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GEOHYDROLOGICAL STUDY

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GEOHYDROLOGICAL STUDY FOR

PUTFONTEIN CEMETERY

EKURHULENI METROPOLITAN MUNICIPALITY

GAUTENG PROVINCE OF SOUTH AFRICA

December 2020

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GEOHYDROLOGICAL STUDIES FOR PUTFONTEIN CEMETERY

EKURHULENI METROPOLITAN MUNICIPALITY

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EXECUTIVE SUMMARY

Tshanduko Environmental Engineering (Pty) Ltd appointed Crysbol (Pty) Ltd to undertake a geohydrological assessment for the refurbishment and operation of Putfontein cemetery.

Putfontein cemetery is located approximately 14km east of Kempton park Central Business District (CBD). It is also located 10km North east of Benoni. The site can be accessed through M44 road from Benoni which interchanges to springs road in approximately 8km .

The project area falls within the Upper Vaal quaternary catchment area "C21D". The study area has almost a gently dipping to the south west direction surface at the central part while gently sloping to the west as observed during the site visit in Novembeer 2020.

A total of 2 surface water samples were collected within the 2km radius from the site and submitted to laboratory registered with the South African National Accreditation Systems (SANAS) for quality control purposes. Surface water surrounding the site were identified as consumable by human beings due to the analytical parameters not exceeding the minimum standard set by the South African Bureau of Standards (SABS).

As a result, the following recommendations were made:

- Drilling of at least two groundwater monitoring boreholes to be located at both upper and down-gradients
- Boreholes to be designed to prevent surface water runoff ingress inside the top casing
- At least quarterly sampling for the first year and review monitoring frequency with the agreement from the relevant authority (e.g. Department of Water and Sanitation, DWS).
- The boreholes need to be at least 30m deep or pass the water levels by 5m and perforated casing to capture floating pollutants such as Light Non-Aqueous Phase Liquids (LNAPLs)
- Supporting infrastructure such as service lines need to be securely installed to prevent possible lift by the rise of water table due to the shallow groundwater table

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Appendix B	Laboratory Results

LIST OF ABBREVIATIONS

c.	*circa* (approximately)
AMD	Acid mine drainage
CBD	Central Business District
DWS	Department of Water and Sanitation
DWAF:	Department of Water Affairs and Forestry
EAP	Environmental Assessment Practitioner
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
e-WULAAS	Electronic Water Use Application and Authorisation System
GA	General Authorisation
KL /a	Kilolitres per annum

KL /d	Kilolitresper day
KL /h	Kilolitres per hour
LNAPLs	Light Non-Aqueous Phase Liquids
KL /m	Kilolitres per month
mamsl	metres above mean sea level
mbgl	metres below ground level
µg/L	micro-grams per litre
mg/L	milligrams per litre
mS/m:	milli Siemens per metre
NGA	National Groundwater Archive
NWA	National Water Act 36 of 1998
S	Storativity
SABS	South African Bureau of Standards
SANS	South African National Standards
SANAS	The South African National Accreditation System
T	Transmissivity
TDS	total dissolved solids
WUA	Water Use Authorisation
WULA	Water Use Licence Application

1 INTRODUCTION

1.1 Preamble

By November 2020, Tshanduko Environmental Engineering (Pty) Ltd appointed Crysbol (Pty) Ltd to undertake a geohydrological assessment of the Development of Putfontein cemetery.

This report serves as a specialist geohydrological study to evaluate the overall geohydrological character of the site to inform the impact assessment and proposed mitigation measures where applicable. The report aims to covers the minimum requirements set by the Department of Water and Sanitation (DWS) for water use license applications in accordance to National Water Act (No. 36 of 1998).

The study area is located approximately 17km east of Kempton Park Central Business District (CBD). It is also located 10km North east of Benoni (Figure 1). The site can be accessed through M44 road from Benoni which interchanges to springs road in approximately 8km. the site is situated on the left of the spring's road.

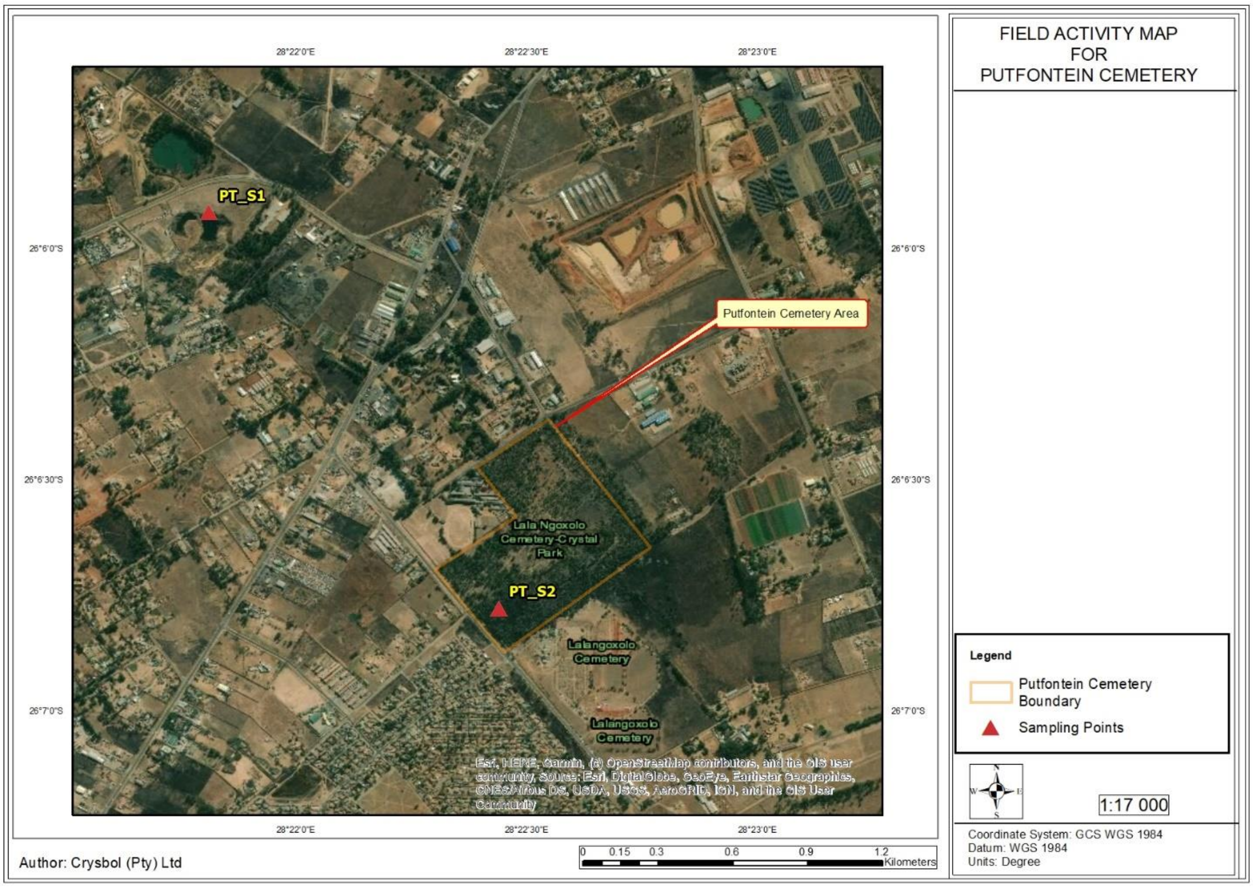

Figure 1: Locality map for site under investigation

Figure 2: Putfontein cemetery

1.2 Background Information

Crysbol (Pty) Ltd were appointed as the Consulting Engineers for the development of a cemetery by Tshanduko Environmental Engineering (Pty) Ltd. The project involves development of the site into a cemetery.

