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Aquatic fauna assessment

for the upgrade of the Bushkoppies Waste Water Treatment Works

July 2019

Compiled by: Mr Bertus Fourie (M.Sc. Aquatic Health, Pr. Sci. Nat)

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DECLARATION OF INDEPENDENCE

I, **Bertus Fourie,** declare that -

- I am subcontracted as specialist consultant by Limnology for the project.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the National Environmental Management Act, 1998 (Act No. 107 of 1998), regulations and any guidelines that have relevance to the proposed activity; I will comply with the Act, regulations and all other applicable legislation;
- I will take into account, to the extent possible, the matters listed in Regulation 8;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing
  - any decision to be taken with respect to the application by the competent authority; and
  - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of section 24 F of the Act.

Bertus Fourie (Pr. Sci. Nat)

Limnologist

SACNASP Pr.Sci.Nat. Reg. No: 400126/17

1. Introduction

Limnology (Pty) Ltd was appointed to conduct aquatic fauna assessment (using aquatic macroinvertebrates and fish population assimilation and water quality testing) and to assess the impact of the proposed new Primary Sedimentation/settling Tank (PST) for the Bushkoppies Waste Water Treatment Works (WWTW).

1.1.Background

An aquatic ecosystem is defined as "an ecosystem that is permanently or periodically inundated by flowing or standing water or which has soils that are permanently or periodically saturated within 0.5 m of the soil surface" (Ollis *et al.* 2013). This term is further defined by the definition of a watercourse. In the National Water Act, 1998 (Act No. 36 of 1998) a watercourse is defined as:

(a) A river or spring;

(b) A natural channel in which water flows regularly or intermittently;

(c) A wetland, lake or dam into which, or from which, water flows; and

(d) Any collection of water which the Minister may, by notice in the *Gazette*, declare to be a watercourse and a reference to a watercourse includes, where relevant, its bed and banks;

The River Health Program (RHP) monitoring systems primarily uses biological indicators such as fish communities, riparian vegetation and aquatic macroinvertebrates to assess the current state or health of river systems in support of the rational management of these natural resources. The biological indicators is supplemented with physio-chemical parameters. The use of biological indicators provides a direct, complete and integrated measure of the current ecological state of the river. This is conducted to measure, assess and report on the spatial and temporal trends of the aquatic ecosystem to identify and report emerging problems by providing scientifically and managerially relevant information for national aquatic ecosystem management (DWS, 2006). Biomonitoring also provides a wider scope over time of the impacts to the aquatic ecosystem in terms of the trajectory of river health conditions.

1.2.Scope of work

The scope of this project is:

- Complete baseline aquatic fauna assessment, using the SASS 5 and Fish response assessment index,
- Conduct baseline water quality assessments,
- Report on findings

2. Assumptions and limitations

To determine the riparian or wetland boundary, indicators (as discussed above) are used. If these are not present during the site visit, it can be assumed that they were dormant or absent and thus if any further indicators are found during any future phases of the project, the author cannot be held responsible due to the indicator's variability. Even though every care was taken to ensure the accuracy of this report, environmental assessment studies are limited in scope, time, and budget. Discussions and proposed mitigations are to some extent made on reasonable and informed assumptions built on *bona fide* information sources, as well as deductive reasoning. No biomonitoring or physical chemical aspects of water found on the study were done. The safety of the delineator is of priority and thus in areas deemed, as unsafe limited time was spent.
If the location of the study site is on and near underlying granitic geology the possible presence of cryptic wetlands must be investigated by a suitably qualified soil scientist with field experience.

Deriving a 100% factual report based on field collecting and observations can only be done over several years and seasons to account for fluctuating environmental conditions and migrations. Since environmental impact studies deal with dynamic natural systems additional information may come to light at a later stage.

As aquatic systems are directly linked to the frequency and quantity of rain it will influence the systems drastically. If during dry months or dry seasons studies are done, the accuracy of the report's findings could be affected.

Limnology can thus not accept responsibility for conclusions and mitigation measures made in good faith based on own databases or on the information provided at the time of the directive. This report should therefore be viewed and acted upon with these limitations in mind.

3. Site location and description

The study site is at the Bushkoppies waste water treatment works (Figure 1) (26°18'41.38"S 27°55'51.18"E).

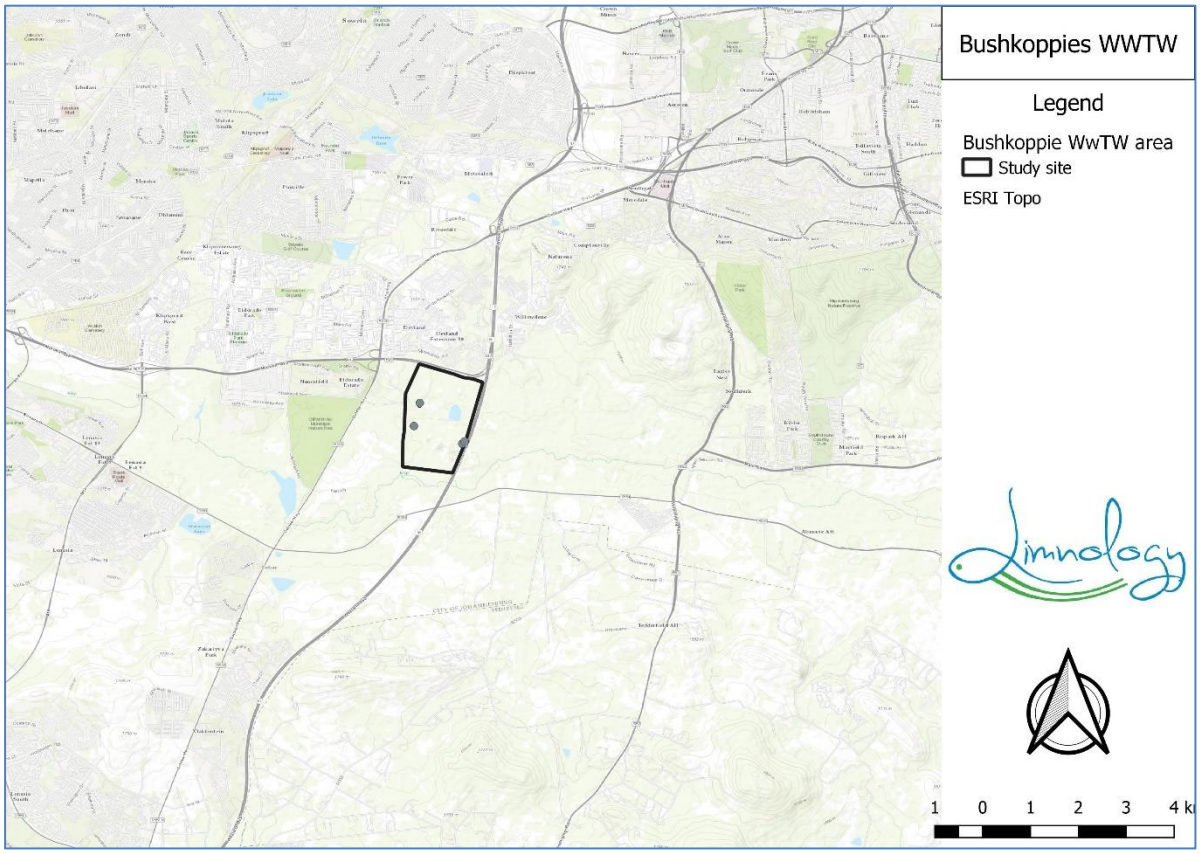

FIGURE 1: STUDY SITE LOCATION

3.1.Activities on site

Upgrading of parts of a municipal waste water treatment works.

3.2.Regional description and vegetation

3.2.1. Gm 9 Tsakane Clay Grassland

Distribution Gauteng and Mpumalanga Provinces: In patches extending in a narrow band from Soweto to Springs, broadening southwards to Nigel and from there towards Vereeniging, as well as north of the Vaal Dam and between Balfour and Standerton (including Willemsdal). Altitude 1 480–1 680 m.

Vegetation & Landscape Features: Flat to slightly undulating plains and low hills. Vegetation is short, dense grassland dominated by a mixture of common highveld grasses such as Themeda triandra, Heteropogon contortus, Elionurus muticus and a number of Eragrostis species. Most prominent forbs

are of the families Asteraceae, Rubiaceae, Malvaceae, Lamiaceae and Fabaceae. Disturbance leads to an increase in the abundance of the grasses Hyparrhenia hirta and Eragrostis chloromelas.
Geology & Soils The most significant rock is the basaltic lava of the Klipriviersberg Group (Ventersdorp Supergroup), together with the sedimentary rocks of the Madzaringwe Formation of the Karoo Supergroup. Soils typical of Ba and Bb land types.

Climate: Strongly seasonal summer rainfall, with very dry winters. MAP 630–720 mm. The overall MAT of 15°C indicates a transition between a cool-temperate and warm-temperate climate. The incidence of frost frequent, increasing towards the southeast. See also climate diagram for Gm 9 Tsakane Clay Grassland (Figure 8.36).

