HYDROGEOLOGICAL INVESTIGATION

at

THE FARM VLAKFONTEIN 523 JR PORTION 25

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I-CAT ENVIRONMENTAL SOLUTIONS

Geo Pollution Technologies - Gauteng (Pty) Ltd
81 Rauch Avenue
Georgeville
0184

P.O. Box 38384
Garsfontein East
0060

Tel: *+27 (0)12 804 8120*
Fax: *+27 (0)12 804 8140*

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Compiled by:	S. C. Nkosi, MSc, Cand.Sci.Nat.
Reviewed by:	M. Burger, MSc, Pr.Sci.Nat.
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(*electronic signature*)

S. C. Nkosi, M.Sc, Cand.Sci.Nat.

Candidate Natural Scientist (No. 100105/13)

Geo Pollution Technologies - Gauteng (Pty) Ltd

Quality Control:

This report was reviewed by:

(electronic signature)

M. Burger; M.Sc., Pr.Sci.Nat

Professional Natural Scientist (No 400296/12)

Geo Pollution Technologies - Gauteng (Pty) Ltd

Customer Satisfaction:

Feedback regarding the technical quality of this report (i.e. methodology used, results discussed and recommendations made), as well as other aspects, such as timeous completion of project and value of services rendered, can be posted onto GPT's website at www.gptglobal.com.

Table of Contents Page no

List of Tables Page no

List of Appendices Page no

List of abbreviations:

AST	=	Aboveground storage tank
BDL	=	below detection limit
BTEXN	=	Benzene, Toluene, Ethylbenzene, Xylenes and Naphthalene
DOR	=	Depth of refusal
FPT	=	Free Phase Thickness
GC-MS	=	Gas Chromatography Mass Spectrometer
ERA	=	Environmental Risk Assessment
LEL	=	Lower Explosion Limit (%)
mbgl	=	metres below ground level
mamsl	=	metres above mean sea level
m/d	=	metres per day
m/y	=	metres per year
mg/kg	=	milligrams per kilogram
mg/ℓ	=	milligrams per litre
N/A	=	Not applicable/no information available
NGA	=	National Groundwater Archive
NM	=	Not measured
PID	=	Photo Ionisation Detector
ppb	=	parts per billion
ppm	=	parts per million
RBCA	=	Risk based corrective action
RBSL	=	Risk based screening level
SPME	=	Solid phase micro extraction
SWL	=	Static (ground) water level
TPH	=	Total petroleum hydrocarbons
VOC	=	Volatile Organic Compound

1. INTRODUCTION

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by I-CAT Environmental Solutions to prepare a basic groundwater assessment for the proposed development of the Rainbow Filling Station on the farm Vlakfontein 523 JR near Bronkhorstspruit, Gauteng Province. The study was undertaken in support of the basic assessment.

The Station has been operational since January 2016, re-fuelling Weltevreden trucks from a 60 000 ℓ above-ground diesel storage tank (AST; shown in Figure 1). The planned development entails construction of a filling station, retail store and office park. The area demarcated for development on Portion 25 is 0.1 km^2 (10 ha) in size.

The impacts on the groundwater environment associated with filling stations, retail stores and office parks are primarily related to storage and handling of petroleum products, as well *ad hoc* solid and liquid waste management. The baseline groundwater and surface water environmental conditions will be used to assess the current groundwater status quo and potential impacts on the receiving environment.

2. OBJECTIVES OF THE INVESTIGATION

The main objectives of a basic groundwater assessment are to investigate the following aspects within a one km radius of the site:

- Depth to groundwater,
- Proximity of groundwater users and nature of use,
- Proximity of surface water bodies,
- Groundwater flow direction,
- Groundwater quality,
- Potential sensitive receptors and other sources of contamination.

3. SCOPE OF WORK

The investigation at the site consists of the following:

- Site Walk Over: The site and surrounding areas were visually assessed to determine the environmental sensitivity of the area. An audit checklist was used to note the land use, topographic features, natural and man-made drainage features and the position of underground services. Signs of surface contamination as well as the condition of any equipment present on site were recorded.
- Based on the site walkover, the receptors of concern were determined. All potential receptors of any contamination that might emanate from the site and the different identified pollution sources around the site were noted. A potential receptor may be any person or place. Examples of receptors include proximate residential areas, schools, parks, and play grounds, as well as surface water bodies and private boreholes supplying water for human consumption. Workers on the site might also be receptors, depending on the identified pathway(s).
- Locate boreholes in the immediate vicinity of the site by conducting a hydrocensus survey. Groundwater samples were collected from nearby private boreholes. GPS coordinates of the

sample points were recorded. The National Groundwater Archive (NGA) was consulted to identify any registered groundwater users within a one km radius of the site.