2 GEOGRAPHICAL SETTING

2.1 Topography and drainage

The study area has almost a flat surface at the central part while gently sloping to the southwest direction. The regional groundwater flow is to the south. The local groundwater flow is predominantly to the south-west on the southern part of the site. Overall, the project area is characterised by dendritic drainage pattern in which the most streams flows westerly.

2.2 Climate

The project area normally receives about 716 mm of rain per year, dependent on wet or dry cycles, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (7 mm) in July and the highest (127 mm) in January. The monthly distribution of average daily maximum temperatures ranges from 9.6 °C in June to 19.9 °C in January. The region is the coldest during July when the mercury drops to 0 °C on average during the night.

3 PROJECT OBJECTIVES

Geohydrological assessment for the development of Putfontein cemetery comprises of the following components:

- Desktop Study
- Hydrocensus Survey (2km radius)
- Water Quality Sampling and Analysis
- Hydrological Baseline Assessment
- Monitoring Programme
- Geohydrological report detailing all the investigation and recommendation of the work done

4 SCOPE OF WORK

Accordingly, in order to satisfy and meet the project objectives, the following activities were undertaken:

- Desktop study which includes collation of existing reports, revising borehole management recommendations of all municipal boreholes within the study area, assessment of existing groundwater use;
- Hydrocensus which includes verifying the status of existing production boreholes
- Hydrochemical sampling of surface water bodies and existing boreholes to determine the water quality status;
- Hydrological baseline assessment to determine water use/demand
- Recommend and set-up a groundwater monitoring and management plan

5 METHODOLOGY

The work completed for the purposes of compiling a geohydrological report was executed as per the requirements from the Department of Water and Sanitation (DWS) and comprised of the following:

5.1 Desktop Study

Prior to the commencement of a fieldwork, a literary review was conducted on the data obtained from previous investigations carried out by both Crysbol and other consultants around this area. Additional information was obtained from the National Groundwater Archive (NGA), the Department of Water and Sanitation (DWS) and published geological and geohydrological reports.

The following documents were utilised in terms of extracting relevant information about the study area:

- Vegter, J R (1995): Groundwater Resources in South Africa: An explanation of a set of national
- Vegter, J R (1997): South African Geological Map of scale 1:250 000
- Water Research Commission, WRC, (2001): Groundwater development in South Africa and introduction to the hydrogeology of groundwater regions (WRC Report No TT 134/00)

5.2 Hydrocensus survey and site assessment

The hydrocensus survey formed the main part of the fieldwork which was aimed at gathering relevant information and records about the following components:

- Boreholes coordinates using handheld GPS (Garmin Montana 650);
- Elevation in meters above mean sea level (mamsl);
- Photos of each recorded point;
- Taking water samples;
- Measuring water levels; and
- Gathering water usage information (quantity and frequency).

The hydrocensus survey was performed in a 2km radius of the study area and a site assessment was performed simultaneously with the hydrocensus survey. The site assessment entailed the following aspects:

- Observation and recording of possible sources of groundwater contaminants;
- Re-evaluation of hydrochemical parameters to be submitted to the laboratory; and
- Groundwater flow conditions and existence of any water courses including streams.

There were no borehole data acquired during desktop study and hydrocensus survey.

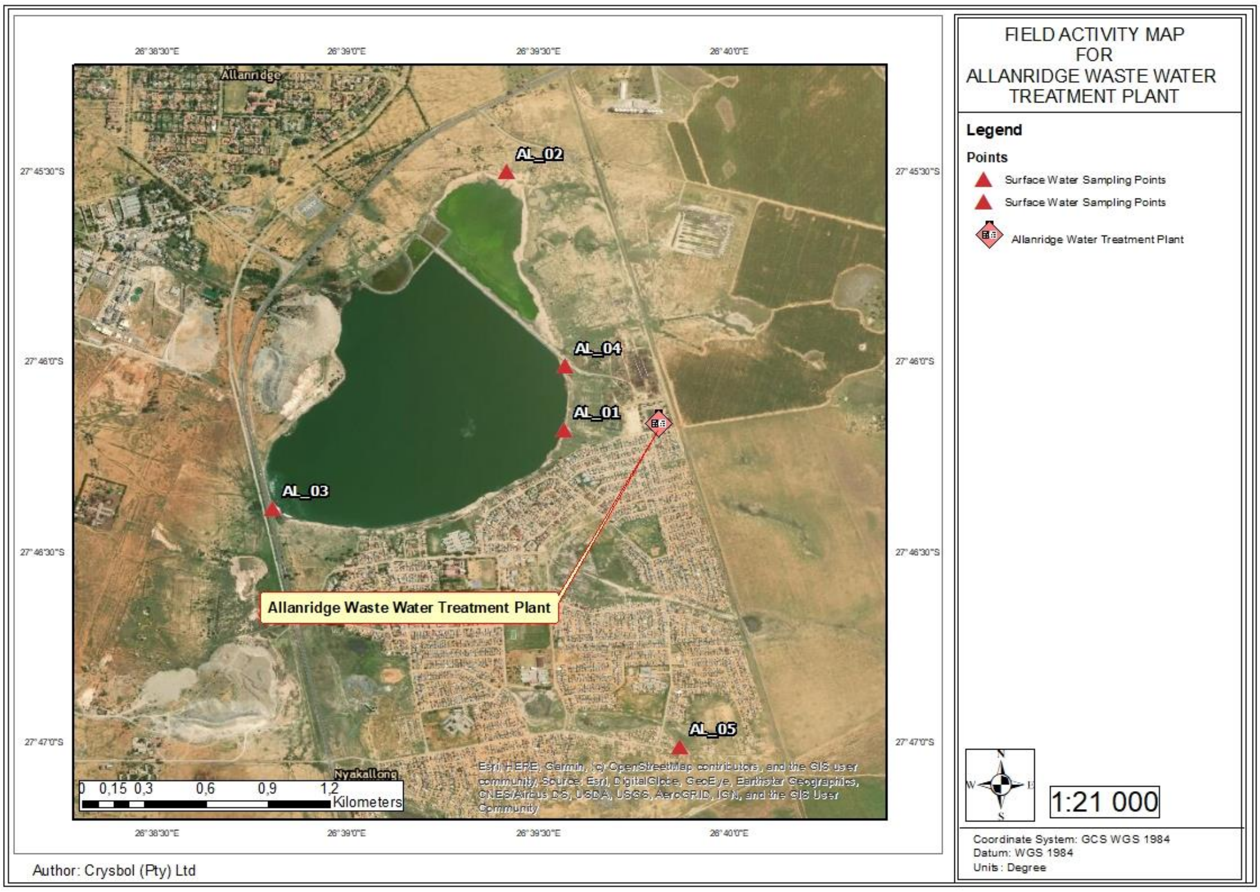

Figure 3: Field Activity Map (Surface Water Samples)

A figure below indicates the key areas observed during hydrocensus stage.

PT_S1 (Surface Water Sample)	**PT_S2 02** (Surface Water Sample)
	

Figure 4: Hydrocensus Field Observation

5.3 Geophysical Survey and Results

The geophysical survey was not considered at this stage. However, the study will be required after acquiring the water use license for sitting of the ground water monitoring boreholes.