Important Taxa: *Graminoids: Brachiaria serrata (d), Cynodon dactylon (d), C. hirsutus (d), Digitaria ternata (d), Elionurus muticus (d), Eragrostis chloromelas (d), E. patentipilosa (d), E. plana (d), E. racemosa (d), Heteropogon contortus (d), Hyparrhenia hirta (d), Microchloa caffra (d), Setaria sphacelata (d), Themeda triandra (d), Trachypogon spicatus (d), Abildgaardia ovata, Andropogon schirensis, Cymbopogon caesius, Diheteropogon amplectens, Melinis nerviglumis, Panicum gilvum, Setaria nigrirostris. Herbs: Acanthospermum australe, Ajuga ophrydis, Eriosema salignum, Euryops transvaalensis subsp. transvaalensis, Gerbera viridifolia, Helichrysum nudifolium var. nudifolium, H. rugulosum, Hermannia depressa, Lotononis macrosepala, Nidorella hottentotica, Pentanisia prunelloides subsp. latifolia, Peucedanum caffrum, Rotheca hirsuta, Selago paniculata, Senecio coronatus, S. inornatus, Sonchus nanus, Vernonia oligocephala. Geophytic Herbs: Aspidoglossum ovalifolium, Hypoxis rigidula var. pilosissima. Semiparasitic Herb: Striga asia¬tica. Low Shrubs: Anthospermum rigidum subsp. pumilum, Chaetacanthus setiger, Tephrosia capensis var. acutifolia. Semiparasitic Shrub: Thesium impeditum.*

Conservation Endangered: Target 24%. Only 1.5% conserved in statutory reserves (Suikerbosrand, Olifantsvlei, Klipriviersberg, Marievale) and a small portion also in private nature reserves (Avalon, Ian P. Coetser, Andros). More than 60% transformed by cultivation, urbanisation, mining, dam-building and roads. Large portions of Alberton, Springs, Tsakane and part of Soweto (all south and east of Johannesburg) were built in the area of this vegetation unit. Urbanisation is increasing and further expansion of especially the southern suburbs of Johannesburg and the towns of the East Rand (especially the Brakpan District) will bring further pressure on the remaining vegetation. Erosion very low (87%) and low (11%) across the entire unit.

3.3.Ecoregion description

The site falls within the **Highveld Ecoregion** as described in the Level 1 Ecoregions by the Department of Water Affairs and Forestry (DWAF, 2005):

Primary boundary determinants:

Plains with a moderate to low relief, as well as various grassland vegetation types (with moist types present towards the east and drier types towards the west and south), define this high lying region.

General:

Several large rivers have their sources in the region, e.g. Vet, Modder, Riet, Vaal, Olifants, Steelpoort, Marico, Crocodile (west), Crocodile (east) and the Great Usutu. The level 1[1] description of the Water Management Area, as from DWAF, 2007 lists the system as part of the Crocodile (West) River and is characterised by the following:

This is generally a low laying, dry to arid, hot region with virtually no perennial streams originating in the area itself. Perennial rivers that traverse this region include the Crocodile (west), Marico, Mokolo, Lephalala, and Mogalakwena.

- Mean annual precipitation: Low to arid.
- Coefficient of variation of annual precipitation: Moderately high to high
- Drainage density: Mostly low but with some areas in the north having a high drainage density.
- Stream frequency: Mostly low to medium, but high in north-eastern areas.
- Slopes <5%: Generally >80% of the area.
- Median annual simulated runoff: Very low to low.
- Mean annual temperature: High to very high

[1]**Level I:** This level of typing is based on the premise that ecosystems and their components display regional patterns that are reflected in spatially variable combinations of causal factors such as climate, mineral availability (soils and geology), vegetation and physiography. In South Africa physiography, climate, geology, soils and potential natural vegetation have been used as the delineators of Level I (DWAF, 2007).

3.4.Catchment description

The site lies in quaternary catchment C22A has a mean annual precipitation (MAP) of 694 mm with a mean annual runoff (MAR) of 31.5mm. This equates to a MAP:MAR of 4.5% . The study sites drain to the Vaal River via the Klipriver. See **FIGURE 2** below for the Google Earth description of the site, as provided by the Department of Water Affair's Resource Quality Services (RQS) department.

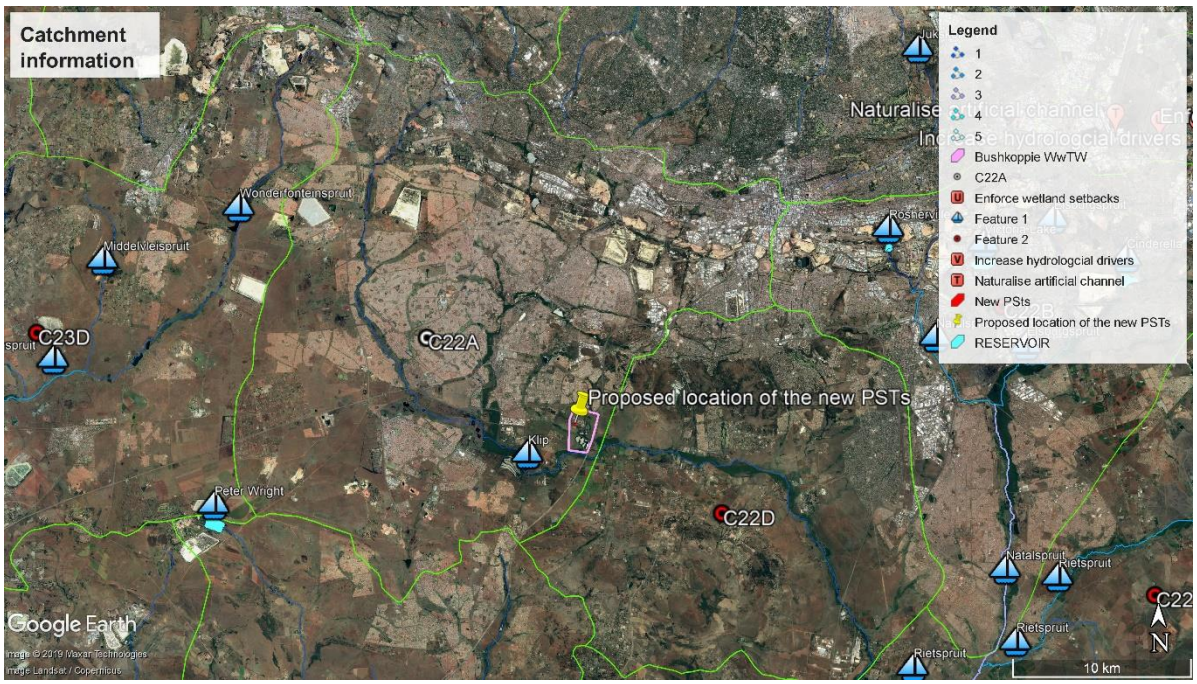

FIGURE 2: THE CATCHMENT AND HYDROLOGICAL DATA FOR THE STUDY SITE, AS AVAILABLE FROM DWA RQS SERVICES.

4. Methods

4.1.Fish population response assessment

The fish population response assessment is done using the Fish Response Assessment Index (FRAI), which consists of 8 steps as described by (Kleynhans, 2007c) (Table 1).

TABLE 1: THE EIGHT STEPS OF FRAI AS DESCRIBED BY KLEYNHANS, 2007

Steps 1-8	Procedure
Step 1: Selection of river for assessment	As for study requirements and design
Step 2: Determination of the reference fish assemblage	Use historical data & expert knowledge Model: use ecoregions and other environmental information Use expert fish reference frequency if occurrence database if available
Step 3: Determination of the present state of drivers	Hydrology Physico-chemical Geomorphology *Or* Index of habitat integrity
Step 4: Selection of representative sampling sites	Field survey in combination with other survey activities
Step 5: Determination of fish habitat condition	Assess fish habitat potential Assess fish habitat condition
Step 6: Fish sampling	Sample all velocity depth classes per site if feasible Sample at least three stream sections per site.
Step 7: Collate and analyse fish sampling data	Transform fish sampling data to frequency of occurrence ratings
Step 8: Execution of FRAI model	Rate the FRAI metrics in each metric group Enter species reference frequency of occurrence data Enter species observed frequency of occurrence data

Steps 1-8	Procedure
	Determine weights for metric groups Obtain FRAI value and category Present both modelled FRAI and adjusted FRAI

4.1.1. Step 1: Selection of river for assessment

As per the study site location, *in situ* flow and habitat conditions.

4.1.2. Step 2: Determination of the reference fish assemblage

Fish Response Assessment Index (FRAI) is based on a comparison between historical and in situ fish population assemblage data i.e. a historical list of all fish species presents at a specific site compared to a current list of species identified. For the quaternary catchment a FROC was available and used for the site. FROC C2KLIP-ZWART was used (Kleynhans, et al., 2007a). See Figure 3 for the location of the FROC on site.

