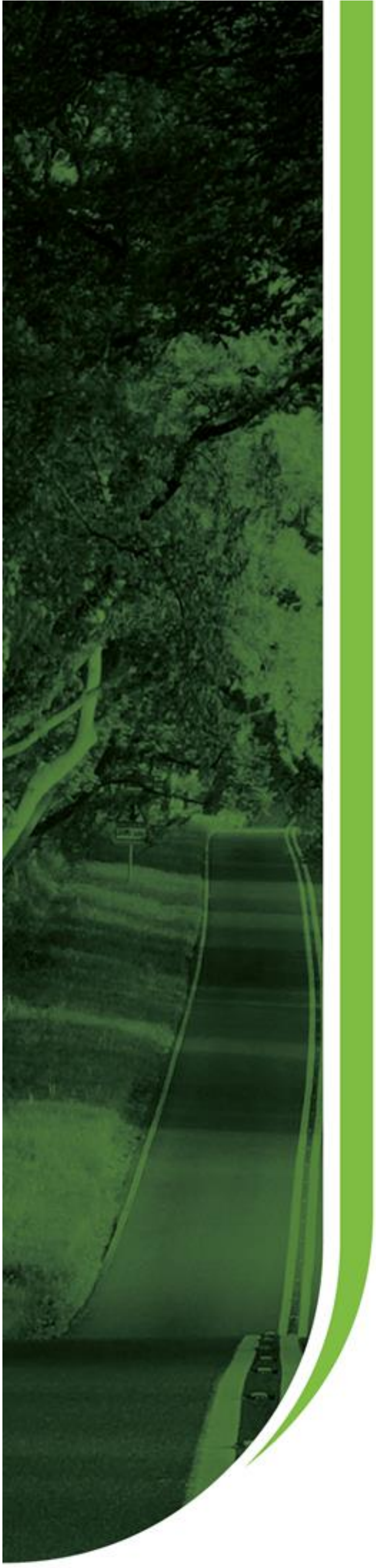

GEOHYDROLOGICAL IMPACT ASSESSMENT FOR THE PROPOSED EXPANSION OF CHICKEN HOUSES FROM APPROXIMATELY 30 000 TO 60 000 CHICKENS, BULHOEK FARM, NEAR SWARTRUGGENS, NORTH WEST PROVINCE

Geohydrological Report

October 2021

Prepared for:

QUANTUM FOODS

Prepared by:

Me Rolene Lubbe
(MSc. Geohydrology)
rolene@enviroworks.co.za

EXECUTIVE SUMMARY

Enviroworks (PTY) Ltd. was appointed to compile a Geohydrological Impact Assessment as part of Specialist Studies required for a Basic Assessment Process as well as a Water Use License Application for the proposed expansion of the proposed chicken houses and associated infrastructure in Quaternary catchment A22D, Crocodile (West) and Marico Water Management Area, on the Bulhoek Farm, near Swartruggens, North West Province.

The facility poses a **low** risk in terms of groundwater contamination potential and a **low** risk in surface water contamination potential. Any risks can be decreased by taking the recommendations and mitigation measures identified during the Geohydrological investigation into account.

PROJECT DESCRIPTION

Enviroworks (PTY) Ltd. was appointed to compile a Geohydrological Impact Assessment for an Environmental Assessment, Water Use License Application and associated licensing processes for the proposed expansion of existing chicken houses from approximately 30 000 to 60 000 chickens on Bulhoek Farm, near Swartruggens, North West Province (Figure 2).

Waste removal: After the quarantine period on the farm, the chicken carcasses will be taken to the local zoo and the remaining general waste will be disposed of a registered landfill site. The chicken manure is collected by an external farmer to use as fertilizer.

Sewage and wastewater: Sewage on site is kept in holding tanks until it is removed by a service provider. Wash water is disposed of in the field, however it is proposed that wash water from cleaning the chicken houses be treated in evaporation ponds. Should it be decided to irrigate fields with the wash water from the chicken houses, the water will need to be tested to ensure that it meets the minimum requirements. If the wash water quality does not comply with the minimum requirements, water should be treated prior to irrigation.

The layout of the current development can be seen in Figure 1.

The site is situated off the N4 road, approximately 34 km from Swartruggens, North West Province as seen in Figure 3.