5.4 Drilling and sitting of boreholes

No drilling and sitting of boreholes conducted at this stage. The groundwater condition was determined from historical borehole data acquired during hydrocensus stage.

5.5 Aquifer testing

No pump testing carried out at this stage. The background understanding of the distribution of groundwater in the study area was based on the desktop study and data acquired during hydrocensus.

5.6 Sampling and chemical analysis

There is no borehole identified within a 2km radius of the site during hydrocensus field survey. Sampling is limited to two (2) surface water samples collected from surrounding water ponds and lakes. Sampling was undertaken to primarily determine if the water is suitable for human consumption and to obtain an understanding of the water quality environment. The locations of water sampling points are presented in figure below;

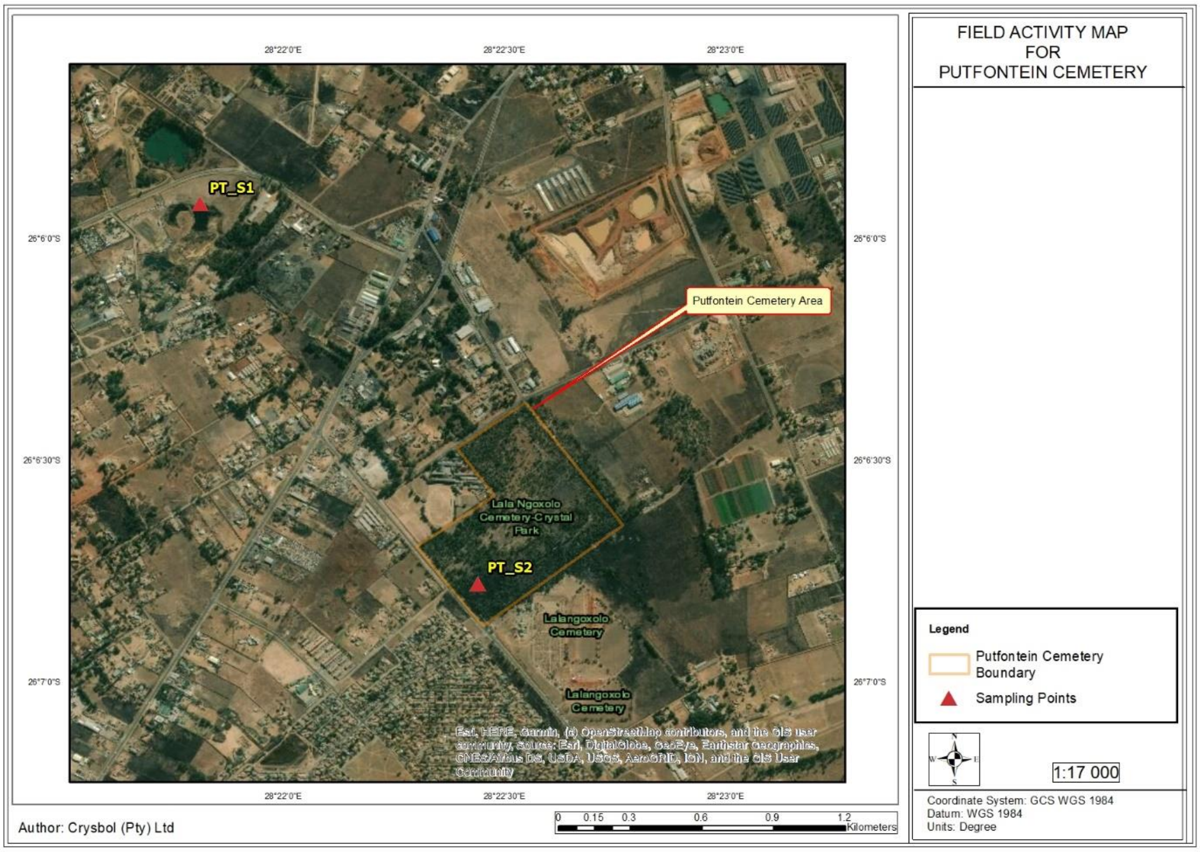

Figure 5:Location of water sampling points across the study area

The collected water samples were submitted to an accredited laboratory for water quality analysis based on SANS 241 standards and DWAF guideline for domestic use.

Parameters analysed during the water sampling are based on water quality guidelines for domestic and drinking water use. Table 1 shows the list of main parameters analysed together with other trace metals included in the Water Quality Standards.

Table 1: List of parameters analysed

Physical Parameters	Macro determinants	Micro determinants
pH	Ammonium as NH_4	Aluminium (Al)
Electrical Conductivity (EC)	Calcium (Ca)	Cadmium (Cd)
Total Dissolved Solids (TDS)	Chloride (Cl)	Total Chromium as Cr
Microbiology	Fluoride (F)	Total Fe (Fe)
	Magnesium (Mg)	Lead (Pb)
	Nitrate as N	Manganese (Mn)
	Potassium (K)	
	Sodium (Na)	
	Sulphate (SO_4)	
	Zinc (Zn)	

The analytical results were compared to the following standards;

a) Department of Water Affairs and Forestry, domestic water quality guidelines, volume 1,1996 and Water Research Commission, water quality guidelines, 1998; and
b) South African National Standards, drinking water standards, 2015 (SANS 241:2015).

The SANS 241:2015 drinking water standard is used as a reference as it includes risk-based elements, whereas the DWAF 1998 guidelines were used to classify and discuss the baseline water quality water quality classes discussing the baseline water quality (Table 3).

Table 2: DWAF Water Quality Classes (1998)

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users, but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

The analysed parameters were compared with South African National Standards for drinking water (SANS 241:2015). Parameters exceeding the standard limits are indicated with bold text in the table of analytical results presented below. It is evidence that the surface water in sampled points PT_S1 and PT_S2 are fit for human consumption due to low level of dissolved solids, electrical conductivity, Chlorides (Cl), Sulphates (SO4) and Sodium (Na) and therefore is classified between class 1.

The groundwater quality within the study area was also found fit for human consumption and falls under class 1. The assessment was based on information obtained from desktop study and hydrocensus survey records. For detail interpretation on ground water quality, refer to section 5.6 (ground water quality).

Table 3: Laboratory Analytical Results

Analyses in mg/ℓ (Unless specified otherwise)	Method Identification	SANS 241: 2015 Limits	PT_S1	PT_S2
pH - Value @ 25 ºC	WLAB065	≥5 to ≤ 9.7	7.0	7.3
Electrical Conductivity in mS/m @ 25°C	WLAB002	≤170	24.1	23.2
Total Dissolved Solids @ 180°C	WLAB003	≤1200	136	116
Total Alkalinity as $CaCO_3$	WLAB007	---	76	40
Total Hardness as $CaCO_3$	WLAB051	---	80	84
Chloride as Cl	WLAB046	≤300	9	7
Sulphate as SO_4	WLAB046	≤500 / ≤250	36	2
Fluoride as F	WLAB014		0.3	0.5
Nitrate as N	WLAB046	≤11	<0.1	<0.1
Ortho Phosphate as P	WLAB046	---	<0.1	<0.1
Free and Saline Ammonia as N	WLAB046	≤1.5	<0.1	<0.1
Ammonium as N	WLAB046	---	<0.1	<0.1
Sodium as Na	WLAB015	≤200	16	15
Potassium as K	WLAB015	---	4.3	2.5
Calcium as Ca	WLAB015	---	21	19
Magnesium as Mg	WLAB015	---	7	9
Aluminium as Al	WLAB015	≤300	0.343	<0.100
Copper as Cu	WLAB015	≤2000	<0.010	<0.010

Iron as Fe	WLAB015	≤ 2000 / ≤300	0.740	0.974
Manganese as Mn	WLAB015	≤ 400 / ≤100	0.041	0.097
Water Quality (DWA Class)			Class I	Class I

5.7 Groundwater Recharge Calculation

Aquifer pump testing and groundwater recharge calculation was not performed as there is no intention of extracting groundwater for operation purpose. The ground water recharge was purely based on the desktop study and records acquired during hydrocensus and desktop study. Details on ground water recharge is discussed under geohydrological evaluation section 5.9 (Groundwater availability assessment).