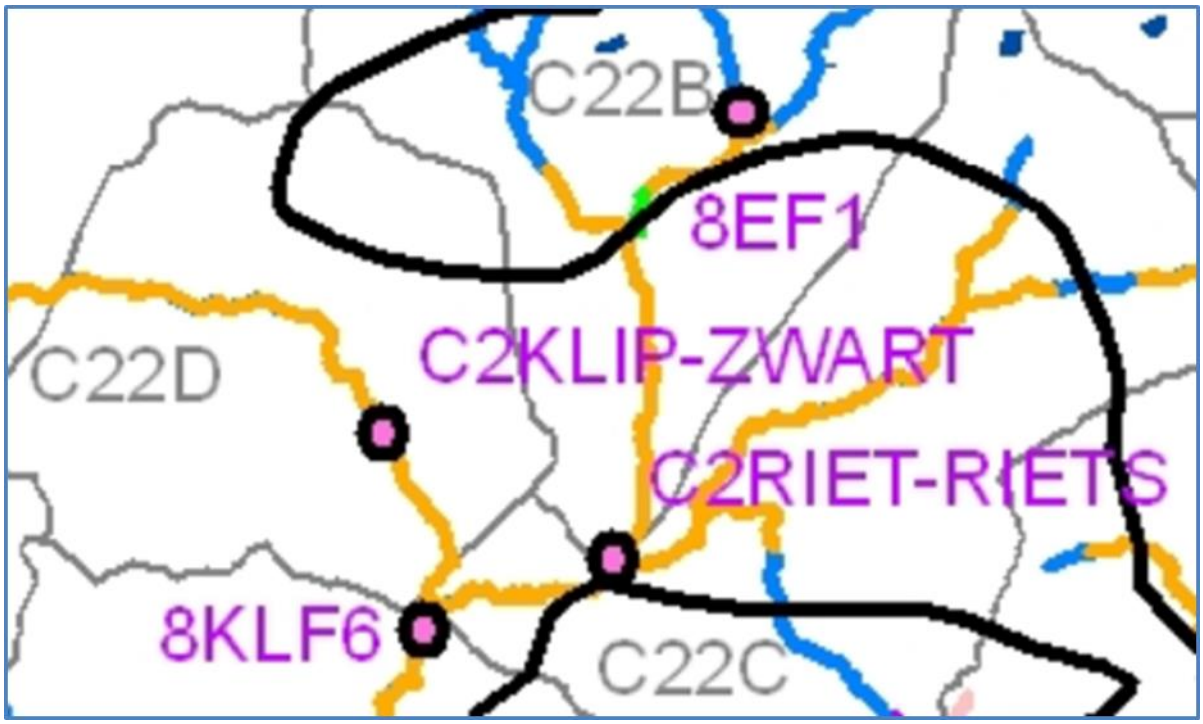

FIGURE 3: LIST OF FROC SITES NEAR THE STUDY SITE AS PART OF QUATERNARY CATCHMENT

4.1.3. Reference FROC list (0 = absent and 5 = very abundant)

The reference only listed a total of 14 species for the study sites. See Table 2 for the extended list of species.

TABLE 2: FROC SPECIES LIST FOR THE STUDY SITE (*INDICATES ALIEN EXOTIC SPECIES)

	Species	Confidence	Abundance
C2KLIP-ZWART	BANO	5	2
C2KLIP-ZWART	BNEE	3	1
C2KLIP-ZWART	BPAU	3	2
C2KLIP-ZWART	BAEN	5	2
C2KLIP-ZWART	BKIM	2	1
C2KLIP-ZWART	LCAP	5	2
C2KLIP-ZWART	LUMB	5	1
C2KLIP-ZWART	CGAR	5	1
C2KLIP-ZWART	ASCL	3	1
C2KLIP-ZWART	PPHI	5	1
C2KLIP-ZWART	TSPA	5	1
C2KLIP-ZWART	CCAR*		
C2KLIP-ZWART	MSAL*		
C2KLIP-ZWART	GAFF*		

4.1.4. Step 3: Determination of the present state of drivers

These include habitat and water quality.

4.1.5. Step 4: Selection of representative sampling sites

Due to the fixed location of the study site, sampling will be limited to the water column of the study site based on habitat descriptors as per Dickens & Graham (2001).

4.1.6. Step 5: Determination of fish habitat condition

Habitat condition is determined according to the FRAI field data sheet per habitat type including the identification and rating of overhanging vegetation, undercut banks and root wads, substrate and aquatic macrophytes. A rating scale of 0 – 5 is used to assess the habitat condition where 0 = absent and 5 = very abundant (Kleynhans, 2007c).

4.1.7. Step 6: Fish sampling

4.1.7.1. Electronarcosis

Sampling is done through electronarcosis in each habitat type (fast-deep, fast-shallow, slow-deep, slow-shallow depending on availability) for 15 minutes at each site as described by Kleynhans (2007). Electronarcosis involves the induction of an electric current in the water, which renders the fish in near proximity to the electrical field immobile for a short period of time, allowing the collection of fish using a scoop net. The specific equipment used is a Samus 725M electrofisher. This sampling method is in line with the methodology recommended for the FRAI protocol as described by Kleynhans (2007c). Each fish collected is identified to species level and the frequency of occurrence of each species is noted on a pre-prepared FRAI fish data sheet. After identification, fish are returned to the river.

4.1.7.2. Passive trapping

Using simple baited Frabil minnow traps (Figure 4) placed in the fish habitats no less than 15 minutes. The traps were checked after the minimum 15 minutes and all fish removed.

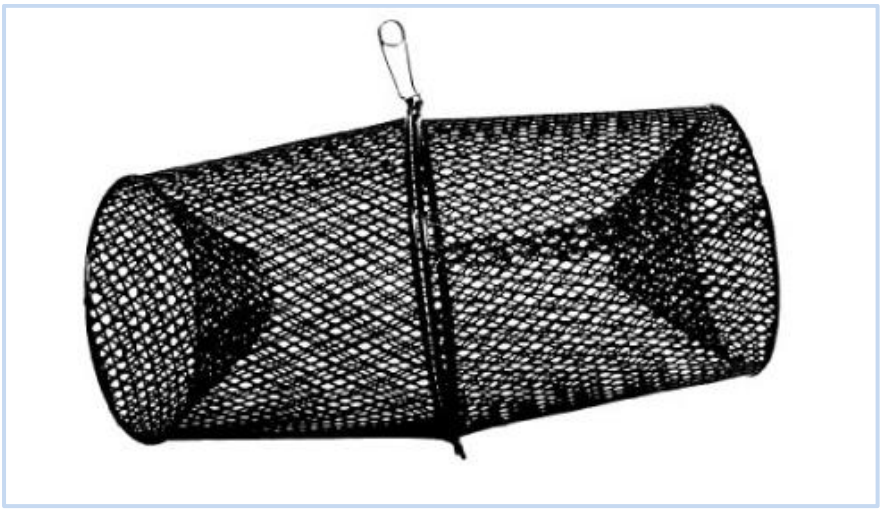

FIGURE 4: IMAGE OF THE FRABIL MINNOW TRAPS

4.1.8. Step 7: Collate and analyse fish sampling data

Data collected is collated into an occurrence rating. A rating scale of 0 – 5 is used where 0 = absent and 5 = very abundant (Kleynhans, 2007c).

4.1.9. Step 8: Execution of FRAI model

All the data collected from steps 1-7 is imported into the FRAI Excel model (Kleynhans, 2007c). A FRAI percentage value and EcoCondition (Present Ecological State (PES)) rating (A-F) is calculated per site (Table 3):

TABLE 3: THE PRESENT ECOLOGICAL STATE CATEGORY INTERPRETATION GUIDE

Description	Combined impact score	PES Category
Unmodified, natural.	**0-0.9**	**A**
Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place.	**1-1.9**	**B**
Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact	**2-3.9**	**C**
Largely modified. A large change in ecosystem processes and loss of natural habitat and biota has occurred.	**4-5.9**	**D**
The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	**6-7.9**	**E**
Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	**8 – 10**	**F**

4.2.SASS 5 method

In South Africa, the River Health Programme (under the Department of Water Affairs) has developed a suite of different programs to rapidly assess the quality of aquatic systems. One of the most popular and robust indicators of aquatic ecology health is the South African Scoring System or SASS currently in version 5 (SASS5).

The South African Scoring System is a biotic index initially developed by Chutter (1998). It has been tested and refined over several years and the current version is SASS5 (Dickens and Graham, 2002). This technique is based on a British biotic index called the Biological Monitoring Working Party (BMWP) scoring system and has been modified to suit South African aquatic micro-invertebrate fauna and conditions. SASS5 is a rapid biological assessment method developed to evaluate the

impact of changes in water quality using aquatic macro-invertebrates as indicator organisms. SASS is widely used as a bio-assessment tool in South Africa because of the following reasons:

- It does not require sophisticated equipment
- Method is rapid and relatively easy to apply.
- This method is very cheap in comparison to chemical analysis of water samples and analysis and interpretation of output data is simple.
- Sampling is generally non-destructive, except where representative collections are required, (the biodiversity index of SASS5 is described in Dickens and Graham (2002).
- It provides some measure of the biological status of rivers in terms of water quality.

SASS is therefore a method for detection of current water quality impairment and for monitoring long-term trends in water from an aquatic invertebrate's perspective. Although SASS5 is user-friendly and cheap, it has some limitations. The method is dependent on the sampling effort of the operator and the total SASS score is greatly affected by the number of biotopes sampled.

SASS5 is not accurate for lentic conditions (standing water) and should be used with caution in ephemeral rivers (systems that do not always flow) (Dickens and Graham, 2002) The resolution of SASS5 is at family level; therefore, changes in species composition within the same family due to environmental changes cannot be detected.

Although the SASS5 score acts as a warning 'red flag' for water quality deterioration, it cannot pinpoint the exact cause and quantity of a change. SASS5 does not cover all invertebrate taxa. SASS also cannot provide information about the degradation of habitat, so habitat assessment also indices, to show the state of the habitat. The initial SASS protocol was described by Chutter (1998) and refined by Dickens and Graham (2002) require collections of macro-invertebrates from a full range of biotopes available at each site.

The biotopes sampled include vegetation both in and out of current (VG- aquatic and marginal), stones (S- both stones in current and out of current) and gravel, sand and mud (GSM) (Dickens & Graham, 2002). The standardised sampling methods allow comparisons between studies and sites. Macro-invertebrate sampling is done using a standard SASS net (mesh size 1000 mm, and a frame of 30 cm x 30 cm). There are nineteen (19) possible macro-invertebrates from each biotope that are tipped into a SASS tray half filled with water and families are identified for not more than 15 minutes/biotype at the streamside.

Invertebrates encountered from each biotope are recorded on a SASS5 score sheet, with their abundance being noted on the sheet. Each taxon (usually a family) of invertebrates from South African rivers has been allocated a score ranging from 1 for those taxa that are most tolerant of pollutants, to 15 for those that are most sensitive to pollutants (Chutter, 1998). To complete the SASS exercise the scores for all the taxa are added together (total score). The average score per taxon (ASPT) is calculated by dividing the total score by the number of taxa. All three scores (SASS5, ASPT and number of families) are used in the interpretation of the status of the site or river being assessed dependant on operator choice.