- Recovered water samples were submitted to a SANAS accredited laboratory for the analysis of petroleum hydrocarbon compounds by GC-MS screening and inorganic analyses and for physical parameters.
- Compare the targeted hydrocarbon concentrations detected in the water samples with TIER 1 Risk Based Corrective Action (RBCA) values to determine the inherent risks and health hazards for each identified contamination pathway, associated with petroleum hydrocarbons.
- Present the results of the investigation to the client in the form of a report.

4. DESCRIPTION OF THE NATURAL ENVIRONMENT

4.1. Locality, topography and drainage

The proposed filling station, office park and retail park will be located on Ptn 25 of the farm Vlakfontein 325-JR, near Bronkhorstspruit, Gauteng. The locality map is shown in Figure 2 below. The site of the development site is relatively flat with a general surface slope of 0.06 in a north westerly direction, where the slope is steeper forming a valley. The site is located in the Olifants Water Management Area downstream (north) of the Bronkhorstspruit Dam, 350 m from the *Bronkhorstspruit* which flows north in the quaternary catchment B20D. The *Bronkhorstspruit* in this area flows permanently throughout the whole year. The site is located at an elevation of 1410 mamsl. Surface drainage is easterly towards the *Bronkhorstspruit*. Groundwater flow is expected to follow topography flowing towards a discharge point, i.e. the *Bronkhorstspruit*.

Figure 1: Current status of the development site (17 August 2016)