5.8 Groundwater Modelling

Groundwater modelling was not deemed necessary due to the low yielding nature of the boreholes under consideration and the low groundwater demand.

5.9 Groundwater Availability Assessment

The site is located in the Upper Vaal Quaternary Catchment C21D, which has a total reserve of 3.74 Mm^3/a. This catchment receives an annual precipitation of 716 mm/a with a mean groundwater recharge of 8.56 Mm^3/a (DWAF, 2016).

The catchment area is characterised by fractured and intergranular aquifer system mainly due to the presence of dolerite sills and dykes. The fractured and intergranular aquifer is derived from the dual porosity characteristics that are exhibited at intrusive contact zones. Generally, dolerite sills and dykes intrude the host rock (mainly Karoo Supergroup sediments) at fracture and fault zones, but the dolerite itself weathers to a porous intergranular type aquifer. Borehole yields associated with the fractured and intergranular aquifers hosted by the Karoo Supergroup sediments vary considerably, i.e. 0.1-10 L/s, depending on the type and fracturing of the sediments (Barnard, 2000).

The DWA (2005) reports an estimate of 0.6 Mm3/a groundwater use across the catchment area. This estimate was used to obtain an indication of the relative sustainability and distribution of groundwater use in the study area. It has been identified that the majority of groundwater is used for

Industries and aquatic purposes. A table below summarises the ground water use within the Quaternary Catchment C21D.

Table 4: Summary of groundwater use in the Upper Vaal Quaternary Catchment C21D (DWA, 2005) (values in Mm3/a)

Quaternary Catchment	Total	Rural	Municipal	Agriculture		Mining	Industry	Aquatic
				Irrig.	Livestock			
C21D	0.8413	0.0	0.2614	0.0	0.0012	0.0384	0.207	0.3333

The groundwater threats within the Upper Vaal Quaternary Catchment are related to mining activities (e.g. abandoned mines), although agriculture and urban activities also influence the quality of groundwater. In the Upper Vaal subarea, the following sources contribute to the degradation of the groundwater quality (DWAF, 2003b):

- acid mine drainage;
- mine residue (waste) deposits, e.g. tailings dams and waste rock dumps;
- recirculation of process water, i.e. between metallurgical plants, mine residue areas and underground;
- return water dams;
- pipe bursts and spills at gold metallurgical plants; and
- decant from abandoned mines.

Typically, the groundwater exhibits higher than normal salinity with a CaMgNa/SO4 or CaMgNa/HCO3 chemical composition. The pH, however, is generally in the neutral to slightly basic range (7-8) due to the neutralising effect of the dolomitic strata. High concentrations of certain metals are sometimes evident, e.g. Fe, Mn and Al (DWAF, 2003b). Problems have also been experienced with seepage of groundwater containing manganese from mining areas into the Vaal River (DWAF, 2003a).

6 PREVAILING GROUNDWATER CONDITIONS

6.1 Regional Geology

The study area is underlain by Karoo Supergroup sedimentary rocks of the Vryheid Formations of the Ecca Group. These are largely comprised of sandstone, mudstone, shale, siltstone, and coal seams. The geological description was compiled using information obtained from the South

African Geological Survey 1:250 000 Geological series 2726C and supported by background data and field observations.

The Vryheid Formation consists predominantly of grey to black shale with thin siltstone and sandstone beds occurring near the upper and lower boundaries of the succession. This formation is not known to contain significant coal in the region. The Vryheid Formation underlies the Volksrust Formation as the main coal bearing formation.

Table 2: Summary of the Stratigraphy of the area (From Moodley, et al. 2006)

Age	Supergroup	Group	Subgroup	Formation	Lithology
Quaternary					Alluvium
					Aeolian sand
Jurassic					Dolerite
Permian	Karoo	Beaufort	Adelaide	Estcourt	Shale and Mudstone
		Ecca		Volksrust	Shale and Sandstone
				Vryheid	Shale, Sandstone and Coal
Mokolian					Diabase
Vaalian	Transvaal	Pretoria		Hekpoort	Andesite
				Timeball Hill	Shale and Quartzite
		Chuniespoort	Malmani		Dolomite
	Ventersdorp			Black Reef	Quartzite
		Klipriviersberg			Basaltic lavas
Randian	Witwatersrand	Central Rand	Turffontein		Quartzite, Conglomerate and Shale
			Johannesburg		Quartzite and Conglomerate
		West Rand	Jeppestown		Shale, Quartzite and Conglomerate
			Government		Quartzite, Greywacke and Conglomerate
			Hospital Hill		Shale, Quartzite and Banded ironstone
				Orange Grove	Quarzite and Shale
Swazian	Basement Complex				Granite and Gneiss

6.2 Local Geology

The local geology comprises of sedimentary deposits of the Karoo Supergroup, mainly sandstone, mudstone, siltstone and shale with thin layers of coal. The sequence dips towards the south-south-east. Intrusive dolerite sills and dykes dominate the structural setting with minor faulting reported.

The groundwater systems in the study area are described as a complex multi-level aquifer system. The records obtained from historical boreholes indicated shallow (upper) aquifer with low measurable water strikes. Groundwater occurrence in the shallow water bearing horizon is controlled by the degree and depth of weathering of the underlying Karoo lithologies and alluvium deposits along drainages with their associated flood plains.

The deep-water bearing horizon is controlled by the lateral and vertical distribution of the deeper fractures within the shale, sandstone and coal beds as well as the contact zones with dolerite sill and dyke intrusions.