The objectives of the study were as follow:

- A desktop study of the area under investigation for the purpose of establishing a conceptual model.
- A site visit to obtain information of the area under investigation.
- A hydro-census of all the boreholes within a one (1) km radius of the area of investigation to determine the state of the groundwater use of these boreholes.
- Analysis of both the groundwater- and surface water quality.
- To assess the groundwater vulnerability in the vicinity of the facility.
- A geophysical investigation using aeromagnetic data.
- A geophysical survey to confirm desktop findings.
- To conduct a Geohydrological Impact Assessment.
- To compile a Geohydrological Report with recommendations and mitigation measures.

Quantum Foods, Bulhoek Farm, North West Province, is mainly dependant on groundwater, supplied from three (3) existing boreholes on site, for the use of:

- Drinking water for the chickens;
- Human consumption;
- Cleaning the chicken houses; and,
- Domestic use – sanitation and showers.

The waste associated with the proposed development of the facility that can be potential groundwater and surface water contaminants are:

- Three (3) septic tanks that is situated on site which is serviced and disposed of by honey suckers as requested;
- Chicken manure that is removed manually from the chicken houses onto an impermeable surface, whereafter it is given to surrounding farmers to use as fertilizer; and,
- Eleven (11) evaporation ponds that will be used to treat the wash water from cleaning the chicken houses.

SITE PLAN

The site layout of the Bulhoek Farm with respect to the existing chicken houses, new proposed chicken houses and proposed evaporation ponds, can be seen in Figure 1 below.

Figure 1. The layout of the development of the Bulhoek Farm, Swartruggens, North West Province. The evaporation ponds area indicated in blue and the new chicken houses are indicated by red.

UNCERTAINTIES & ASSUMPTIONS

The following uncertainties and assumptions were made during the Geohydrological investigation:

- All information provided by the applicant and engineering design team to the environmental specialist was correct and valid at the time that it was provided;
- The desktop study was based on information obtained via literature, google maps, ArcGIS, which is assumed to be correct and of the latest information available;
- The report was written within a specified time frame and any changes that may have occurred after the time of the writing of the report as well as the site visit are disregarded in regards with this report;
- The geophysical investigation consists of aeromagnetic data and a geophysical survey at the critical areas where waste is handled;
- It is assumed that certain conditions identified in the vicinity of Rustenburg, North West Province are similar to the site-specific conditions of the facility such as climate, precipitation *etc.;*
- Enviroworks is an independent environmental consulting firm and as such, all processes and attributes of the specialist investigations and EIA are addressed in a fair and unbiased/objective manner. It is believed that through the running of a transparent and participatory process, risks associated with assumptions, uncertainties and gaps in knowledge can be and have been acceptably reduced;
- A geophysical survey was done on 22 September 2021 at the evaporation ponds positions as indicated on the previous layout plans prior to the distribution of the new positions of the evaporation ponds.

DECLARATION OF INDEPENDENCE OF THE GEOHYDROLOGICAL IMPACT ASSESSMENT SPECIALIST

I, **Rolene Lubbe**, **ID (9503040181087)**, declare that I:

- am a Geohydrological Specialist at Enviroworks;
- act as an independent Specialist Consultant in the field of Geohydrological Impact Assessments;
- am assigned as Specialist Consultant for this proposed project;
- do not have or will not have any financial interest in the undertaking of the activity other than remuneration for work as stipulated in the terms of reference;
- remuneration for services by the proponent in relation to this proposal is not linked to approval by decision-making authorities responsible for permitting this proposal;
- the consultancy has no interest in secondary or downstream developments as a result of the authorisation of this project;
- have no and will not engage in conflicting interests in the undertaking of the activity;
- disclaim responsibility for any changes that may have occurred after the time of the site visit and the time that the report was written;
- assumed that the information in this report is to be the of the latest available information;
- undertake to disclose to the client and the competent authority any material, information that have or may have the potential to influence the decision of the competent authority required in terms of the Environmental Impact Assessment Regulations 2017; and,
- will provide the client and competent authority with access to all information at my disposal, regarding this project, whether favourable or not.