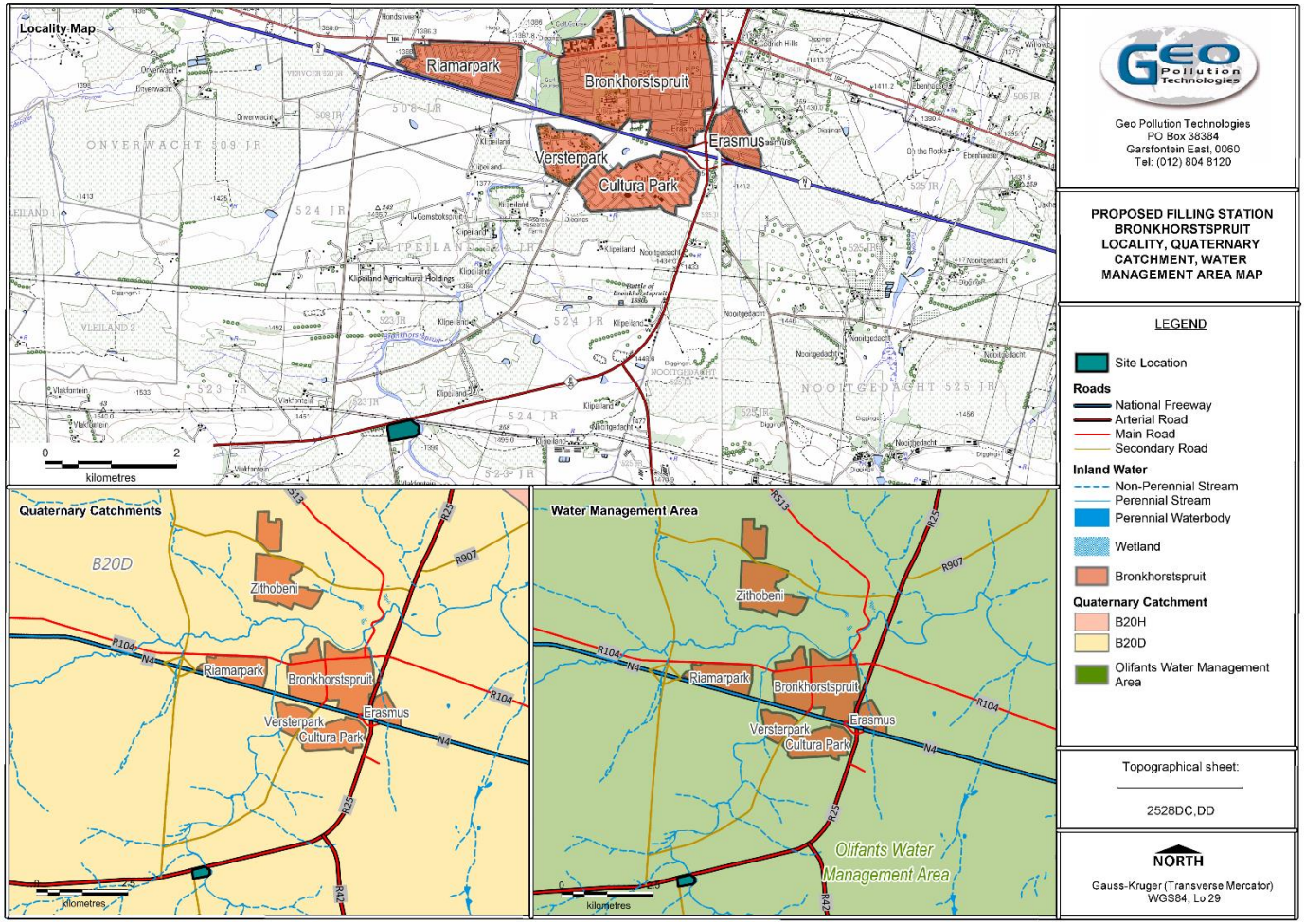

Figure 2: Locality map

4.2. Regional Geology

The investigated area falls within the 2528 Pretoria 1:250 000 geology series maps and is situated approximately 8 km south-west of the town of Bronkhorstspruit, Gauteng. An extract of the map is shown in Figure 3.

The site of the planned development is underlain by quartzite with interlayers of shale and sub-greywacke of the Rayton Formation of the Pretoria Group, Transvaal Supergroup. Around the site outcrops dolerite dykes or sills.

Pretoria Group quartzites are extensive and competent; they reach up to 300 m in thickness at places. The Transvaal Supergroup rocks are of Vaalian age and underwent deformation related to the intrusion of the BIC and granitic provinces resulting in small-scale folding and faulting. The average dip of the quartzite layers is 18° north-east.

4.3. Hydrogeology

As discussed, the site is underlain by the Rayton Formation. At outcrop areas and if weathered, the Pretoria Group quartzites tend to form extensive aquitards with improved porosity and permeability.

The potential for groundwater occurrence will depend on the presence of joints and fractures in the quartzites. Weathering and fracturing may increase the aquifer potential, thus zones of weathering and fracturing within the quartzites will act as targets for potential groundwater exploration. The thickness of Pretoria Group quartzites may reach up to 300 m but the depth of weathering is thin (up to 15 m), it can be concluded that groundwater users in the area tap their water from this weathered/fractured quartzitic aquifer. The average recharge values assigned to quartzite in outcrop areas is ± 10 % of the mean annual precipitations (MAP) (Groundwater Decision Tool). The natural/background water quality is commonly within target water quality limits.

4.3.1. Shallow weathered aquifer

Quartzite/shale and sandstone complexes are found to generally have low transmissivities, except if weathered and form extensive aquitards in outcrop areas. The sandy soil horizon is expected to allow for rapid infiltration into the vadose zone during precipitation events at recharge. High runoff rates are expected on the steep slopes to the east towards the *Bronkhorstspruit*. Streams that converge at right angles are common in jointed, folding or faulted quartzites. Folding leads to a high degree of fracturing and the shallow weathered aquifer is thought to have developed a high fracture density due to folding.

The main source of recharge into the shallow alluvial aquifer is rainfall that infiltrates the aquifer through the unsaturated zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity. Groundwater recharge was estimated to be an average of 10% of mean annual precipitation. The commonly expected values of porosity and hydraulic conductivity are 0.05 and 0.1 m/day, respectively. This aquifer is thought to be the main productive aquifer in the area.

4.3.2. Fractured aquifer

At depth, Pretoria Group quartzites are generally competent rock and tend to develop good jointing systems. Primary porosity is virtually inexistent and the presence of water is generally limited to secondary structures, i.e. joints and fractures.

Both the porosity and the hydraulic conductivity of these aquifers are known to be low. The commonly expected values of porosity and hydraulic conductivity are 0.035 and 0.01 m/day, respectively. Movement of groundwater in this aquifer occurs primarily in secondary structures such as faults and fractures. The Pretoria Group quartzites are low-yielding aquifers, with a low groundwater development potential at depths greater than 40 m below the surface.