TABLE 4: ECOLOGICAL CATEGORIES FOR INTERPRETING SASS DATA

Ecological Category	Ecological Category Name	Description	Colour
A	Natural	Unmodified natural	Blue
B	Good	Largely natural with few modifications	Green
C	Fair	Moderately modified	Yellow
D	Poor	Largely modified	Red
E	Seriously modified	Seriously modified	Purple
F	Critically modified	Critically or extremely modified	Black

4.2.1. Invertebrate Habitat Assessment System (IHAS)

Invertebrate Habitat Assessment System (IHAS) was specifically developed to be used in conjunction with SASS, based on habitat availability (McMillan, 1998). The scoring system is based on sampling habitat (i.e. availability of a range of habitats, which could be utilized by in-stream invertebrates) and more general stream characteristics such as anthropogenic or natural impacts (McMillan, 1998). This habitat scoring system is based on 100 points (or percentage) and is divided into two sections reflecting the sampling habitat (50 points) and stream characteristics (50 points).

The sampling habitat section is further broken down into three subsections: stones in current (20 points), vegetation (15 points) and other habitats (15 points) (McMillan, 1998). Very specific questions and answers score between 0 and 5. Higher scores indicate better habitat for macro-invertebrates. The ideal condition is not based on the ultimate pristine stream, but rather on the

representation of all habitats adequately and in reasonable conditions. The IHAS form must be completed for each site sampled during each sampling season. This index is mostly subjective with the data collected dependent on the assessor's visual observation and level of expertise. IHAS data was to aid the interpretation of SASS data.

4.3.Water sampling procedure: In situ water quality

In addition to laboratory assessment of water quality, sampling was also completed using a Hanna handheld probe- HI 9813-5 Portable pH, EC, TDS, Temperature (°C) meter. The probe is placed in water and a minimum of one minute is timed. Results are reviewed until readings on the LCD screen is stable. The result is then photographed using a GPS recording camera (Nikon AW110).

4.4.Water sampling procedure: Laboratory sampling (Figure 5)

All sampling of water quality is done in accordance with the Department of Water and Sanitation's guide: Quality of domestic water supplies Volume 2: Sampling Guide I (ISBN No: 1 86845 543 2, Water Research Commission No: TT 117/99). See Figure 5 for an image of the sampling procedure as taken from the guide.

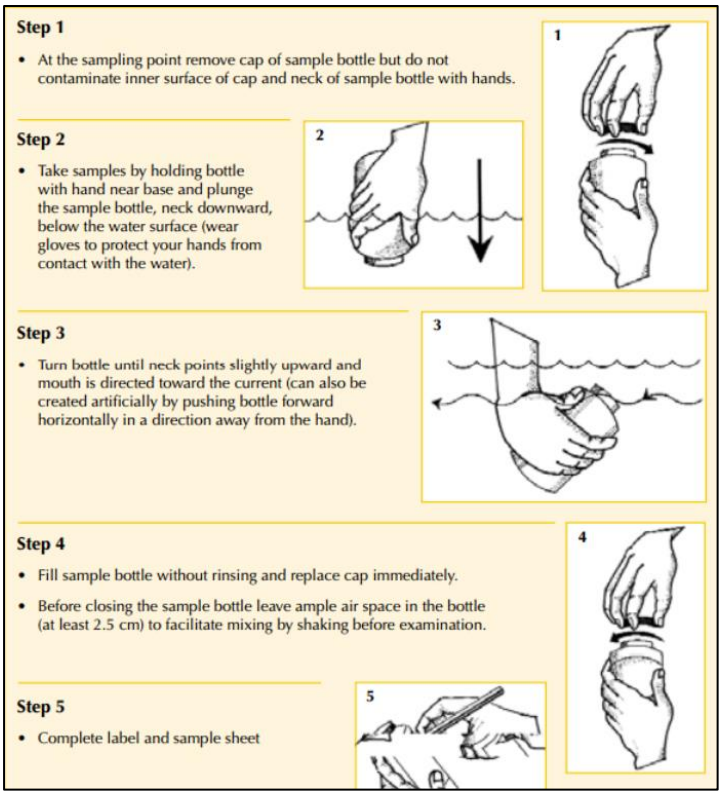

FIGURE 5: WATER SAMPLING PROCEDURE

4.4.1. Physical properties of water

The physical properties of water are based on the temperature, Electrical conductivity (EC), pH, and oxygen content of the water- using physical methods. The physical properties of water influence the aesthetical – as well as the chemical qualities of water. Relevance of the indicators of the physical properties of water include pH- affects the corrosiveness of water and EC- an indication of the "freshness" of water (indicates the presence of dissolved salts and other dissolved particles). Included in the physical properties of water is the suspendoid's effects on water quality. This includes turbidity, and total suspended solids. Turbidity is measured in Nephelometric Turbidity Units (NTU's) and is the indication of the ability of light to pass through water. See **TABLE 5** for a list of physical properties of water and comparative results.

TABLE 5: TABLE FOR COMPARATIVE RESULTS OF PHYSICAL PROPERTIES OF WATER

pH Values	
pH > 8.5	Alkaline
pH 6.0-8.5	Circumneutral
pH < 6.0	Acidic
Total Hardness (in **mg CaCO3/l)**	
Hardness < 50 mg/l	Soft
Hardness 50-100 mg/l	Moderately soft
Hardness 100- 150 mg/l	Slightly hard
Hardness 150-200 mg/l	Moderately hard
Hardness 200-300 mg/l	Hard
Hardness 300-600 mg/l	Very hard
Total Dissolved Solids as indicator of salinity of water	
TDS <450 mg/l	Non saline
TDS 450-1000 mg/l	Saline
TDS 1000-2400 mg/l	Very saline
TDS 2400-3400 mg/l	Extremely saline
Total suspended solids (TSS)	
Background TSS concentrations are < 100 mg/l	Any increase in TSS concentrations must be limited to < 10 % of the background TSS concentrations at a specific site and time.

4.4.2. Chemical properties of water

The chemical quality of the water refers to the nature and concentrations of dissolved substances such as organic or inorganic compounds (including metals) in the water body. Many chemicals in water are essential for the biotic community and may form an integral part of the nutritional requirements. Various chemical properties can be tested for and is costly to conduct full spectrum analysis. For that reason, only select aspects are possibly tested for. See **TABLE 6** for a list of some of the chemical aspects tested for.

TABLE 6: SOME OF THE CHEMICAL ASPECTS TESTED FOR

Dissolved oxygen	• Dissolved oxygen concentrations can be increased by natural diffusion of gaseous oxygenfrom the atmosphere into water. Diffusion continues until the saturation concentration is reached. The rate of increase of dissolution of oxygen can be accelerated if turbulence of the water increases, causing entrainment of air from the atmosphere. • Under anoxic conditions (in the absence of free and bound oxygen) in the water column or in sediments, heavy metals such as iron and manganese can appear in solution, as ferrous (Fe2+) and manganous (Mn2+) species, and toxic sulphides (S-) may also be released.	**<80-120%** **>60% Sub lethal** **>40% Lethal**

	High water temperatures combined with low dissolved oxygen levels can compound stress effects on aquatic organisms. The depletion of dissolved oxygen in conjunction with the presence of toxic substances can also lead to a compounded stress response in aquatic organisms. Under such conditions increased toxicity of zinc, lead, copper, cyanide, sulphide and ammonia have been observed.	
Chloride ion:	Normally all types of water contain chloride ion but its concentration is very low in natural water system. Chloride ion concentration increases in case of urine and sewage contaminated water.	Aquatic ecosystems= 0 mg/l Human consumption= 0-100 mg/l

	▪ High concentration of chloride ion give salty taste and also corrodes pipelines of water. ▪ Normally 150 mg/l of chloride ion is harmless. ▪ Maximum permissible limit of chloride ion in drinking water is 200mg/ l.	
Ammonia	▪ In water ammonia come from decomposition of organic matter like protein, amino acids etc. Its concentration also increases during water disinfection process using chloramine. ▪ In water Ammonia (NH3) is first oxidized into nitrite and then into nitrate. Therefore, by measuring the concentration of NH3, nitrite and nitrate, we can predict the time of contamination of organic matter in water.	**Aquatic ecosystems = 0.007 mg NH_3/l** **Human consumption= 0-1.0 mg NH_3/l**

	In recently contamination, concentration of NH3 is very high than nitrite and nitrate. Concentration of NH3 in ground water system is usually 3mg/l If its concentration is greater than 50mg/l it gives characteristic taste and odor.		
Nitrite	It is very unstable intermediate formed during conversion of NH_2 into nitrate. In aerobic condition nitrite is oxidized into nitrate whereas in anaerobic condition, nitrite is reduced to ammonia. If concentration of nitrite is greater in drinking water, it brings serious health hazard to the consumers. Disease caused by high concentration of nitrite in infants is called Blue baby syndrome, which	<0.5 mg/l	Oligotrophic conditions; usually moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or the presence of blue-green algal blooms.
		0.5-2.5 mg/l	Mesotrophic conditions; usually high levels of species diversity; usually productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms seldom toxic.
		2.5-10 mg/l	Eutrophic conditions; usually low levels of species diversity; usually highly productive systems, nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms may include species which are toxic to man, livestock and wildlife.
		>10 mg/l	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic

	is characterized by blue coloration of skin Level of nitrite in drinking water should not exceed 3mg/l.		plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.
Nitrate	It is most stable oxidized form of nitrogen. In water nitrate comes from organic matter decomposition and from atmospheric nitrogen fixation. Like nitrite Nitrate should not exceed 3mg/l in drinking water. It is because nitrate can be reduced into nitrite in gut of infants and causes nitrite poisoning. Nitrate is very important in natural water system like lake and pond because high concentration of nitrate facilitates heavy growth of aquatic plants causing eutrophication.	<0.5 mg/l	Oligotrophic conditions; usually moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or the presence of blue-green algal blooms.
		0.5-2.5 mg/l	Mesotrophic conditions; usually high levels of species diversity; usually productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms seldom toxic.
		2.5-10 mg/l	Eutrophic conditions; usually low levels of species diversity; usually highly productive systems, nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms may include species which are toxic to man, livestock and wildlife.
		>10 mg/l	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.