Rolene Lubbe
MSc. Geohydrology & BSc. Geology

SPECIALIST DETAILS

Business name of Specialist:	Enviroworks
Specialist Name:	Rolene Lubbe
Physical address:	5 Walter Sisulu Road, Park West, Bloemfontein
Postal address:	Suite 116, Private Bag X01, Brandhof, 9324
Telephone:	051 436 0793
E-mail:	rolene@enviroworks.co.za
IAIA Registration Number:	6394
SACNASP Number:	127453
EAPASA Candidate EAP:	2020/2476
Qualifications:	• BSc. Degree in Geology (University of the Free State) (2018) • Honours Degree in Geohydrology (University of the Free State; Institute for Groundwater Studies) (2019) • MSc. Degree in Geohydrology (University of the Free State) (2020)

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Rolene Lubbe

Highest Qualification	**MSc. Geohydrology**
IAIA registration No.	6394
EAPASA Candidate EAP No.	2020/2476
SACNASP Candidate registration No. as: • **Water Resources Science (Candidate Natural Scientist)** • **Geological Science (Candidate Natural Scientist)**	127453

RELEVANT QUALIFICATIONS

- Baccalaureus Scientiae (B.Sc.) in Geology Specialisation: University of the Free State (2018)
- Baccalaureus Scientiae (B.Sc.) Honours in Geohydrology: University of the Free State, Institute for Groundwater Studies (2019)
- Master's degree (M.Sc.) in Geohydrology: University of the Free State, Institute for Groundwater Studies (2020)

WORK EXPERIENCE

January 2020 – Present: Environmental Specialist and Geohydrological Specialist at Enviroworks

KEY PROJECT EXPERIENCE

BASIC ASSESSMENT EXPERIENCE

- The proposed expansion of a wastewater treatment works on the remaining extent (RE) of the Farm Mier No. 585, Rietfontein, Northern Cape Province, South Africa.
- The proposed feedlot expansion of the existing cattle farm, Karan Beef Nigel, on Portion 2 & 3 of the Farm Leeuwenfontein No. 284 and Portion 2 of the Farm Holgatfontein No. 326, Nigel, Gauteng Province.

ENVIRONMENTAL MANAGEMENT PLAN

- The proposed expansion of a wastewater treatment works on the remaining extent (RE) of the Farm Mier No. 585, Rietfontein, Northern Cape Province, South Africa.
- The proposed feedlot expansion of the existing cattle farm, Karan Beef Nigel, on Portion 2 & 3 of the Farm Leeuwenfontein No. 284 and Portion 2 of the Farm Holgatfontein No. 326, Nigel, Gauteng Province.
- Proposed development of a fuel station consisting of one (1) Diesel- and one (1) Petrol tank on a Portion of Portion 2 of Erf 4671, O.R. Thambo Road, Hamilton, Free State Province.

EXPERIENCE IN PERMITS AND LICENCING

- The Water use license of the proposed expansion of a wastewater treatment works on the remaining extent (RE) of the Farm Mier No. 585, Rietfontein, Northern Cape Province, South Africa.
- Water use license additional requested studies, Baramakama Poultry on the remaining extent of Portion 1 of the Farm Elandsfontein No. 21, Molote City, North West province, South Africa.

LEGAL QUERY

- Proposed development of a telecommunication base station for Highwave Consultants on Erf 1298, Bela-Bela, Limpopo Province, South Africa.
- Proposed development of one (1) Paraffin tank on Erf 4658, Nuffield Street, Hamilton, Bloemfontein, Free State Province.
- Proposed development of a fuel station consisting of one (1) Diesel- and one (1) Petrol tank on a Portion of Portion 2 of Erf 4671, O.R. Thambo Road, Hamilton, Free State Province.
- Proposed development of a community hall and associated parking lot on Erven 4978 & Erven 4979 on a Portion of Portion 6 of the Remaining Extent (RE) of the Farm Selosesha Townlands No. 900, Thaba 'Nchu, Free State Province.

GEOHYDROLOGICAL IMPACT ASSESSMENTS

- The proposed expansion of a waste water treatment works on the remaining extent (RE) of the Farm Mier No. 585, Rietfontein, Northern Cape Province, South Africa.
- Water use license additional requested studies, Baramakama Poultry on the remaining extent of Portion 1 of the Farm Elandsfontein No. 21, Molote City, North West province, South Africa.
- Water use license for Quantum Foods Nulaid Eggs for the construction of chicken lay houses on the existing layer farm on Portion 147 and Portion 148 of the Farm Hartebeesfontein No. 472, Hekpoort, Gauteng Province, South Africa.