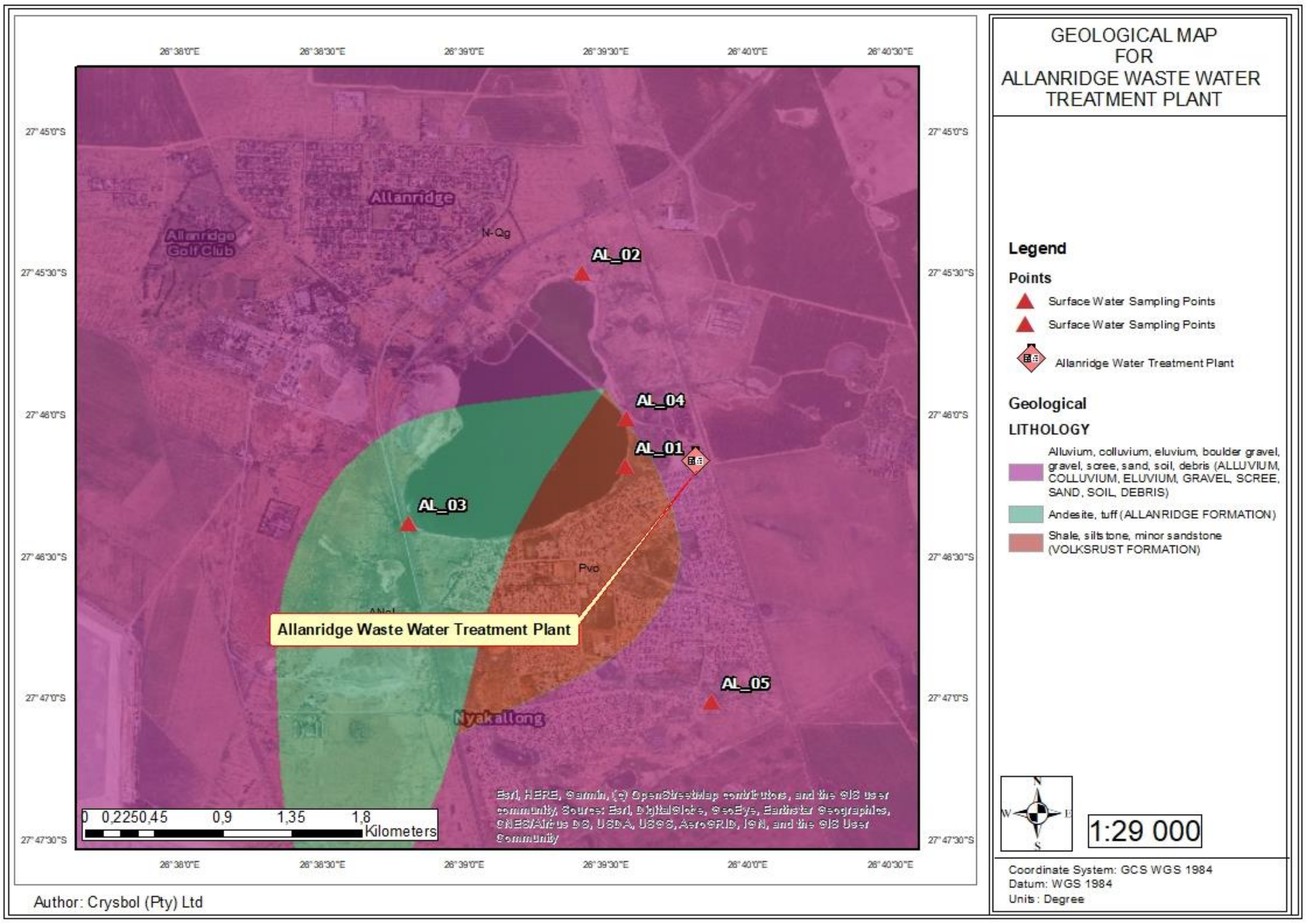

Figure 6: Geology of the Study Area

The study area did not indicate any major structural features such as faults or fractures. Limited tectonic activity is recognised within the study area, and the only evidence of secondary processes is outcrops of intrusive younger dolerite sills mapped in the Karoo sediments.

6.3 Acid generation Capacity

Acid mine drainage ("AMD") occurs when sulphide minerals, such as pyrite (FeS_2), are exposed to air and water and undergo oxidation. This occurs primarily in coal (and gold) mines. After air contact in the presence of sulphide (mostly pyrite) this water is often acidic due to the production of sulphuric acid. The production of AMD depends on the rate of pyrite/sulphide oxidation, the presence of acidophilic bacteria and the influence of carbonate minerals in the host rock. Moreover, upon infiltration by rainwater, mine spoil heaps can leach highly acidic AMD water that mobilizes toxic metal species and contaminates groundwaters. AMD can lower the pH to approximately 2 and total dissolved solids (TDS) in the order of 4000- 5000 mg/l. Sulphate (SO4) is the dominant ion in solution and the largest contributor to the high salinity. Acidification has several negative consequences and most notably includes the solubilisation of a variety of trace metals and metalloids in toxic concentrations.

The surrounding mine waste dump and tailings dam have the potential for generating acid seepage to the groundwater. The geological formation of the surrounding area confirmed lithological type that has the potential for generating acid from carbonaceous shale, grit, and sandstone/mudstone.

The surface water samples confirm low level of dissolved solids, electrical conductivity, Chlorides (Cl), Sulphates (SO4) and Sodium (Na) with a high pH value. The impact during the construction and operation of Putfontein cemetery will, however, be low.

6.4 Hydrogeology

6.4.1 Hydrogeology of the Study Area

Based on the published 1:250 000 hydrogeological map (2628 Johannesburg) and an explanation of the 1:500 000 General Hydrogeological Map "(Meyer, 2001)" the site is underlain by both fractured and intergranular aquifer types. The surface lithology is predominantly argillaceous rocks (Shale, Mudstone and subordinates siltstone). The project area falls within the Upper Vaal quaternary catchment area C25B.

The local farming community depends on this ground water for agricultural practices. The background information on ground water literature review confirms the shallow water table across the Putfontein cemetery.

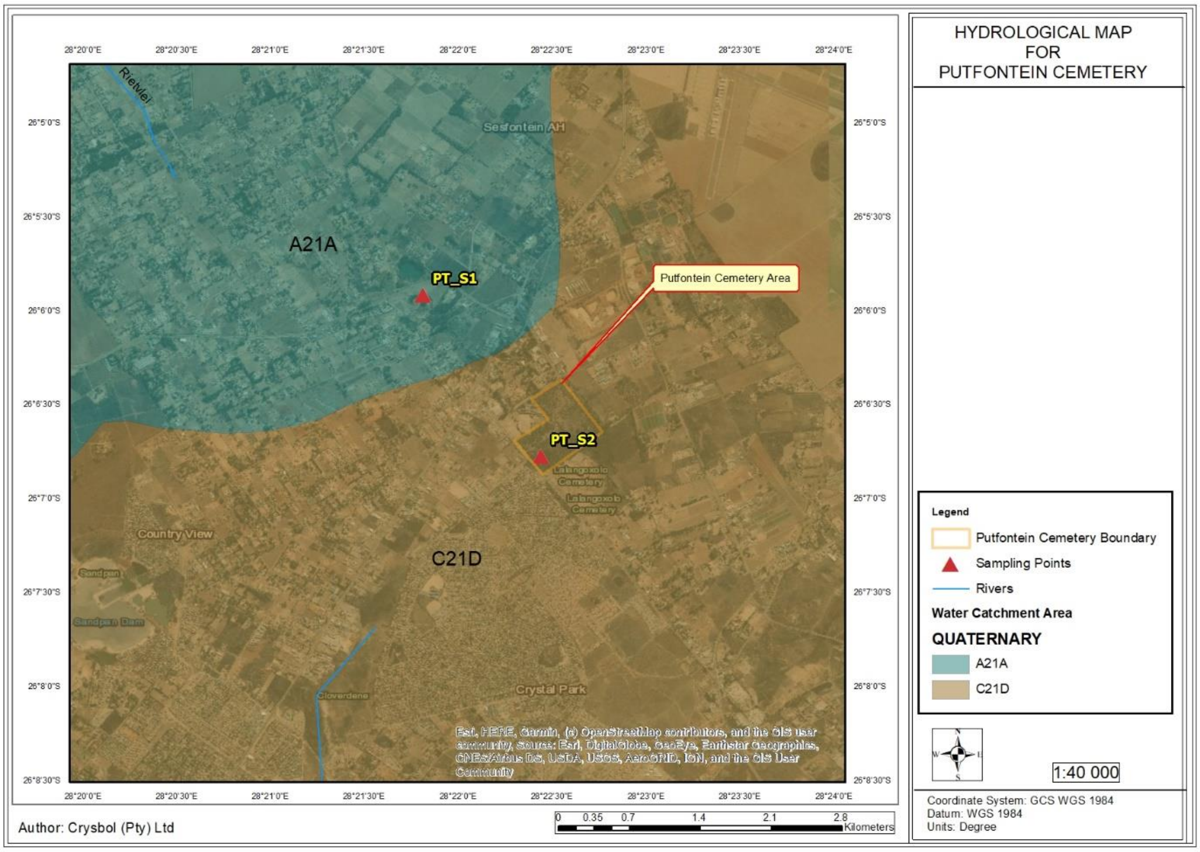

Figure 7: Hydrological Map of the Study Area

6.4.2 Saturated zone

In the saturated zone, at least four aquifer types may be inferred from knowledge of the geology of the area:

- A shallow aquifer formed in the weathered zone, perched on the fresh bedrock.
- An intermediate aquifer formed by fracturing of the Karoo sediments.
- Aquifers formed within the more permeable coal seams and sandstone layers.
- Aquifers associated with the contact zones of the dolerite intrusives.