Phosphate	In water phosphate is present in the form of H_2PO_4-, polyphosphate and as organic phosphate. Phosphate in water sources comes from agricultural wastes, sewage and from industrial effluent. Phosphate is not toxic to human being, but it is important chemical in natural water system like pond because its high concentration facilitates eutrophication.	<5 g/l	Oligotrophic conditions; usually moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or blue-green algae.
		5-25 g/l	Mesotrophic conditions; usually high levels of species diversity; usually productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms seldom toxic.
		25-250 g/l	Eutrophic conditions; usually low levels of species diversity; usually highly productive systems, with nuisance growth of aquatic plants and blooms of blue green algae; algal blooms may include species which are toxic to man, livestock and wildlife.
		>250 g/l	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.
Calcium (Ca)	High levels may be beneficial (see below) and waters which are rich in calcium (and hence are very hard) are very palatable	0	Aquatic ecosystems
		0-32 mg/l	Human consumption
Magnesium	Like calcium (q.v.), magnesium is abundant and a major dietary	0	Aquatic ecosystems
		0-30 mg/l	Human consumption

	requirement for humans (0.3-0.5 g/day). It is the second major constituent of hardness (see above) and it generally comprises 15-20 per cent of the total hardness expressed as CaCO3. Its concentration is very significant when considered in conjunction with that of sulphate, 		

4.4.2.1. Bacteriological properties of water

Generally, the microbiological quality of water refers to the presence of organisms that cannot be individually seen with the naked eye, such as protozoa, bacteria and viruses. Many of these microbes are associated with the transmission of infectious water-borne diseases such as gastro-enteritis and cholera. In order to determine the bacteriological status and safety of water, specifically focuses on total coliforms and *E. coli* (indicator of faecal coliforms) bacteria. Faecal Coliforms indicates recent faecal pollution and the potential risk of contracting infectious diseases and Total coliforms Indicates the general hygienic quality of the water. See **TABLE 7** for interpretation guide for the results.

TABLE 7: FAECAL COLIFORM RESULT INTERPRETATION GUIDE

FAECAL COLIFORM RANGE (COUNTS/ 100 ML)	EFFECTS
Target Water Quality range *0 - 130*	Which occasionally fall in this range. Risk increases if the geometric mean or median levels are consistently in this range *quality range coliforms indicate a possible risk to health, but the absence of indicators does not guarantee no risk*
130 - 600	Risk of gastrointestinal illness indicated at faecal coliforms levels *effects expected. The presence of faecal*
600 - 2 000	Noticeable gastrointestinal health effects expected in the swimmer and bather population. Some health risk, if single samples fall in this range, particularly if such events occur frequently. Four out of five samples should contain < 600 faecal coliforms/100 mr, or 95 % of Faecal coliform analyses should be < 2 000/100 mr
> 2 000	As the faecal coliform count increases above this limit, the risk of contracting gastrointestinal illness increases. The volume of water ingested in order to cause adverse effects decreases as the faecal coliform density increases

5. Results

During the site visit, two points for aquatic fauna assessment were completed (point “upper” and “North” in **FIGURE 6**). These points were chosen as they represent the first water entering and the last water leaving the site and any impacts arising from the site can be detected. These points can also serve as monitoring points for pre-, during- and post development assessments. Various other water sources feed into the channel on site- but most of these flow through areas where the site can impact on the aquatic water habitat and quality.

FIGURE 6: AQUATIC BIOMONITORING SAMPLE SITE LOCATION.

At both sites during the site visit, a strong sewage smell was detected. In conjunction with black water colour (Figure 7), indicates the presence of high amounts of organic pollution (possibly sewage) in the systems. Only the water from the southern oxidation pond were clear. This water is mixed with the dirty water of the channel (Figure 9).

FIGURE 7: UPPER SAMPLE SITE- NOTE DARK COLOUR OF THE WATER WITH FLOCCULANTS ASSUMED TO BE TOILET PAPER

FIGURE 8: OUTLET FROM THE OXIDATION PONDS INTO THE MAIN CHANNEL

FIGURE 9: MIXING OF WATER FROM THE OXIDATION PONDS INTO THE MAIN CHANNEL

5.1.Impacts

The list of impacts to the aquatic ecosystem on the study site and adjacent areas follows:

- Extensive alteration of the catchment by urbanisation,
- Releases of sewage into the channel of the system- this was not due to the activities of the WWTW but rather from the urban areas,
- Alien vegetation establishment and expansion,
- Various road crossing of the system,

Water quality assessments using in situ and laboratory methods was completed. Full SASS 5 protocol and fish population assessment protocol (as described above) was completed.

5.2. Water Quality assessment

5.2.1. In situ

On site assessments was competed using a Hanna HI 9813-6 portable probe[2]. Aspects measured included pH, electrical conductivity, Total dissolved solids, and temperature. See **TABLE 8** for the results.

[2] Calibration of the device was completed by the author on 1 July 2019

TABLE 8: WATER QUALITY PARAMETERS ASSESSMENT

	Upper	North
pH	7.1	8.1
Electrical conductivity	0.41	0.39
Total dissolved solids	294	274
Temperature	18.7	18.1

5.2.2. Laboratory assessment

Three water sample points was completed for the study. These points were placed where one could not impact on the other (Figure 10). Samples was named pollution (from the study site) and control-upstream of the study site. Analysis done at Aquatico in accordance with their SANS standards and requirements. See Figure 11 for a screenshot of the results and Table 9 for the interpretation of the results.

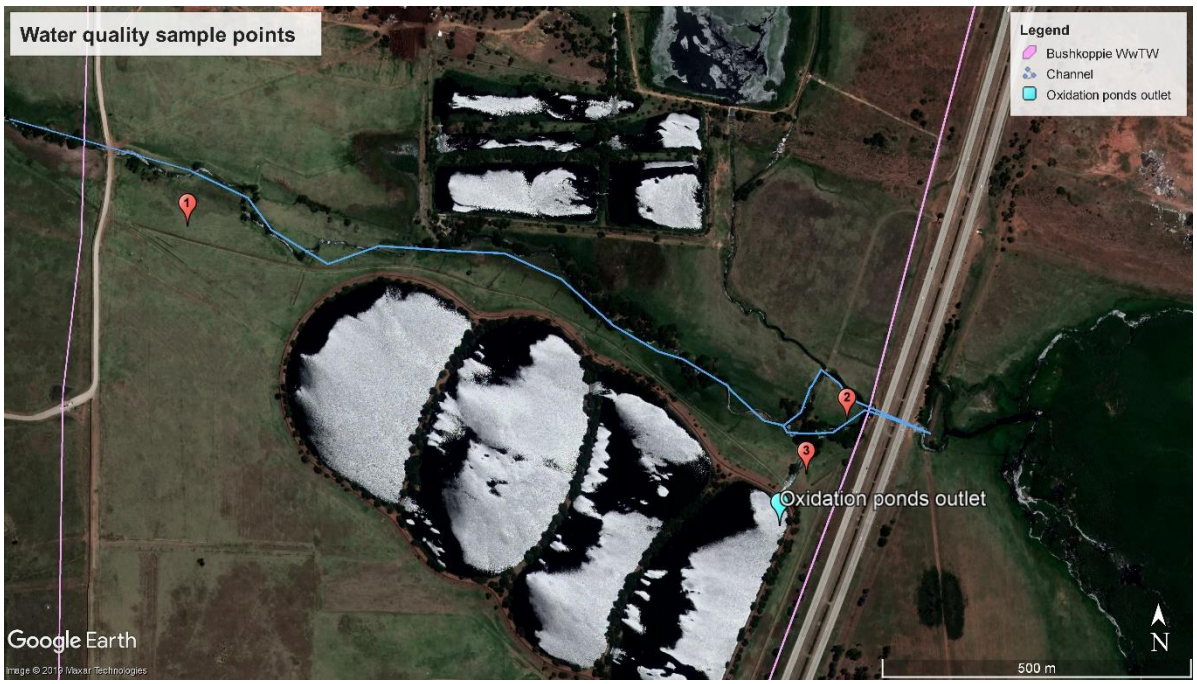

FIGURE 10: WATER QUALITY SAMPLE POINTS

Locality description: Analyses				Bushkoppies 1	Bushkoppies 2	Bushkoppies 3
		Unit	Method			
A	pH @ 25°C	pH	ALM 20	7.80	7.74	7.93
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	69.5	68.9	48.6
A	Total Dissolved solids @ 180°C	mg/l	ALM 24	494	458	330
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.716	0.749	6.26
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.673	1.86	0.636
A	Calcium (Ca)	mg/l	ALM 30	25.8	26.9	24.7
A	Magnesium (Mg)	mg/l	ALM 30	9.40	10.5	9.55
A	E.coli	CFU/100ml	ALM 40	21000	18000	44
A	Total coliform	CFU/100ml	ALM 40	45000	34000	340
N	Free chlorine (Cl_2)	mg/l	ALM 23	<0.10	<0.10	<0.10
A	Total suspended solids (TSS)	mg/l	ALM 25	136	122	<4.5
N	Dissolved oxygen (DO)	mg/l	ALM 28	3.08	3.45	4.39