- Water use license for Quantum Foods Nulaid Eggs for the construction of new chicken lay houses on the existing layer farm Bultfontein No. 475, Portion 75, Skeerpoort, North West Province, South Africa.
- Geohydrological Report for Supreme Poultry on Portion 16 of the Farm Dyssel's Rust No. 2841, Kelly's View Breeders farm, Bloemfontein, Free State Province, South Africa.
- Geohydrological Report for Supreme Poultry on the Remainder of the Farm Belgie No. 1285, Belgie Breeders farm, Bloemfontein, Free State Province, South Africa.
- Geohydrological Impact Assessment, Riet valley Farm, Laventelbos, Gouritz, Western Cape Province.

EXTERNAL AUDIT

- External Annual Audit for Letsatsi Solar PV Plant, Free State Province, South Africa.
- External Annual WUL Audit for REISA Solar PV, Kathu, Northern Cape Province, South Africa.

CHRISTIAAN VERMAAK

Geohydrologist

PROFILE

Throughout his late student years, he managed a company that developed industrial electronic instrumentation, mainly in the mining environment. A Temporary patent was registered for a new slack/tight rope system that was developed. Christiaan started his career as geohydrologist in 2001 and gained experience in environmental geohydrology as well as rural water supply, pollution geohydrology and monitoring and evaluation of water systems. He has a keen interest in the practical side of geohydrology and as a result a number of aquifer testing rigs were designed and built by Tucana Solutions, under his direct supervision. He has a positive attitude towards problem solving. It is of high importance for him to maintain an outstanding standard of work throughout all projects.

CONTACT

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christiaan@tucanasolutions.co.za

HOBBIES

Cycling
Rock climbing
Hiking
Metal work
Electronics

EDUCATION

University of the Free State (South Africa)
2005 – GIS 224 (An introduction to Geographical Information Systems)

University of the Free State (South Africa)
1995 - 2002 – MSc Physics (Segregation of Phosphorus and other impurities in 3CR12 Stainless steel)

University of the Free State (South Africa)
1998 - 2001 – MSc. Geohydrology (Development of Hard and software to monitor pressure transducer water level meters in test wells)

WORK EXPERIENCE

NSVT Consultants (Geohydrologist)
2001 – February 2010
Responsible for environmental impact assessments, specialist geohydrological assessments as well as geophysical surveys and drilling and yield testing supervision.

Tucana Solutions (Geohydrologist (owner))
2010 – Current
Project & Office management, Geohydrological assessments, Design and manufacturing of field equipment, Geophysical surveys, Water monitoring, exploration, drilling and scientific yield testing of boreholes for the purpose of rural water supply. Pollution studies and down the borehole camera surveys. Water conservation and demand management plans. Monitoring and evaluation specialist for Department of water and sanitation. Water use license applications. Installation, Service and maintenance on solar and wind pumping equipment. Installation of photo voltaic solar systems.

PROFESSIONAL AFFILIATIONS

South African Council for Natural Scientific Professions - Pr. Sci. Nat 400100/18
Ground water Division of the Geological Society of South Africa- Central Branch(078)

SHORT COURSES/CONFERENCES

1994 Entrepreneurship and Business management
2006 South African Groundwater Decision Tool Workshop
2008 Groundwater Resource directed measures workshop; Geophysics short course; Mine water Course
2017 Groundwater division of GSSA bi- annual conference- Stellenbosch
2019 Drilling methods and techniques in exploration; Managed Aquifer recharge Workshop, Field School UWC- presenter; 16th Bi Annual Groundwater Conference (PE)

REQUIREMENTS OF A SPECIALIST REPORT

Appendix 6 of Government Notice Regulation 326 of 7 April 2017 outlines the basic requirements of a Specialist Report. Please refer to Table 1 below for all the requirements.

Table 1. Appendix 6 of Government Notice Regulation 326 of 7 April 2017 basic requirements of a specialist report.