Although these aquifers vary considerably regarding geohydrological characteristics, they are seldom observed as isolated units. Usually they would be highly interconnected by means of fractures and intrusions. Groundwater will thus flow through the system by means of the path of least resistance in a complicated manner that might include any of these components.

Shallow perched aquifer

A near surface weathered zone is comprised of transported colluvium and in-situ weathered sediments and is underlain by consolidated sedimentary rocks (sandstone, shale and coal). Groundwater flow patterns usually follow the topography, often coming very close to surface in topographic lows, sometimes even forming natural springs. Experience of Karoo geohydrology indicates that recharge to the perched groundwater aquifer is relatively high, up to 3% of the Mean Annual Precipitation (MAP).

Fractured Karoo rock aquifers

The host geology of the area consists of consolidated sediments of the Karoo Supergroup and consists mainly of sandstone, shale and coal beds of the Vryheid Formation of the Ecca Group. Most of the groundwater flow will be along the fracture zones that occur in the relatively competent host rock. The geology map does not indicate any major fractures zones in this area, but from experience it can be assumed that numerous major and minor fractures do exist in the host rock. These conductive zones effectively interconnect the strata of the Karoo sediments, both vertically and horizontally into a single, but highly heterogeneous and anisotropic unit

Aquifers associated with coal seams

The coal seam forms a layered sequence within the hard rock sedimentary units. The margins of coal seams or plastic partings within coal seams are often associated with groundwater. The coal itself tends to act as an aquitard allowing the flow of groundwater at the margins.

Aquifers associated with dolerite intrusives

Dolerite intrusions in the form of dykes and sills are common in the Karoo Supergroup, and are often encountered in this area. These intrusions can serve both as aquifers and aquifuges. Thick, unbroken dykes inhibit the flow of water, while the baked and cracked contact zones can be highly conductive. These conductive zones effectively interconnect the strata of the Ecca sediments both vertically and horizontally into a single. These structures thus tend to dominate the flow of groundwater. Unfortunately, their location and properties are rather unpredictable. Their influence on the flow of groundwater is incorporated by using higher than usual flow parameters for the sedimentary rocks of the aquifer.

6.4.3 Unsaturated Zone

The unsaturated zone in the proposed area is in the order of between 1 and 13 metres thick (based on static groundwater levels obtain from hydrocensus borehole data) and consists of colluvial sediments at the top, underlain by residual sandstone/siltstone/mudstone of the Ecca Group that becomes less weathered with depth.

6.4.4 Hydraulic conductivity

Hydraulic conductivity (K) can be defined as the rate of flow of water in cubic metres per day through a cross section of one square metre of aquifer under a unit hydraulic gradient (Units: m3/day/m2 or m/day).

Based on the desktop study and hydrocensus survey records, it is anticipated that the hydraulic conductivity ranges from 0.01 to 4 for the general area. Higher conductivity values are associated with well-developed fracture zones around the project area.

6.5 Groundwater levels

The regional average groundwater level is between 6 and 12m while other areas can be less than 10m. The local average groundwater levels were not determined due to limited/absent boreholes records.

6.6 Groundwater Potential Contamination

Groundwater contamination should be assessed based on the recharge concentration (i.e. rate of contamination) which takes the following factors consideration:

- Percentage of water infiltrating into the subsurface
- Assessment of borehole water quality
- Aquifer physical parameters such as permeability; and
- Natural attenuation.

Hydrocarbons are regarded as Light Non-Aqueous Phase Liquids (LNAPLs) which means they float on top of water due to their low density compared to water. As a result, the mobility with the pore space is considerably higher than other contaminants. The installation of boreholes needs to consider
perforation which will capture the floating hydrocarbons.

The regional groundwater quality data indicate water quality being within the acceptable drinking water standard in exception of total harness CaCo3.

The assessment of impacts on groundwater was also based on the “Source – Pathway – Receptor” principle. The hierarchy of Source – Pathway – Receptor principle can be further explained in the following manner:

Source

The identification of the source of contamination into the subsurface forms part of the "sources". The potential groundwater source of contamination has been identified as existing surface water bodies due to excess Standard Limits.

Pathway

The media in which the material is carried from one point to another and usually in this case is influenced by water recharge into the subsurface. Particle pores, fissures and fractures serve as a pathway to allow contamination to mobilize within the aquifer. Weathered dykes can act as preferential flow and the identification of them on site is important. No lineament or dyke has been identified from site during the assessment and also assessment from the geological maps.
Another aspect is the assessment of the depth to water table which is projected to 11m for the entire site. Water forms part of the mechanism driving the pollution away from the source. The shallow water table will need to be considered in the development and operation of the site going forward. It is recommended that soil compaction and waterproofing be considered on site for reduction of the contamination rate.

Receptors

Receptors can be well classified as points of discharge such as boreholes used for water drinking, rivers or streams where animal (including humans) and plants come into contact or consume contaminated water. The nearest river from is identified is approximately 3km north east of the site. However, it is unlikely the contamination will be towards this river since the possible sources of contamination are located on the different catchment.

The recommendations below provide solutions in terms of preventive measures for any potential future groundwater contamination from the Putfontein cemetery.

- Drilling of at least two groundwater monitoring boreholes to be located at both upper and down-gradients
- Borehole to be designed to prevent surface water runoff ingress inside the top casing
- At least quarterly sampling for the first year and review monitoring frequency with the agreement from the relevant authority (e.g. Department of Water and Sanitation, DWS).
- The boreholes need to be at least 30m deep or passes the water levels by 5m and perforated casing need to be installed to capture floating pollutants such as Light Non-Aqueous Phase Liquids (LNAPLs)

- Supporting infrastructure such as service lines need to be well secure to prevent possible lift by rise of water table due to shallow groundwater table

6.7 Groundwater Quality

A study of the regional grounds water quality shows the following information

Table 5 Groundwater Quality Reserve Quaternary catchment C21D (National Gazette no 42127 of 21-December-2018, Volume 642)

Chemical Parameter	Unit	Vaal WMA – Quaternary catchment: C21D*			
		[A]	[B]	[C]	[D]
		No. of Samples	GW quality (median value)[1]	BHN Limit[2]	Groundwater Quality Reserve[3]
pH		17	7.37	9.5 – 5.0 (±0.05)	8.1
Electrical Conductivity	mS/m	17	27.50	<150	30
Calcium as Ca	mg/l	17	19.10	<150	21
Magnesium as Mg	mg/l	17	11	<70	12
Sodium as Na	mg/l	17	13.40	<200	15
Potassium as K	mg/l	17	2.20	<50	2.4
Total Hardness as $CaCO_3$	mg/l	17	101.60	<300	112
Chloride as Cl	mg/l	17	8.50	<200	9
Sulphate as SO_4	mg/l	17	6.10	<400	7
Nitrate as NO_x-N	mg/l	17	0.23	<10	0.25
Fluoride as F	mg/l	17	0.12	<1.0	0.13
				Water Quality Class	Class 0