FIGURE 11: WATER QUALITY ANALYSIS RESULTS

TABLE 9: WATER QUALITY ANALYSIS RESULTS WITH WATER QUALITY TARGET

Analysis	Result			Target water quality range	Discussion
	1	2	3		
pH	**7.8**	**7.74**	**7.93**	**6.5-8.5**	Circumneutral- not of concern and within range
EC	**69.5**	**68.9**	**48.6**	**Within range**	EC is a functional assessment of TDS and thus results can be interpreted as the same as the TDS.
TDS	**494**	**458**	**330**	**450-1000 mg/l**	Saline water indicating the water is "not fresh".
TSS	**136**	**122**	**-4.5**	**Background TSS concentrations are < 100 mg/l**	Any increase in TSS concentrations must be limited to < 10 % of the background TSS concentrations at a specific site and time
PO4	**0.673**	**1.86**	**0.636**	**<5000 mg/l** Oligotrophic conditions	Oligotrophic conditions; usually moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or blue-green algae.
Ca	**25.8**	**26.9**	**24.7**	**0= aquatic ecosystems 0-32 mg/l human consumption**	Exceeds limits for aquatic ecosystems and close to the maximum for human consumption. This is of concern as all the samples had elevated Mg results. Could indicated hardness in water
Mg	**9.4**	**10.5**	**9.55**	**0= aquatic ecosystems 0-30 mg/l human consumption**	Exceeds limits for aquatic ecosystems within range for the maximum for human consumption. This is of concern as all the samples had elevated Ca results. Could indicated hardness in water
Cl2 (Free clorine)	**-0.1**	**-0.1**	**-0.1**	**Within range**	Normally all types of water contain chloride ion but its concentration is very low in natural water system

Do	**3.08**	**3.45**	**4.39**	**Within range**	Sample time was between 10h00 and 12h00. Samples at laboratory at 14h00.
E.Coli	**21000**	**18000**	**44**	**> 2 000 mg/l**	As the faecal coliform count increases above this limit, the risk of contracting gastrointestinal illness increases. The volume of water ingested in order to cause adverse effects decreases as the faecal coliform density increases
Total Coliforms	45000	34000	**340**	**> 2 000 mg/l**	

5.3. SASS 5

The assessment of benthic aquatic macroinvertebrates was completed for the sites. Flows of point A were very high. Habitat such as Gravel sand and mud (GSM) was limited due to high flows. Vegetation out of current (VOOC) was well established. See **FIGURE 12** for an image of the site.

FIGURE 12: UPPER SAMPLE POINT

Similar conditions were observed at the north sample (**FIGURE 13**). Assessment was however completed in very slow-moving water. This is due to the site located in a channelled valley bottom wetland. The stones habitat was absent at the sample point.

FIGURE 13: NORTH SAMPLE POINT

The SASS 5 results are given in **FIGURE 14** and **FIGURE 15** with a summary in **TABLE 10**.

TABLE 10: SASS RESULTS SUMMARY

	SASS score	Number of taxa	Average score per taxa (ASPT)
Upper	40	8	5
North	39	7	5.6

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					**HEMIPTERA (Bugs)**						**DIPTERA (Flies)**					
COELENTERATA (Caidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3					Corixidae* (Water boatmen)	3					Blephariceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5		A		A
Oligochaeta (Earthworms)	1					Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2				
Hirudinea (Leeches)	3					Naucoridae* (Creeping water bugs)	7					Culicidae* (Mosquitoes)	1		A		A
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midges)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3		A		A	Pleidae* (Pygmy backswimmers)	4					Enlydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8		A		A	Veliidae/Mesoveliidae* (Ripple bugs)	5					Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					**MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)**						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5				
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1	A			A
Notonemouridae	14					**TRICHOPTERA (Caddisflies)**						Tabanidae (Horse flies)	5		A		A
Perlidae	12					Dipseudopsidae	10					Tipulidae (Crane flies)	5				
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					**GASTROPODA (Snails)**					
Bivalidae 1sp	4	A			A	Hydropsychidae 1 sp	4					Ancylidae (Limpets)	6			A	A
Bivalidae 2 sp	6					Hydropsychidae 2 sp	6					Ballinae*	3				
Bivalidae > 2 sp	12					Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Caenfly)	6					Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flathcaded mayflies)	13					Psychomyiidae/Dipseudopsidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9					**Cased caddis:**						Thiaridae* (=Melaniidae)	3				
Oligoneuriidae (Brushlegged mayflies)	15					Barbarochthonidae SVC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					**PELECYPODA (Bivalves)**					
Prosopistomatidae (Water specs)	15					Glossosomatidae SVC	11					Corbiculidae (Clams)	5				
Teloganodidae SVC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9					Hydrosalpingidae SVC	15					Unionidae (Purly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					**SASS Score**					40
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6					**No. of Taxa**					8
Chlorocyphidae (Jewels)	10					Petrothrincidae SVC	11					**ASPT**					5,0
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					**Other biota:**					
Coenagrionidae (Sprites and blues)	4					Sericostomatidae SVC	10										
Lestidae (Emerald Damselflies/Spreadwings)	8					**COLEOPTERA (Beetles)**											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8										
Aeshnidae (Hawkers & Emperors)	8	1			1	Gyrinidae* (Whirligig beetles)	5					**Comments/Observations:**					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5										
Gomphidae (Clubtails)	6					Hydraenidae* (Minute moss beetles)	12										
Libellulidae (Darters/Skimmers)	4					Hydrochidae* (Water scavenger beetles)	8										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Hydrophilidae* (Water scavenger beetles)	5										
Crambidae (Pearlides)	12					Limnichidae (Marsh-Loving Beetles)	10										
						Psephenidae (Water Pennies)	10										

FIGURE 14: UPPER SASS RESULTS

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					**HEMIPTERA (Bugs)**						**DIPTERA (Flies)**					
COELENTERATA (Caidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3					Corixidae* (Water boatmen)	3					Blephariceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5		A		A
Oligochaeta (Earthworms)	1					Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2				
Hirudinea (Leeches)	3					Naucoridae* (Creeping water bugs)	7					Culicidae* (Mosquitoes)	1		A		A
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midges)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3		A		A	Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8		A		A	Veliidae/Mesoveliidae* (Ripple bugs)	5					Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					**MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)**						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5				
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				
Notonemouridae	14					**TRICHOPTERA (Caddisflies)**						Tabanidae (Horse flies)	5		A		A
Perlidae	12					Dipseudopsidae	10					Tipulidae (Crane flies)	5				
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					**GASTROPODA (Snails)**					
Bisetidae 1sp	4	A			A	Hydropsychidae 1 sp	4					Ancylidae (Limpets)	6			B	B
Bisetidae 2 sp	6					Hydropsychidae 2 sp	6					Bythiniae*	3				
Bisetidae > 2 sp	12					Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Caenfles)	6					Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13					Prosthemiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9					**Cased caddis:**						Thiaridae* (=Melanoidae)	3				
Oligoneuriidae (Brushlegged mayflies)	15					Barbarochthonidae SVC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					**PELECYPODA (Bivalves)**					
Prosopistomatidae (Water specs)	15					Glossosomatidae SVC	11					Corbiculidae (Clams)	5				
Teloganodidae SVC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9					Hydrosalpingidae SVC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					**SASS Score**					39
Calopterygidae ST T (Demoiselles)	10					Leptocerida	6					**No. of Taxa**					7
Chlorocyphidae (Jewels)	10					Petrothrincidae SVC	11					**ASPT**					5,6
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisulidae	10					**Other biota:**					
Coenagrionidae (Sprites and blues)	4					Sericostomatidae SVC	10										
Lestidae (Emerald Damselflies/Spreadwings)	8					**COLEOPTERA (Beetles)**											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8										
Aeshnidae (Hawkers & Emperors)	8	1			1	Gyrinidae* (Whirligig beetles)	5					**Comments/Observations:**					
Cordulidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5										
Gomphidae (Clubtails)	6					Hydraenidae (Minute moss beetles)	8										
Libellulidae (Darters/Skimmers)	4					Hydrophilidae* (Water scavenger beetles)	5										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Limnichidae (Marsh-Loving Beetles)	10										
Crambidae (Pearlidae)	12					Psephenidae (Water Pennies)	10										

FIGURE 15: NORTH SASS RESULTS

5.3.1. Index of Habitat Assessment System (IHAS) results

IHAS is used to assess the habitat conditions of the SASS sites, as all the required habitat types are not always available. The results are given in percentage. See **TABLE 11** and **TABLE 12** for the calculations. It is clear to see from the IHAS results that the sites are different, and the absence of the stones in site B, reduced the score drastically.