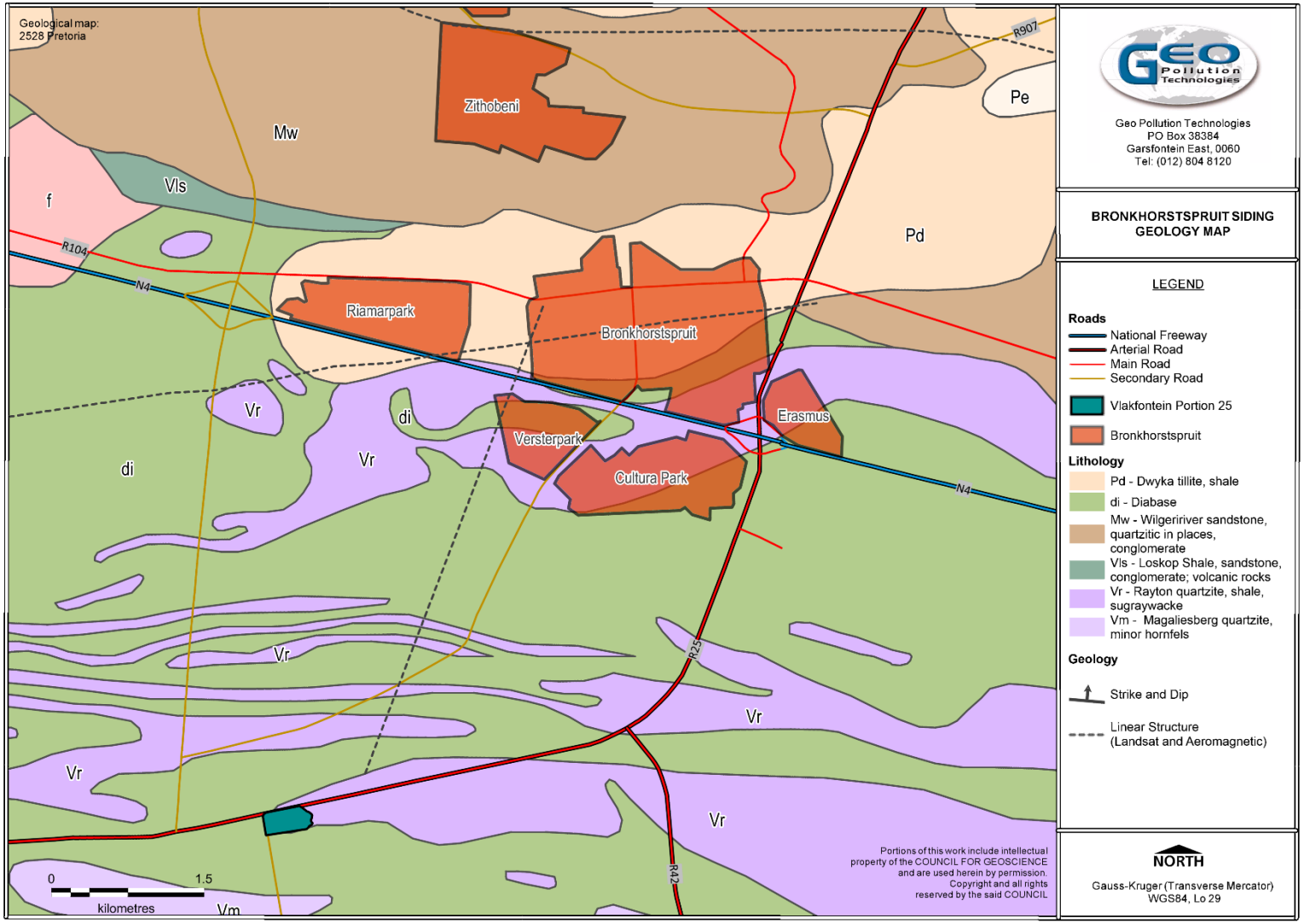

Figure 3: Regional Geology Map (1:250 000 geology series map)

5. RESULTS OF THE INVESTIGATION

5.1. Hydrocensus survey

A hydrocensus survey was conducted on 17 August 2016 within a one km radius of the site of development to identify groundwater users and natural drainage features. Three privately-owned abstraction boreholes were identified in the surrounding area. One abstraction borehole was found at the proposed filling station site. The dominant groundwater use in the area is human consumption, with minor livestock watering. The average depth to water table across the area is 8.5 mbgl. The proposed development site is located 350 m of the *Bronkhorstspruit* and samples were taken upstream and downstream of Ptn 25. The hydrocensus positions are shown on the locality map in Figure 2 below. The hydrocensus data sheet for each borehole is attached under Appendix III.

The hydrocensus information is summarised in Table 1. Six ground- and surface water samples were submitted for laboratory analysis for selected inorganic constituents and petroleum hydrocarbons associated with filling stations.