[1] Based on long-term groundwater quality datasets (DWS Water Management System). Minimum number of analyses used for the statistical evaluation is nine (9);
[2] Upper limit of Class I water quality [Drinking] (WRC et al. 2nd Edition, 1998, Volume 1: Assessment Guide);and
[3] Median value plus 10%.
* Based on pre-1995 hydrochemistry dataset (most representative spatial dataset)

Surface water samples were collected from the identified water bodies (PT_S1 and PY_S2) and submitted to Waterlab (SANAS accredited laboratory) in Pretoria for a major cation/aion analysis. This was done to establish the baseline water quality on-site. Laboratory reports of the chemical analysis are presented Appendix B. The analytical results were compared with the SABS drinking water standards (SANS 241-1:2015, edition 2).

Water is classified unfit for human consumption if the Standard Limits are exceeded. It can be concluded that surface water within the 2km radius of the site is fit for human consumption as analysed parameters does not exceed the SABS drinking water standards limits.

6.8 Aquifer Classification

The aquifer(s) underlying the project area were classified in accordance *with "A South African Aquifer System Management Classification, Roger Parsons-December 1995."*

Classification has been done in accordance with the following definitions for Aquifer System Management Classes:

- Sole Aquifer System: An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Electrical Conductivity of less than 150 mS/m).
- Minor Aquifer System: These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- Non-Aquifer System: These are formations with negligible permeability that are regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

Based on information collected during the hydrocensus it can be concluded that the aquifer system in the study area can be classified as a "Minor Aquifer System". Although groundwater is not a sole source of water, boreholes are used on small scale for a number of uses.

In order to achieve the Groundwater Quality Management Index a points scoring system as presented in Table 3, Table 4 and Table 5 was used.

Table 6. Ratings for the Aquifer System Management and Second Variable Classifications

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	2
Major Aquifer System:	4	
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		

Class	Points	Study area
High:	3	3
Medium:	2	
Low:	1	

Table 7. Ratings for the Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	2
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	1
Medium:	2	
Low:	1	

The occurring aquifer(s), in terms of the above definitions, is classified as a Minor Aquifer System.

The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as **low**. A shallow water table (<1 metre below ground level at places) and intergranular primary aquifer underlies the site.

The level of groundwater protection based on the Groundwater Quality Management Classification is as follows:

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 2 X 1 = 2

Table 8. GQM index for the study area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 - 3	Low Level	2
3 - 6	Medium Level	
6 - 10	High Level	
>10	Strictly Non-Degradation	

Aquifer Susceptibility

Aquifer susceptibility, a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and which includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification, in terms of the above, is classified as **low**.

Aquifer Protection Classification

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a Groundwater Quality Management Index of 6 for the study area, indicating that **low level groundwater protection** may be required.

7 GROUNDWATER MODELLING

Groundwater modelling was not deemed necessary due to the low yielding nature of the boreholes under consideration and the low groundwater demand.

8 GEOHYDROLOGICAL IMPACT ASSESSMENT

The method used to assess the significance of the potential impacts is consistent to that described in the Department of Environmental Affairs' (DEA's) Guideline Document on the Environmental Impact Assessment Regulations (1998).

8.1 Description of Potential Impacts

Before assessing the potential impacts on the geohydrological environment, the following assumptions were made as part of refurbishment of the waste water treatment plant.

Water supply: Water reticulation infrastructure will comprise of graves and water mains.

Waste Water Treatment Plant: The development of the cemetery will include upgrade on the irrigation network, control building, construction of new pipe work

Domestic Waste: Waste will be collected and disposed off-site in a landfill site.

The most significant impacts on the groundwater considered as part of the impact assessment is listed below:

Construction Phase

- Waste generated during construction activities;
- Generation of domestic waste water discharge; and
- Accidental spills of materials stored and handled.

Operation Phase

- Generation of domestic waste and waste water; and
- Development will have impermeable surfaces (graves, etc.) and this will reduce direct recharge to groundwater beneath these surfaces.

Decommissioning Phase

The Putfontein cemetery aims to treat water much of the water used by homes, industries, and businesses before it is released back to the environment. There is a very limited possibility that this Project would be decommissioned. It is most likely that with correct and ongoing maintenance of the infrastructure, and necessary replacements as and when certain infrastructure reaches its design life, it would be replaced with something of equal or improved standard. Therefore, the project is expected to likely exist into perpetuity and no decommissioning phase was assessed.

8.1.1 Bulk Water Supply

BULK WATER SUPPLY	**Only alternative**	
Description of alternative specific attributes (environmental / social)	Except for construction activities, the project will have no impact on the groundwater quality. No impact on groundwater table as groundwater supply during construction purposes will be from a municipal supply.	
List of negative impacts	Contamination of groundwater during construction activities due to: • Waste generated; • Generation of domestic waste and waste water; • Accidental spills of materials stored and handled.	
List of potential mitigations	1) Good housekeeping practises 2) Adequate Ablution Facilities 3) Storage and handling of materials as per industry specifications 4) Adeaqutely trained persons in Emergency Spill Response Procedures	
Assessment		
Nature		Negative
Duration		Short term
Extent		Small
Magnitude		Medium
Probability		Medium
Confidence		Medium
Reversibility		Reversible
Resource irreplaceability		High
Mitigatability		Medium
Significance		Low

8.1.2 Bulk Sewer

BULK SEWER	**Only alternative**	
Description of alternative specific attributes (environmental / social)	Except for construction activities, the project will have no impact on the groundwater quality. No impact on groundwater table as groundwater supply during construction purposes will be from a municipal supply. Formal sewer pipeline will have no impact on groundwater quality as opposed to french drains.	
List of negative impacts	Contamination of groundwater during construction activities due to: • Waste generated; • Generation of domestic waste and waste water; • Accidental spills of materials stored and handled.	
List of potential mitigations	1) Good housekeeping practises 2) Adequate Ablution Facilities 3) Storage and handling of materials as per industry specifications 4) Adeaqutely trained persons in Emergency Spill Response Procedures	
Assessment		
Nature		Negative
Duration		Short term
Extent		Small
Magnitude		Medium
Probability		Medium
Confidence		Medium
Reversibility		Reversible
Resource irreplaceability		High
Mitigatability		Medium

8.1.3 Waste Water Treatment Plant

CEMETERY	Only alternative
Short description	The development of the cemetery is planned to provide burial area for dead human beings. The bodies will be placed 6 feet underground on site.
Description of alternative specific attributes (environmental / social)	Except for construction activities, the project will have no impact on the groundwater quality if operated according to design specifications. No impact on groundwater table as groundwater supply during construction purposes will be from a municipal supply. Treated effluent will be discharged via the existing underground stormwater system. If effluent is treated to required quality, the plant and treated effluent will have no impact on groundwater quality.
List of negative impacts	Contamination of groundwater during construction activities due to: • Waste generated; • Generation of domestic waste and waste water; • Accidental spills of materials stored and handled. Contamination of groundwater during operational phase due to: • Spillages of untreated sewage or treated sewage not meeting effluent standard at the plant. • Spillages of untreated sewage or treated sewage not meeting effluent standard due to blocked stormwater.
List of potential mitigations	1) Good housekeeping practises 2) Adequate Ablution Facilities 3) Storage and handling of materials as per industry specifications 4) Adeaqutely trained persons in Emergency Spill Response Procedures

	5) Adequate Operation and Maintenance of the Sewage Treatment Plant and Storm Water System
Assessment	
Nature	Negative
Duration	Long term
Extent	Low
Magnitude	Medium
Probability	Medium
Confidence	Medium
Reversibility	Reversible
Resource irreplaceability	Medium
Mitigatability	Medium
Significance	Medium

9 GROUNDWATER MONITORING SYSTEM

9.1 Groundwater monitoring network

The purpose of a groundwater monitoring network is to provide an early warning of possible adverse effects of the proposed activities on both quantity and quality of the affected groundwater systems. The study has recorded baseline conditions in a 2km radius of the site. It is important that water levels and water quality of potentially affected aquifer systems continue to be monitored over an extended time to confirm these baseline conditions prior to any development.