TABLE 11: IHAS RESULTS FOR UPPER SITE

Integrated Habitat Assessment System (IHAS)

Column1	Column2	Column3	Column4	Column5	Column6	Column7
SAMPLING HABITAT SCORE	**0**	**1**	**2**	**3**	**4**	**5**
Stones in current (SIC)						
Total lengths of white water rapids (riffles)(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 sizes kicked (in cm's)(< 2>10<2or>10)(<2=gravel)	None	<2>10	2-5	5-10	2-10	
Amount of stone surface clear (of algae, sediment, etc.)(in percent)		0-25	25-50	50-75	>75	
PROTOCOL: time spent actually kicking SIC's (in minutes	0	<1	1	2	3	>3
(A=SIC boxes total; B=adjustment to equal 20 C=final total)	**20**	**A**	**0**	**B**	**20**	**C**
Vegetation						
Length of fringing vegetation sampled (banks) (in metres)	None	0-0.5	0.5-1	1-2	2	>2
Amount of aquatic vegetation/algae sampled (underwater)(in m^2)	None	0-0.5	0.5-1	>1		
Fringing vegetation sampled in: (none, pool or still only, mixture or both)	None		run	pool		mix
Type of veg (% leafy vegetation as opposed to stems/shoots)(aq. veg. only=50)		0	1-25	25-50	50-75	>75
(D=veg. boxes total; E=adjustment to equal 15; F=final total)	**17**	**D**	**0**	**E**	**17**	**F**
Other Habitat						
Stones out of Current (SOOC) sampled: PROTOCOL in m^2	None	0-0.5	0.5-1	1	>1	
Sand Sampled (PROTOCOL in Minutes)	None	0-0.5	0.5-1	1	>1	
Mud sampled (PROTOCOL in minutes)	None	0-0.5	0,5	>0.5		
Gravel sampled (PROTOCOL in minutes)	all	None	0-0.5	0,5	>0.5	
Bedrock sampled (all=no SIC, sand, gravel)	None	Some			all	
Tray identification (PROTOCOL using time corr = correct times		Under		corr		over
(G= O>H boxes total; H=adjustment to equal 15; I=final total)	**16**	**G**	**0**	**H**	**16**	**I**
(J=Total adjustment (B+E+H) K=Total habitat (C+F+I) Habitat Total			**0**	**J**	**53**	**K**
STREAM CHARACTERISTICS						
Physical						
River make up (pool=pool/stil/dam only; run only; rapid only: 2 mix=2 types etc)	pool		run	rapid	2mix	3mix
Average width of stream: (meters)		>10	5-10	<1	1-2	2-5
Average depth of stream: (meters)	>2	1-2	1	0.5-1	0,5	<0.5
Approximately velocity of stream (slow = 0.5m/s fast = 1m/s)	still	slow	fast	med		mix

Water colour (disc=discoloured with visible colour but still clearish	silly	opaq		discol	clear	crystal
Visible disturbance due to: (constr. = ongoing construction)	flood	constr	livest	other		none
Bank/riparian vegetation is: (grass=includes reeds, shrubs=includes trees)	none		grass	shrub		mix
Surrounding impacts:(erosn=erosion, informal settlements, farmland, nature.	erosn	settle	farm	trees	clear	nature
Left bank cover (rocks and vegetation): in % (shear =0%)	shear	<50	50-80		80-95	>95
Right bank cover (rocks and vegetation): in % (shear =0%)	shear	<50	50-80		80-95	>95
(L=Physical boxes final total) **Stream Characteristics Total;**					**32**	**L**
Total IHAS Score: (K+L)		85		**M**		

TABLE 12: IHAS OF NORTH

Integrated Habitat Assessment System (IHAS)

Column1	Column2	Column3	Column4	Column5	Column6	Column7
SAMPLING HABITAT SCORE	**0**	**1**	**2**	**3**	**4**	**5**
Stones in current (SIC)						
Total lengths of white water rapids (riffles)(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 sizes kicked (in cm's)(< 2>10<2or>10)(<2=gravel)	None	<2>10	2-5	5-10	2-10	
Amount of stone surface clear (of algae, sediment, etc.)(in percent)		0-25	25-50	50-75	>75	
PROTOCOL: time spent actually kicking SIC's (in minutes	0	<1	1	2	3	>3
(A=SIC boxes total; B=adjustment to equal 20 C=final total)	**0**	**A**	**0**	**B**	**0**	**C**
Vegetation						
Length of fringing vegetation sampled (banks) (in metres)	None	0-0.5	0.5-1	1-2	2	>2
Amount of aquatic vegetation/algae sampled (underwater)(in m²)	None	0-0.5	0.5-1	>1		
Fringing vegetation sampled in: (none, pool or still only, mixture or both)	None		run	pool		mix
Type of veg (% leafy vegetation as opposed to stems/shoots) (aq .veg .only=50)		0	1-25	25-50	50-75	>75
(D=veg. boxes total; E=adjustment to equal 15; F=final total)	**15**	**D**	**0**	**E**	**15**	**F**
Other Habitat						
Stones out of Current (SOOC) sampled: PROTOCOL in m²	None	0-0.5	0.5-1	1	>1	
Sand Sampled (PROTOCOL in Minutes)	None	0-0.5	0.5-1	1	>1	
Mud sampled (PROTOCOL in minutes)	None	0-0.5	0,5	>0.5		
Gravel sampled (PROTOCOL in minutes)	all	None	0-0.5	0,5	>0.5	
Bedrock sampled (all=no SIC, sand, gravel)	None	Some			all	
Tray identification (PROTOCOL using time corr = correct times		Under		corr		over
(G= O>H boxes total; H=adjustment to equal 15; I=final total)	**12**	**G**	**0**	**H**	**12**	**I**
(J=Total adjustment (B+E+H) (C+F+I) **Habitat Total**			**0**	**J**	**27**	**K**
STREAM CHARACTERISTICS						
Physical						
River make up (pool=pool/stil/dam only; run only; rapid only: 2 mix=2 types etc)	pool		run	rapid	2mix	3mix

Average width of stream: (meters)		>10	5-10	<1	1-2	2-5
Average depth of stream: (meters)	>2	1-2	1	0.5-1	0,5	<0.5
Approximately velocity of stream (slow = 0.5m/s fast = 1m/s)	still	slow	fast	med		mix
Water color (disc=discolored with visible color but still clearish	silly	opaq		discol	clear	crystal
Visible disturbance due to: (constr. = ongoing construction)	flood	constr	livest	other		none
Bank/riparian vegetation is: (grass=includes reeds, shrubs=includes trees)	none		grass	shrub		mix
Surrounding impacts:(erosn=erosion, informal settlements, farmland, nature.	erosn	settle	farm	trees	clear	nature
Left bank cover (rocks and vegetation): in % (shear =0%)	shear	<50	50-80		80-95	>95
Right bank cover (rocks and vegetation): in % (shear =0%)	shear	<50	50-80		80-95	>95
(L=Physical boxes final total) **Stream Characteristics Total;**					**22**	**L**
Total IHAS Score: (K+L)		49		**M**		

5.4. Macroinvertebrate Response Assessment Index (MIRAI)

MIRAI is an excel based calculation tool to further interpret SASS 5 results and compare this to a reference condition as provided by The Department of Water and Sanitation's Reserve Quality Services (DWS RQS). This allows for the assessment of the SASS results against historical data. The data set was received from DWS RQS on 9 May 2018. The MIRAI was subsequently calculated and results are given in **TABLE 13**.

TABLE 13: MIRAI CALCULATION RESULTS.

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	14,9	*0,150*	2,23077	3	30
HABITAT	H	10,0	*0,350*	3,5	2	70
WATER QUALITY	WQ	21,7	*0,500*	10,8451	1	100
CONNECTIVITY & SEASONALITY	CS	64,4	*0,000*	0		
						200
INVERTEBRATE EC				16,5758		
INVERTEBRATE EC CATEGORY				F		
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

From the calculations the EC using MIRAI was calculated to F. This indicates the study site is **"Critically modified: Critically or extremely modified".** This is of great concern, for the systems sampled. It however does not indicate impacts from the study site itself, and the impacts must be attributed to the catchment land use.

5.5. Fish population assessment

Sampling was done on site using Electrofishing techniques described above. Fish trapping was also completed for a duration of two hours. **No fish was found at both sites.** Main possibilities exist for the absence of fish:

- No fish left in the system- if this was the case it would have been echoed by the SASS scores of the system. The SASS scores were average and not indicative of a system impacted in recent times,
- Hydrological disconnect from the rest of the system- this is not the case as the FROC and RQS indicates fish in the system,
- No fish in the specific area of sample due to local migration, habitat not suiting (unlikely), or other not observed reasons.
- **Stochastic event (possibly pollution (sewage) reducing habitat viability and removing fish from the sample site),**
- Salinity of the water,
- Sampling equipment error- unlikely, as aquatic macroinvertebrates responded to the electro-narcosis.

The FRAI assessment was completed in **TABLE 14** below. The EC was calculated to E/F.

TABLE 14: FRAI ASSESSMENT RESULTS.

AUTOMATED	
FRAI (%)	20,0
EC: FRAI	E/F
ADJUSTED	
FRAI (%)	20,0
EC: FRAI	E/F

6. Impact assessment

The risk assessment methodology follows the Department of Environmental Affairs and Tourism (2006): *DEAT (2006) Risk Management, Integrated Environmental Management Information Series 23, Department of Environmental Affairs and Tourism (DEAT), Pretoria*. The impact assessment method is based on two main categories: Likelihood and Consequence.

- **Likelihood** is calculated using Probability of potential occurrence of the Impact and Frequency of potential occurrence of the Impact

- **Consequence** is calculated using Nature / Intensity / Severity of Impact, Spatial extent of Impact and Duration of Impact.