5.2. Groundwater depth and flow direction

It can generally be assumed that the groundwater table emulates the surface topography. Groundwater flow is therefore inferred to take place in an westerly direction. The average depth to the water table in the area is 8.5 mbgl.

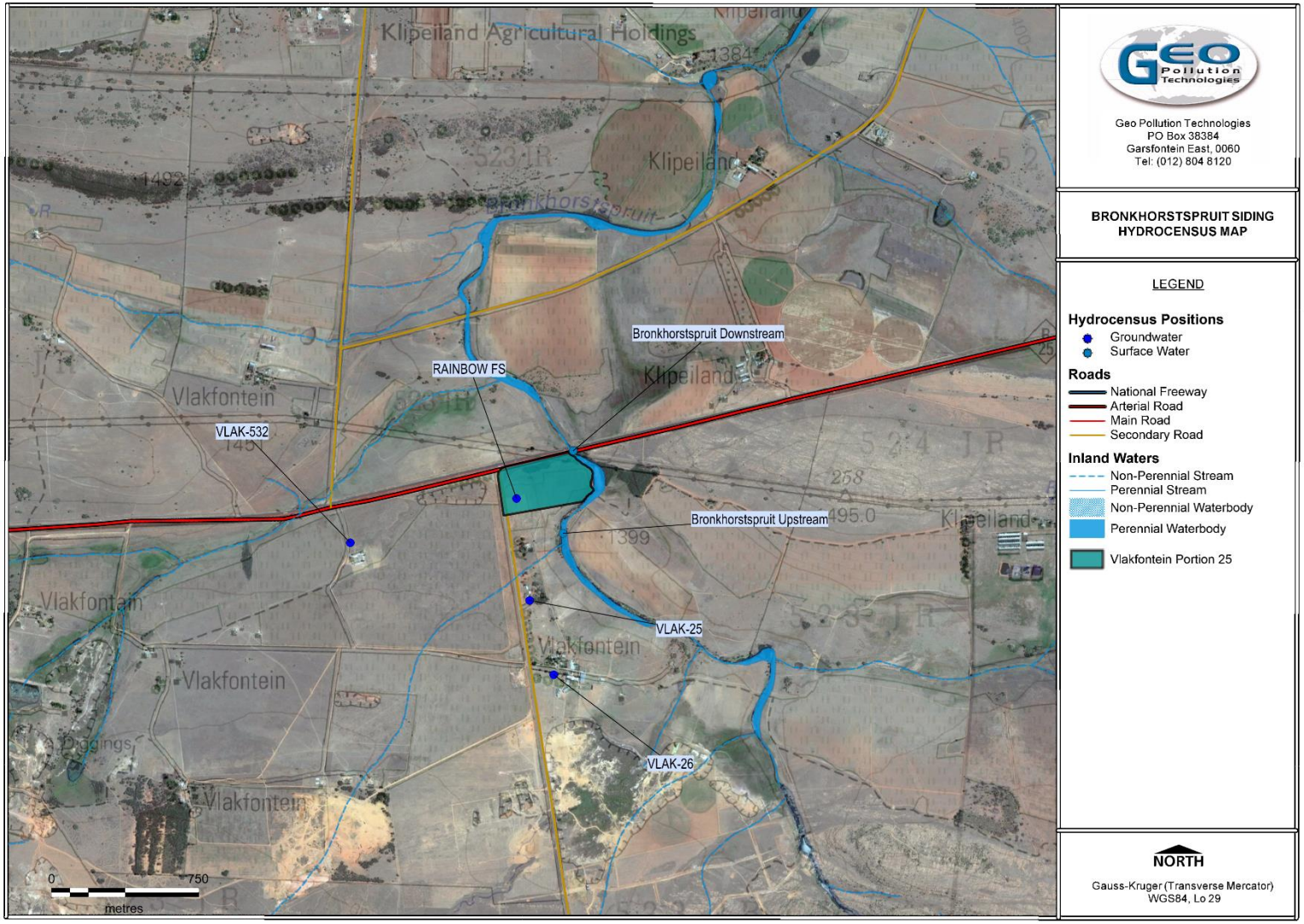

Figure 4: Hydrocensus map

Table 1: Hydrocensus information

No.	ID	Latitude	Longitude	Elevation (mamsl)	Owner	Property	Casing height	Static water level (mbgl)	Static water level (mamsl)	Sampled (Y/N)	Use
Groundwater											
1	RAINBOW FS	-25.85852	28.70007	1413	J. J. Erasmus	Rainbow Filling Station	0.025	-	-	Yes	Domestic
2	VLAK-25	-25.86319	28.70074	1419	Mr. Tinus Strydom	Unit 25 Vlakfontein	0.024	11.5	1407.5	Yes	Domestic
3	VLAK-26	-25.8666	28.70198	1427	Mr. Tinus Strydom	Unit 26 Vlakfontein	0.000	7.1	1419.9	Yes	Domestic and Livestock
4	VLAK-532	-25.86054	28.69161	1411	Vlakfontein Trust	Unit 532 Vlakfontein	0.000	6.9	1404.1	Yes	Domestic
Surface water											
1	Bronkhorstspruit Upstream	-25.86012	28.70244	1392	NA	*Bronkhorstspruit*	0.000	0	1392	Yes	NA
2	Bronkhorstspruit Downstream	-25.85633	28.70295	1388		*Bronkhorstspruit*	0.000	0	1388	Yes	

5.3. Water Quality Assessment

5.3.1. Water Quality (Organic analyses)

The collected water samples were stored below 4°C prior to submission to UIS Organic Laboratory (Pty) Ltd for the screening of volatile petroleum hydrocarbons by gas chromatography mass spectrometry (GC-MS) screening technique. The results are listed in Table 2 with copies of the laboratory reports attached under Appendix I.

No targeted petroleum hydrocarbons were detected in any of the groundwater and *Bronkhorstspruit* samples.