REQUIREMENTS	YES/NO
A Specialist report prepared in terms of these Regulations must contain – a. Details of – i. The Specialist who prepared the report; and, ii. The expertise of that Specialist to compile a specialist report including a curriculum vitae;	YES
b. A declaration that the Specialist is independent in a form as may be specified by the Competent Authority;	YES
c. An indication of the scope of, and the purpose for which, the report was prepared; i. An indication of the quality and age of base data used for the Specialist Report; ii. A description of existing impacts on site, cumulative impacts of the proposed development and levels of acceptable change;	YES
d. The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	YES
e. A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	YES
f. Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	YES
g. An identification of any areas to be avoided, including buffers;	N/A
h. A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	N/A
i. A description of any assumptions made and any uncertainties or gaps in knowledge;	YES
j. A description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	YES
k. Any mitigation measures for inclusion in the EMP’r	YES
l. Any conditions for inclusion in the Environmental Authorisation;	YES
m. Any monitoring requirements for inclusion in the EMP’r or Environmental Authorisation;	YES
n. A reasoned opinion – i. Whether the proposed activity, activities or portions thereof should be authorised; ii. If the opinion is that the proposed activity, activities, or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMP’r, and where applicable, the closure plan;	YES

o.	A description of any consultation process that was undertaken during the course of preparing the specialist report;	YES
p.	A summary and copies of any comments received during any consultation process and where applicable all responses thereto; and,	N/A
q.	Any other information requested by the Competent Authority.	N/A

GEOHYDROLOGICAL IMPACT EVALUATION CRITERIA CHECKLIST

As per the Provincial Government of the Western Cape Guideline for involving a Hydrogeological Specialists in the EIA Process (DEA&DP, 2005), a Geohydrological Assessment should include the following criteria (Table 2):

Table 2. Requirements for a Geohydrological Report in the EIA Process (DEA & DP, 2005).

REQUIREMENTS	YES/NO
Meet the minimum requirements for a geohydrological assessment;	YES
If a hydro-census is not included, reasons for this must be clearly motivated;	N/A
Includes a conceptual model that describes recharge, flow, discharge, and the type of aquifer;	YES
A summary Impact Assessment table using the defined impact assessment and significance rating criteria;	YES
Clear indication of whether impacts are irreversible or result in an irreplaceable loss to the environment and/or society;	YES
A statement as to whether or not the proposed project would comply or be consistent with international conventions, treaties, or protocols and with national, provincial, and local legislation, policies and plans as applicable;	YES
The need, where relevant, for higher order assessment to address potentially significant cumulative effects, or issues which fall outside the scope of the EIA process;	N/A
Statement of impact significance for each issue and alternative, before and after management, specifying whether thresholds of significance have been exceeded;	YES
Identification of beneficiaries and losers from the proposed development;	N/A
Specification of key risks and uncertainties that may influence the impact assessment findings, including a clear statement of limitations and/or gaps in knowledge and information;	YES
The specialist's assumptions and degree of confidence in the impact assessment prediction;	YES
Summary of key management actions that fundamentally affect impact significance;	YES
Identification of the best practicable environmental option, providing reasons;	YES
Identification of viable development alternatives not previously considered;	N/A
References of all sources of information and/or data used.	YES

REQUIREMENTS OF A TECHNICAL REPORT (NATIONAL WATER ACT NO. 36 OF 1998)

The Water Use Licence Applications and Appeals Regulations, 2017 of Government Notice Regulation 267 of 24 March 2017 outlines the basic requirements of Technical Reports. Table 3 below lists the relevant requirements, indicates whether the relevant information is included in this report or not and provides cross-references as to where the relevant information can be found in this report.

Table 3. Technical Report requirements of a Geohydrology Report in terms of Regulation 267 of the Government Notice Regulations of 24 March 2017, under section 26 (1) (k) and 41 (6) of the National Water Act (Act No. 36 of 1998).

REQUIREMENTS	YES/NO	REPORT SECTION REFERENCE
A Geohydrology Report prepared in terms of these regulations must contain –	YES	
1. Introduction		1
2. Geographical Setting	YES	
2.1. Topography and Drainage		4.3
2.2. Climate		4.2
3. Scope of Work	YES	2
4. Methodology	YES	3
4.1. Desk Study		
4.2. Hydro-census		
4.3. Geophysical survey and results		
4.4. Drilling and siting of boreholes		
4.5. Aquifer testing		
4.6. Sampling and chemical analysis		
4.7. Groundwater recharge calculations		
4.8. Groundwater modelling		
4.9. Groundwater availability assessment		
5. Prevailing Groundwater Conditions	YES	
5.1. Geology		4
5.1.1. Regional Geology		4.4.1
5.1.2. Local Geology		4.4.2
5.2. Acid Generation capacity		-
5.3. Hydrogeology		5
5.3.1. Unsaturated zone		5.6.4
5.3.2. Saturated zone		5.6.3
5.3.3. Hydraulic conductivity		5.6.6
5.4. Groundwater levels		5.6.1
5.5. Groundwater Potential contaminants		9.2
5.6. Groundwater Quality		5.5
6. Aquifer Characterisation	YES	
6.1. Groundwater Vulnerability		5.6
6.2. Aquifer Classification		5.6.3
6.3. Aquifer Protection Classification		5.6.3
7. Groundwater Modelling	N/A	
7.1. Software model choice		
7.2. Model set-up and boundaries		
7.3. Groundwater elevation and gradient		
7.4. Geometric structure of the model		
7.5. Groundwater sources and sinks		
7.6. Conceptual model		
7.7. Numerical model		
7.8. Results of the model		
7.8.1. Pre-facility operations		
7.8.2. During facility operations		
7.8.3. Post-facility operations		

