyidae	8					Veliidae/M..veliidae*	5					Muscidae	1				
Cond: 56.9 mS/m	Palaemonidae	10					**MEGALOPTERA:**						Psychodidae	1				
BIOTOPES SAMPLED:	**HYDRACARINA**	8					Cordalidae	8					Simuliidae	5				
SIC: TIME: minutes	**PLECOPTERA:**						Sialidae	6					Syrphidae*	1				
SOOC:	Notonemouridae	14					**TRICHOPTERA**						Tabanidae	5				
BEDROCK:	Perlidae	12					Dipseudopsidae	10					Tipulidae	5				
AQUATIC VEG: DOM SP:	**EPHEMEROPTERA**						Ecnomidae	8					**GASTROPODA**					
M VEG IC: DOM SP:	Baetidae 1sp	4	**A**			**A**	Hydropsychidae 1sp	4					Ancylidae	6				
M VEG OOC: DOM SP:	Baetidae 2 sp	6		**A**	**A**		Hydropsychidae 2 sp	6					Bulininae*	3				
GRAVEL:	Baetidae >2 sp	12				**B**	Hydropsychidae >2 sp	12					Hydrobiidae*	3				
SAND:	Caenidae	6	**A**		**A**	**B**	Philopotamidae	10					Lymnaeidae*	3				
MUD:	Ephemeridae	15					Polycentropodidae	12					Physidae*	3				
HAND PICKING/VISUAL OBS:	Heptageniidae	13					Psychomyiidae/Xiphocen.	8					Planorbidae*	3				
FLOW:	Leptophlebiidae	9					**CASED CADDIS:**						Thiaridae*	3				
TURBIDITY:	Oligoneuridae	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
RIPARIAN LAND USE:	Polymitarcyidae	10					Calamoceratidae ST	11					**PELECYPODA**					
	Prosopistomatidae	15					Glossosomatidae SWC	11					Corbiculidae	5				
	Teloganodidae SWC	12					Hydroptilidae	6					Sphaeriidae	3				
	Tricorythidae	9					Hydrosalpingidae SWC	15					Unionidae	6				
	ODONATA:						Lepidostomatidae	10					**SASS SCORE:**		20	30	20	56
DISTURBANCE IN RIVER:	Calopterygidae ST,T	10					Leptoceridae	6					**NO OF TAXA:**		6	6	4	12
	Chlorocyphidae	10					Petrothrincidae SWC	11					**ASPT:**		3.33	5.00	5.00	4.67
	Chlorolestidae	8					Pisuliidae	10					**IHAS**:	57%				
	Coenagrionidae	4		**A**		**A**	Sericostomatidae SWC	13					**OTHER BIOTA**:					
	Lestidae	8					**COLEOPTERA:**						JUV. FISH (SAME AS WB1)					
SIGNS OF POLLUTION:	Platycnemidae	10					Dytiscidae*	5					**COMMENTS**:					
	Protoneuridae	8					Elmidae/Dryopidae*	8					* = airbreathers					
	Zygoptera juvs.	6					Gyrinidae*	5					SWC = South Western Cape					
	Aeshnidae	8		**1**		**1**	Halipidae*	5					T = Tropical					
	Corduliidae	8					Helodidae	12					ST = Sub-tropical					
OTHER OBSERVATIONS:	Gomphidae	6					Hydraenidae*	8					S = Stone & rock					
	Libellulidae	4		**1**		**1**	Hydrophilidae*	5		**A**	**1**	**A**	VG = all vegetation					
	LEPIDOPTERA:						Limnichidae	10					GSM = gravel, sand & mud					
	Pyralidae	12					Psephenidae	10					1=1, A=2-10, B=10-100, C=100-1000, D=>1000					