Table 2: Results of the petroleum hydrocarbon analyses on water samples (mg/ℓ)

	Sample no.	BRONKHORSTSPRUIT DONWSTREAM	BRONKHORSTSPRUIT UPSTREAM	RAINBOW FS	VLAK-25	VLAK-26	VLAK-532
	Sample depth (mbgl)						
Gasoline Range Organics	Benzene	BDL	BDL	BDL	BDL	BDL	BDL
	Toluene	BDL	BDL	BDL	BDL	BDL	BDL
	Ethylbenzene	BDL	BDL	BDL	BDL	BDL	BDL
	Xylenes	BDL	BDL	BDL	BDL	BDL	BDL
	MTBE	BDL	BDL	BDL	BDL	BDL	BDL
	TAME	BDL	BDL	BDL	BDL	BDL	BDL
	Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL
	1,2,4 Trimethyl benzene	BDL	BDL	BDL	BDL	BDL	BDL
	1,3,5 Trimethyl benzene	BDL	BDL	BDL	BDL	BDL	BDL
Poly Aromatic Compounds	Acenapthene	BDL	BDL	BDL	BDL	BDL	BDL
	Acenaphthylene	BDL	BDL	BDL	BDL	BDL	BDL
	Fluorene	BDL	BDL	BDL	BDL	BDL	BDL
	Phenanthrene	BDL	BDL	BDL	BDL	BDL	BDL
	Anthracene	BDL	BDL	BDL	BDL	BDL	BDL
	Fluoranthene	BDL	BDL	BDL	BDL	BDL	BDL
	Pyrene	BDL	BDL	BDL	BDL	BDL	BDL
Diesel Range Organics	TPH Aliphatic C_8-C_{10}	NA	NA	NA	NA		
	TPH Aliphatic C_{10}-C_{12}	BDL	BDL	BDL	BDL	BDL	BDL
	TPH Aliphatic C_{12}-C_{16}	BDL	BDL	BDL	BDL	BDL	BDL
	TPH Aliphatic C_{16}-C_{20}	BDL	BDL	BDL	BDL	BDL	BDL
	TPH Aliphatic C_{10}-C_{14}	BDL	BDL	BDL	BDL	BDL	BDL
	*TPH Aliphatic C_{15}-C_{36}	BDL	BDL	BDL	BDL	BDL	BDL
	Total VPHs Identified	BDL	BDL	BDL	BDL	BDL	BDL
	Estimated VPHs Unidentified	BDL	BDL	BDL	BDL	BDL	BDL
	Estimated TOTAL VPHs	BDL	BDL	BDL	BDL	BDL	BDL
* Assuming unidentified compounds fall in this range							

5.3.2. Water Quality (Inorganic analyses)

Four (4) groundwater samples and two surface water samples were submitted to UIS Analytical Services (Pty) Ltd for major cation and anion inorganic analyses to determine the general drinking water quality. The results are listed in Table 3 and Appendix II.