8. Geohydrological Impacts 8.1. Construction phase 8.1.1. Impacts on Groundwater Quantity 8.1.2. Impacts on Groundwater Quality 8.1.3. Groundwater Management 8.2. Operational phase 8.2.1. Impacts on Groundwater Quantity 8.2.2. Impacts on Groundwater Quality 8.2.3. Impacts on Surface Water 8.2.4. Groundwater Management 8.3. Decommissioning phase 8.4. Post-mining phase 8.4.1. Groundwater Quantity 8.4.2. Groundwater Quality 8.4.3. Cumulative Impacts 8.4.4. Groundwater Management	YES	7
9. Groundwater Monitoring System 9.1. Groundwater monitoring network 9.1.1. Source, plume, impact, and background monitoring 9.1.2. System response monitoring network 9.1.3. Monitoring frequency 9.2. Monitoring parameters 9.3. Monitoring boreholes	YES	8 8.1 8.2 8.3
10. Groundwater Environmental Management Programme 10.1. Current Groundwater conditions 10.2. Predicted impacts of facility (mining) 10.3. Mitigation Measures 10.3.1. Lowering of groundwater levels during facility operation 10.3.2. Rise of groundwater levels post-facility operations 10.3.3. Spread of groundwater pollution post-facility operations	YES	9 9.1 9.2 9.3
11. Post Closure Management Plan 11.1. Remediation of physical activity 11.2. Remediation of Storage facilities 11.3. Remediation of environmental impacts 11.4. Remediation of water resources impacts 11.5. Backfilling of the pits	YES	10
12. Conclusion and Recommendations	YES	11 & 12

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GLOSSARY FOR GEOHYDROLOGICAL- AND GEOLOGICAL TERMS

Term	*Definition*
Aquifer	A geological formation that contains enough water to be used for economical uses such as domestic use *etc*.
Aquiclude	An impermeable geological unit that is incapable of transmitting water. Thus, cannot transmit nor store water.
Aquitard	Saturated low permeable geological formation that restricts the movement of water (despite their capability to store water).
Confined aquifer	An aquifer that is bound between two confining layers (that does not transmit water) like shale where the pressure of the water is usually higher than that of the atmosphere.
Dolerite	A volcanic rock (like basalt), that contains crystals which can be seen with a hand lens. This indicates that it cooled slowly.
Fracture aquifer	A geological formation in which the groundwater moves through joints, faults, and cracks in solid rock. Most South African aquifers are fractured aquifers.
Fault	A planar fracture in a volume of rock, across which there has been significant displacement along the fracture plane.
Groundwater recharge	Groundwater recharge is the process by which surface water moves through the process of percolation/drainage into the saturated zone. This process takes place within the vadose zone.
Hydraulic conductivity (K)	The volume of water that will move through a porous medium in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.
Intrusive rock (Igneous rock)	Rocks that are formed by magma forced into older rocks at depths within the Earth's crust, which then slowly solidifies below the Earth's surface.
mamsl	Meters above mean sea level.
mbgl	Meters below ground level.
Permeability	The ease with which water can flow through a geological formation.
Porosity (n)	A measure of the storage capacity of a geological formation.
Porous media aquifer	An aquifer that consists of aggregates of individual grain particles such as gravel, sand, and silt.
Saturated zone	Zone of subsurface that is completely saturated with water.
Sedimentary rock	Rocks that are formed by the accumulation or deposition of small particles (sediments).
Specific yield (S_y)	The amount of water that drains from a saturated rock due to the attraction of gravity to the total volume of water in the saturated aquifer.