9.1.1 Source plume, impact and background monitoring

Prior to the design of any monitoring programme, the current understanding of the groundwater system must be understood in terms of i) flow dynamics and behaviour, ii) potential sources of groundwater and related surface water impacts; iii) receptors that may be affected by impacts to groundwater and surface water; and iv) the pathways that could potentially connect them. No risk exists if an impact source is not linked to a potential receptor.

A deterioration in groundwater quality is the most significant risk associated with the activity. The source-pathway-receiver model provides a conceptual portrayal of the mode through which contaminants act and the potential harm they may inflict on a receiving water body and/or organism. The conceptual model is used to develop management action plans and reclamation alternatives that are directed towards mitigating potentially harmful effects caused by the contaminants of concern. Refer to the groundwater potential contamination discussion under Section 6.6 for a more detailed discussion on interaction between potential sources of contamination and receptors that could be affected using the source – pathway – receptor methodology.

9.1.2 System response monitoring network

A Water Management Plan is required to ensure that the construction and operation of Putfontein cemetery do not impact negatively on groundwater levels and quality to unacceptable levels. It will also serve as early warning systems to implement mitigation measures at early stages to reduce cumulative impacts. To ensure that the groundwater environment is protected, monitoring of water quality and levels are required on an on- going basis.

Monitoring is required for the following purposes:

- To detect the actual impact on groundwater quality timeously.
- To assess whether the mitigation measures are effective, supporting the update of mitigation measures where necessary.
- To interrogate unknowns identified in this report, in which various field investigations can be carried out to test and improve the conceptual hydrogeological understanding of the aquifer system.

Monitoring in general should follow the risk-based approach to define or characterise the risks that the operations and associated infrastructure may pose on the receiving environment.

Risk assessments involve the understanding of the generation of a hazard, the probability that the hazard will occur, and the consequences should it occur, i.e. understanding the complete cause and effect cycle. The most basic risk assessment methodology is based on defining and understanding the three basic components of the risk, i.e. the source of the risk (source term), the pathway along which the risk propagates, and finally the target that experiences the risk (receptor). The risk assessment approach is aimed at describing and defining the relationship between cause and effect.

9.1.3 Monitoring frequency

Groundwater monitoring should occur on a quarterly frequency and the receiving surface water on a monthly frequency. The frequency is recommended to be initiated for a minimum period of one (1) year where after the programme should be revised.

9.2 Monitoring Parameters

The following parameters are proposed to be included in the water monitoring programme.

- pH, EC
- TDS
- Major cations including Ca, Mg, Na, K
- Major anions including Cl, SO_4, T-Alk (HCO_3^-/CO_3^-)
- Minor cations/metals including As, B, Fe, Al, Mn, F
- Nutrients including PO_4^-, NO_3-, $NH4^+$
- Groundwater levels

9.3 Monitoring Boreholes

It is recommended that at least two groundwater monitoring boreholes be drilled at both upper and down-gradients. The recommendations below provide solutions in terms of preventive measures for any potential future groundwater contamination from the Putfontein cemetery.

- Borehole to be designed to prevent surface water runoff ingress inside the top casing
- At least quarterly sampling for the first year and review monitoring frequency with the agreement from the relevant authority (e.g. Department of Water and Sanitation, DWS).
- The boreholes need to be at least 30m deep or passes the water levels by 5m and perforated casing need to be installed to capture floating pollutants such as Light Non-Aqueous Phase Liquids (LNAPLs)

10 GROUNDWATER ENVIRONMENTAL MANAGEMENT PROGRAMME

10.1 Current Groundwater Conditions

The present/status of groundwater conditions do not indicate any type of impact on the geohydrological regime. Refer to the hydrocensus (Section 5.2) and groundwater quality (Section 6.7) discussions for an additional discussion on status of groundwater conditions.

10.2 Predicted Impacts of Facility

The predicted impact on the Putfontein cemetery groundwater conditions is primarily associated with contaminated surface water and deterioration of the groundwater quality, possibly from the surrounding mine waste dump and tailings dams.

The laboratory results on surface water bodies indicated low level of dissolved solids, electrical conductivity, Chlorides (Cl), Sulphates (SO_4) and Sodium (Na). During the operational phase, it is expected that mitigations should be put in place to maintain ground water quality.

10.3 Mitigation Measures

10.3.1 Lowering of groundwater levels during facility operation

Given the nature of the Putfontein cemetery no substantial drawdown is expected within the weathered or shallower fractured aquifer into which most privately owned boreholes are drilled. No sensitive receptors' boreholes are located within this zone of influence.

10.3.2 Rise of groundwater levels post- facility operation

The operation of Putfontein cemetery does not involve pumping of underground water. As a result, the Putfontein cemetery will not have effect on the rise of groundwater level. There is a very limited possibility that this Project would be decommissioned as water much of the water used by homes, industries, and businesses needs to be treated before it is released back to the environment.

10.3.3 Spread of groundwater pollution post- facility operation

There is no groundwater plume expected to migrate from the Putfontein cemetery as the site is absent of any geological structures such as faults and dykes.

11 POST CLOSURE MANAGEMENT PLAN

The operation of Putfontein cemetery is expected to likely exist into perpetuity and no post closure management plan is developed.

12 CONCLUSIONS AND RECOMMENDATIONS

Based on information acquired during the desk study, hydrocensus and consequent impact assessment, it can be concluded that the development will have a "Negligible Negative" impact on the groundwater environment after implementation of appropriate mitigation measures.

The geohydrological information obtained from archives and records relating to the geohydrological condition of the surrounding area indicated abundance of ground water resources with water level ranging between 6 and 12 meters. The project area is characterised by high groundwater recharge and believed to be as a result of fractured rocks. Therefore, the quantity of groundwater is sufficient for large abstraction by public.

The study has found the groundwater quality to be within the standard limit set by South African Bureau of Standards. It is therefore critical to ensure the implementation of groundwater pollution mitigation measures which among others include good housekeeping, storage and handling of materials as per industry specifications, emergency spill response procedures, adequate operation and maintenance of the sewage treatment plant and storm water system. It is recommended that only treated effluent be discharged via the existing underground stormwater system. If effluent is treated to required quality, the cemetery will have no impact on groundwater quality.

It is further recommended that a minimum of two groundwater monitoring boreholes be developed at both upper and down-gradients. It is required that the boreholes be sampled quarterly as in line with requirements of water use license.

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