The water results are compared with the maximum recommended concentrations for domestic use as defined by the SANS 241-1: 2015 target water quality limits. The SANS 241-1: 2015 standard is applicable to all water services institutions and sets numerical limits for specific determinants to provide the minimum assurance necessary that the drinking water is deemed to present an acceptable health risk for lifetime consumption. Colours of individual cells refer to the drinking water classification of the specific groundwater sample.

Table 3 indicates that all the sampled boreholes and the *Bronkhorstspruit* upstream and downstream of the proposed development's water constituent concentrations comply with the SANS 241 limits for human consumption.

Table 3: Results of the drinking water quality analyses compared with the SANS 241:2015 limits

Paramter		Unit	SANS 241: 2015 Recommended Limits	Risk	Results					
					RAINBOWFS	VLAK-25	VLAK-26	VLAK-532	BRONKHORSPRUIT UPSTREAM	BRONKHORSPRUIT DOWNSTREAM
Physical & Aesthetic determinands										
Electrical conductivity at 25^0C	EC	mS/m	≤ 170	Aesthetic	18.6	16.6	13.7	19.3	36.8	36.2
Total Dissolved Solids	TDS	mg/liter	≤ 1200	Aesthetic	130	116	95.6	135	257	253
pH at 25^0C		pH units	≥ 5 to ≤9.7	Aesthetic	8	7.5	7.96	7.34	8.12	8.19
Chemical Determinands - Macro determinands										
Nitrate as N	NO_3	mg/liter	≤ 11	Acute Health	1.11	1.45	1.25	2.04	1.66	1.57
Sulphate	SO_4	mg/liter	Acute Health ≤500; Aesthetic ≤250	Acute Health/Aesthetic	2.24	0.5	0.8	3.08	30	27.1
Fluoride	F	mg/liter	≤1.5	Chronic Health	0.12	0.174	0.13	0.149	0.428	0.42
Chloride	Cl	mg/liter	≤ 300	Aesthetic	5.78	1.96	1.96	8.06	23.2	23.1
Sodium	Na	mg/liter	≤ 200	Aesthetic	10.6	8.92	8.38	12.4	21.5	20
Concentration deemed to present an unacceptable health risk for lifetime consumption.										

6. PETROLEUM HYDROCARBON HUMAN HEALTH RISK ASSESSMENT

The concentrations of targeted hydrocarbon compounds in water samples were compared to Risk Based Screening Levels (RBSLs as determined by BP RISC 4.03) in order to determine the potential health risks posed to human receptors by petroleum hydrocarbons. The RBSLs are available on request[1].

A carcinogenic risk is the probability of incurring cancer as a result of exposure to the contaminants of concern. The Hazard Quotient (Hazard) is associated with non-carcinogenic compounds, which may compromise human health.

6.1. Water Screening Levels

From the results presented in Table 4 below it can be seen that none of the detected hydrocarbon compounds in the water samples exceed Tier 1 RBSLs.

In terms of the source, pathway and receptor assessment methodology, consideration is given to the following potential exposure pathways and likely receptors:

- ***Ingestion of contaminated groundwater:*** The source-pathway-receptor linkage is incomplete, thus there is no risk to human health and aquatic ecosystems as there is no source of contaminants or contamination.
- ***Indoor inhalation of air vapours:*** This pathway is not regarded as relevant at this stage.
- ***Outdoor inhalation of air vapours:*** This pathway is not regarded as relevant at this stage.

NB *The petroleum hydrocarbon human health risk assessment is based on the results of analyses on baseline or pre-development conditions. This means that risk profiles can change as land use changes.*

[1] collen@gptglobal.com

Table 4: Water screening results

Relevant GW Exposure Pathway	BRONKHORSTSPRUIT DONWSTREAM	BRONKHORSTSPRUIT DONWSTREAM	RAINBOW FS	VLAK-25	VLAK-26	VLAK-532
Tier 1 RBSL GW Ingestion - Commercial	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*
Tier 1 RBSL Indoor Air - Commercial	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*
Tier 1 RBSL Outdoor Air - Commercial	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*	*No compound exceeded its screening level*

6.2. Potential impacts

No targeted petroleum hydrocarbon compounds were detected in the water samples from abstraction boreholes in the vicinity of the proposed filling station site. The background or baseline environmental status of the area is within water quality objectives as set out in RBSL and SANS 241:2015 guidelines.

In future, potential leakages and/or spillages from the proposed filling station may have a negative impact on these receptors through the pathways of soil, air and/or groundwater. However, it is understood that the future product installation will comply with the latest standards and that the necessary mitigatory measures and early warning systems will be in place to minimise any potential impact on the environment as a result of possible product leakages and/or spillages.