Using various ratings from 0 to 5, the calculations allow for the assessment of the impact using a sliding scale (Table 15)

TABLE 15: IMPACT ASSESSMENT GUIDE USING CONSEQUENCE AND LIKELIHOOD

CONSEQUENCE											
LIKELIHOOD		2	3	4	5	6	7	8	9	10	11
	0	2	3	4	5	6	7	8	9	10	11
	1	3	4	5	6	7	8	9	10	11	12
	2	4	5	6	7	8	9	10	11	12	13
	3	5	6	7	8	9	10	11	12	13	14
	4	6	7	8	9	10	11	12	13	14	15
	5	7	8	9	10	11	12	13	14	15	16
	6	8	9	10	11	12	13	14	15	16	17

Low	Where it will not have a significant influence on the environment. Management measures can be proposed to ensure that significance does not increase	**3- 10**
Medium	Where it could have a significant influence on the environment unless it is mitigated or managed	**11- 15**
High	Where it would have a significant influence on the environment regardless of any possible mitigation and hence must be either avoided or managed	**16- 17**
Medium positive	In the case of an impact having a positive outcome.	**High positive**

See Table 16 for the impact assessment for the site. it must be noted that this was done in terms of aquatic fauna assessment. From this the impact score was calculated to average 12 before mitigation and 7.75 after ***"Where it will not have a significant influence on the environment. Management measures can be proposed to ensure that significance does not increase".***

TABLE 16: IMPACT ASSESSMENT OF THE DEVELOPMENT

Impact aspect	Consequence									Likelihood						Impact assessment		With management action description
	Nature / Intensity / Severity of Impact			Spatial extent of Impact			Duration of Impact			Probability of potential occurrence of the Impact			Frequency of potential occurrence of the Impact			Before management	With Management	
	Negligent	0	The impact is listed but it is deemed negligent.	Activity	1	Impact occurs only at activity	Short-term	1	Through dilution and dispersion, the impact reduces to insignificant within 1 week.	Improbable	0	The possibility of the impact materializing is very low either because of design or historic	Currently not occurring	0	Currently this impact is not occurring.			
	Low	1	Impacts affect the environmental in such a way that natural, cultural and/or social functions and processes are not affected.	Site	2	Impact occurs on the site	Medium-term	2	Through dilution and dispersion, the impact reduces to insignificant within the life of the mine.	Probable	1	There is a distinct possibility that the impact will occur	Once-off	1	Impact occurs only once-off			
	Medium	2	Impacts affect the environment in such a way that natural, cultural and/or social functions and processes are altered	Local	3	Impact occurs outside of site but within boundaries.	Long-term	3	The impact will cease after the operational life of the mine either because of natural process or by human intervention	Highly probable	2	It is most likely that the impact will occur	Regularly	2	Impact occurs regularly.			
	High	3	Impacts affect the environment in such a way that natural, cultural and/or social functions and processes will temporarily or permanently cease.	Regional	4	Impact occurs outside of local boundaries.	Permanent	4	Where mitigation either by natural process or by human intervention will not occur in such a way or in such a time span that the impact can be considered transient.	Definite	3	The impact will occur regardless of any prevention measures	Continuously	3	Impact occurs continuously			
MANAGEMENT	Before		With	Before		With	Before		With	Before		With	Before		With			
Increase sewage release into system	3		1	4		1	2		2	3		2	3		2	✗ 15	✓ 8	Prevent sewage ingress into the system
Physical disturbance of development	2		0	1		1	4		4	3		3	3		3	! 13	! 11	reduced footprints of impacts
Reduced opertational capacity during construction	3		1	1		1	1		1	2		1	1		1	✓ 8	✓ 5	management of volumes and expected impacts
Alteration of water treatment parameters due to construction	3		2	4		1	2		1	2		2	1		1	! 12	✓ 7	increased monitoring of water treatment parameters with result feedback system
AVERAGE																! 12	✓ 7,75	

7. Discussion

The in-situ water quality measured was all within limits of the Department of Water and Sanitations guidelines. The laboratory assessments indicated the system to be impacted by sewage pollution and other chemical aspects was also altered. The aquatic biodiversity assessment of the site indicted the site to be highly impacted and degraded. The MIRAI score was calculated to F. No fish was observed at the sample sites. This is in stark contrast with the reference list of fish for the site (a total of 14 species) and the FRAI PES results was calculated to E/F.

These results do not indicate the condition of the site, but the impact from the catchments of the reducing the condition of the water quality. Currently, the aquatic ecosystems are highly impacted by this, and cannot afford further degradation due to further pollutants entering the system. Any upgrading of WWTW to reduce pollution risk is welcomed.

It is recommended that a comprehensive aquatic ecosystem rehabilitation plan for the development must be compiled to ensure the functionality of the system remains post development. Secondary to the rehabilitation plan is the compilation of a monitoring plan to ensure the possible impact of sewage into the system is detected and remediated immediately. The monitoring plan must include aquatic fauna monitoring.

7.1.Mitigation of proposed impact

The mitigation of the impacts to the system is based on the perceived impacts for the proposed activities.

7.1.1. Site specific mitigation measures

- No further coliform pollution can be released into the system from the WWTW,
- Water entering the site is already contaminated by coliforms. Management of this is required as the service provided by the site is specifically the treatment of wastewater,
- A systematic adaptive rehabilitation plan should be compiled,
- Implementation of an early warning system to prevent incidences of flooding inundating machinery and decrease risk to human health,
- Allowance must be made for overtopping of the banks of the system during flooding events,

8. Conclusion and recommendations

The proposed upgrade of the WWTW is welcomed in order to mitigate the risk of pollution events into a system already highly polluted. This is emulated by the water quality analysis completed for the site. The SASS PES using MERAI was calculated to E/F. No fish was observed at the sample points- this is possibly due to heavy sewage pollution into the system and altered water quality. Raised Ca and Mg concentrations in combination with increased salts shows the water to be in poor condition.

All environmental assessments (including biodiversity assessments) must always be based on the three main aspects of the National Environmental Management Act, 1998 (Act No. 107 of 1998). These main aspects are the social, the economic, and the environmental aspects of the proposed development. It is also of concern that these aspects must be in balance and that if one outweighs another, good reasoning be sought to ensure the balance is restored. It must be clearly noted that any development on the study site will have an impact on the aquatic ecosystems and must be authorised in terms of Section 21 of the National Water Act (1998).

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10. Appendix A: Glossary of terms:

Buffer zone- The area of land next to a body of water, where activities such as construction are restricted in order to protect the water.

Detritus- Decaying organic matter found in the top layer of soil or mixed with wetland waters; a food source for many small wetland organisms.

Endangered species- Any species of plant or animal that is having trouble surviving and reproducing. This is often caused by loss of habitat, not enough food, or pollution. Endangered species are protected by the government in an effort to keep them from becoming extinct.

Ecosystem- A network of plants and animals that live together and depend on each other for survival.

Emergent- Soft stemmed plants that grow above the water level.

Erosion- Process in which land is worn away by external forces, such as wind, water, or human activity.

Freshwater- Water without salt, like ponds and streams.

Gleyed soil- Mineral wetland soil that is or was always wet; this results in soil colours of grey, greenish grey, or bluish grey.

Habitat- The environment in which an organism lives.

Hydric soil- Soil that is wet long enough for anoxic (oxygenless) conditions to develop. The water in the soil forces air out. This soil type is found in wetlands.

Hydrocarbon Oils, fuels and paints made using fossil fuels (including crude oils, coal etc.)

Hydrophyte- A plant, which grows in water.

Mesotrophic soil- Soils with a moderate inherent fertility. An indicator of soil fertility is its base status, which is expressed as a ratio relating the major nutrient cations (calcium, magnesium, potassium and sodium) found there to the soil's clay percentage.

Organic material- Anything that is living or was living; in soil it is usually made up of nuts, leaves, twigs, bark, etc.

Organism- A living thing.

Peat- Organic material (leaves, bark, nuts) that has decayed partially. It is dark brown with identifiable plant parts, and can be found in peatlands and bogs.

Pollution- Waste, often made by humans, that damages the water, the air, and the soil.

Precipitation- Rain, sleet, hail, snow.

Riparian- Riparian habitat includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterized 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

Redoximorphic conditions- a soil property, associated with wetness, which results from the reduction and oxidation of iron and manganese compounds in the soil after saturation with water and desaturation, respectively. Mottling are common redoximorphic features of soils.

Runoff- Rainwater that flows over the land and into streams and lakes; it often picks up soil particles along the way and brings them into the streams and lakes.

Salinity- The amount of salt in water.

Saturation-The condition in which soil contains as much water as it can hold.

Silt- One of three main parts of soil (sand, silt, and clay); silt is small rock particles that are between .05 mm and .002 mm in diameter.

Submerged aquatic vegetation- Plants that live entirely under water.

Top soil- The top layer of soil; it is full of organic material and good for growing crops.

Water table- The highest level of soil that is saturated by water.

Watershed - All the water from precipitation (rain, snow, etc.) that drains into a particular body of water (stream, pond, river, bay, etc.)

Wetland- Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil."

11. Appendix B: Acronyms

AECO	Aquatic Environmental Control Officer
ASPT	Average Score Per Taxon
CERM	Comprehensive Ecological Reserve Methodology
DSS	Decision Support System
DWA	Department of Water Affairs
DWS	Department of water and sanitation
EC	Ecological Category
ECO	Environmental control officer
EIS	Ecological Importance and Sensitivity
EWR	Environmental Water Requirements
FRAI	Fish Response Assessment Index
FROC	Fish reference of occurrence
GSM	Gravel, Sand, Mud
GDARD	Gauteng Department of Agriculture and Rural Development
IERM	Intermediate Ecological Reserve Methodology
IHAS	Invertebrate Habitat Assessment System
IHI	Index of Habitat Integrity
MIRAI	Macro-Invertebrate Response Assessment Index
MVIC	Marginal Vegetation in Current
MVOOC	Marginal Vegetation out of Current
NFEPA	National Freshwater Ecosystem Priority Areas
PES	Present Ecological State
REC	Recommended Ecological Category
REMC	Recommended Ecological Management Class
RERM	Rapid Ecological Reserve Methodology
RHP	River Health Programme
SASS5	South African Scoring System (Version 5)
SIC	Stones in current

SOG	Soap, oil and grease
SOOC	Stones out of current
TPH	Total petroleum hydrocarbons
TWQR	Target water quality range
VEGRAI	Vegetation Response Assessment Index
Wetland IHI	Wetland index of habitat integrity tool
WMA	Water Management Area
WUL	Water use licence (approved license)
WULA	Water use licence application (license applicatio