The *Bronkhorstspruit* forms the western boundary of the farm portion and is thus regarded as the most sensitive receptor with regards to impacts on water quality. If the average hydraulic conductivity for Pretoria Group sediments is 0.01 m/day and the distance to the *Bronkhorstspruit* is 350 m west of the current AST on-site, a dissolved solute would take ±100 years to reach the *Bronkhorstspruit*. Thus early monitoring will give sufficient time for management and remediation activities to manage potential contamination.

The development will include the construction of a retail store and office park increasing the demand for clean and potable groundwater. The stress on the borehole, RAINBOW FS, will be increased. This may put stress on groundwater availability in the area thus a sustainable yield will have to be determined for the current and future boreholes to be used for water supply in the development.

7. SUMMARY AND CONCLUSIONS

Based on the results of the field work, laboratory analyses and health risk assessment, the following can be concluded:

- Four groundwater supply boreholes were identified within a one km radius of the proposed filling station site during a hydrocensus survey. Water from these abstraction boreholes is used for human consumption and livestock watering.
- The site of the planned development is underlain by quartzite with interlayers of shale and sub-greywacke of the Rayton Formation of the Pretoria Group, Transvaal Supergroup. Around the site outcrops dolerite dykes or sills.
- It can generally be assumed that the groundwater table emulates the surface topography. Groundwater flow is therefore inferred to take place in westerly direction. The average depth to the water table in the area is 8.5 mbgl.
- Six ground- and surface water samples were submitted for laboratory analysis for selected inorganic constituents and petroleum hydrocarbons associated with filling stations. No targeted petroleum hydrocarbons were detected in any of the groundwater and *Bronkhorstspruit* samples.
- The source-pathway-receptor linkage is incomplete, thus currently there is no risk to human health as there is no source of contaminants or contamination.
- If the inorganic laboratory results are compared with the SANS 241-1: 2015 drinking water limits all of the sampled groundwater and surface water points are found to comply.
- Although the proposed filling station will be located in a sensitive area based on the presence of groundwater users and the *Bronkhorstspruit* 350 m from the site, it is understood that the product installation will comply with the latest standards and that the necessary mitigatory measures and early warning systems will be put in place to minimise

any potential impact on the environment as a result of possible product leakages and/or spillages.

- The *Bronkhorstspruit* forms the western boundary of the farm portion and is thus regarded as the most sensitive receptor with regards to impact on water quality. The average hydraulic conductivity for Pretoria Group sediments is taken as 0.01 m/day. The *Bronkhorstspruit* is located 350 m west of the current AST on-site. A dissolved solute would take about 100 years to reach the *Bronkhorstspruit*. Thus early monitoring will give sufficient time for management and remediation activities to manage potential contamination.
- The development will include the construction of a retail store and office park increasing the demand for clean and potable groundwater. The stress on the borehole, RAINBOW FS, will be increased. This may put stress on groundwater availability in the area thus a sustainable yield will have to be determined for the current and future boreholes to be used for water supply in the development.

8. RECOMMENDATIONS

In terms of responsible environmental management practices, GPT recommends the following:

- All tankage and equipment must be constructed as per relevant SANS standards. In addition, all equipment must be installed using approved contractors.
- The fuel supplier must ensure that sufficient training is presented to the operators of the refuelling area. Training must include general site operation, spill response and emergency procedures, and site safety.
- Safety signage and emergency response systems must be put in place.
- All fuel spillages on site must be addressed immediately.
- Filler points and tank manholes must be fitted with secondary containment measures to ensure that any tank overfills are contained.
- Concrete containment slabs must be constructed around filler points and the dispensing area.
- In the unlikely event of a major spillage or leakage, an appropriate spill response and clean-up contractor must be contacted immediately to assist in clean-up operations. An independent hydrogeologist must be commissioned to determine the lateral and vertical extent of the contamination plume as well as to provide recommendations and assist with remediation and rehabilitation of the affected area. The Department of Water Affairs must be notified immediately of spillages larger than 200 liters.
- Installation of a groundwater monitoring borehole drilled up to 15 -20 m down-gradient of the storage tank(s) towards the *Bronkhorstspruit* to act as an early warning system to detect groundwater contamination. The drilling and construction of the borehole should be overseen by a hydrogeologist.
- The borehole should be monitored on a yearly basis for volatile petroleum hydrocarbons by gas chromatography mass spectrometry (GC-MS).

APPENDIX I: LABORATORY CERTIFICATES

APPENDIX II: HYDROCENSUS INFORMATION