Storativity/ Storage Coefficient (S)	The quantity of water that an aquifer will release from storage or take into storage per unit of its surface area due to a unit change in head.
Susceptibility	A measure of the relative ease with which an aquifer can be contaminated by any anthropogenic activity.
Sustainable yield	The sustainable amount of water that an aquifer can produce without dewatering the aquifer.
SWL	Static water level. It is the level of water in a well under normal, undisturbed, no-pumping conditions. Thus, the level of groundwater before pumping.
Transmissivity (T)	The rate at which groundwater flows through the entire saturated thickness of the aquifer per unit width under a unit hydraulic gradient.
Unconfined aquifer	A water table aquifer which is bounded by an aquiclude below but not at the top, resulting in the pressure of the water in the formation to be equal to that of the atmospheric pressure.
Vadose zone	Unsaturated zone of subsurface that is not saturate with water and determines the vulnerability of groundwater to pollution or contamination generated on the surface.
Vulnerability	The likelihood of groundwater to be contaminated.
Water table	Dividing line between the saturated- and unsaturated zone in the subsurface in unconfined aquifers. Thus, the level of water in the saturated zone in unconfined aquifers.

LIST OF ACRONYMS AND ABBREVIATIONS

DWS - Department of Water and Sanitation

GDP - Gross Domestic Product

IDP - Integrated Development Plan

Kw - Kilowatt

MAP - Mean Annual Precipitation

mS/m - millisiemens/meter

NEMA - National Environmental Management Act, 1998 (Act No. 107 of 1998)

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

SACNASP - South African Council for Natural Scientific Professions

SANS 241 - South African National Standards

SANSA - South African National Space Agency

WMA - Water Management Area

WULA - Water Use Licence Application

1 INTRODUCTION

As per the Provincial Government of the Western Cape Guideline for involving a Hydrogeologist Specialist in the EIA Process (Saayman; DEA&DP, 2005), there are three (3) categories of groundwater related impacts:

1. Where chemicals or effluent with the potential to change the groundwater quality is handled as part of the project/discharges into the environment.

2. Where the volume of groundwater in storage or entering groundwater storage is changes beyond what is allowed by DWAF (Department of Water Affairs and Forestry).

3. Where the groundwater flow regime is changed.

Quantum Foods, Bulhoek Farm is categorised as Category 1, which is why a Geohydrological Impact Assessment report was done as a specialist requirement for a Basic Assessment Process and Water Use License (WUL) as well as associated licensing.

This Geohydrological Investigation was done at Quantum Foods, Bulhoek Farm, Swartruggens, situated in the North West Province, South Africa.

The proposed project entails a Geohydrological Investigation and Impact Assessment at Quantum Foods, Bulhoek Farm, Swartruggens. The aim of the Investigation was to compile an Impact Assessment based on the Geohydrological, Hydrological & Geological aspects of the study area.

2 SCOPE OF WORK

The objectives to achieve this aim were as follow:

- A desktop study of the area under investigation for the purpose of establishing a conceptual model and obtaining a good understanding of the area as well as the Geological, Hydrological & Geohydrological setting.
- A topographical map of the study area to understand the surface water and groundwater drainage directions of the area under investigation.
- A site visit to obtain information of the area under investigation and to confirm the information obtained from the desktop study.
- A hydro-census of all the boreholes in a one (1) km radius of the area of investigation to collect information such as the borehole coordinates, static water levels, utilisation of the existing boreholes as well as photographs of these boreholes.
- Water samples of the groundwater to determine the background water quality.
- A description of the underlaying aquifer.
- An airborne geophysical magnetic map to determine the presence of geological intrusions that could influence the rate and direction of groundwater migration and possible contaminant transport.
- A geophysical ground survey to confirm geophysical desktop information.
- A preliminary Geohydrological, Hydrological and Geological Impact Assessment of the proposed development of geohydrological and geological setting.
- The compilation of a comprehensive Geohydrological Report.

3 METHODOLOGY

The Geohydrological investigation consists of the following:

1. Desktop Study that investigates the geographical setting of the area, the climate, and the geology.
2. Geohydrological investigation consisting of a general understanding of the geohydrology in the area of investigation, a site visit where a hydro-census was done to determine the utilisation of the groundwater in the area and groundwater recharge.
3. Groundwater vulnerability classification in the vicinity of the facility.
4. Geophysical investigation with respect to geological features for groundwater exploration (Aeromagnetic data and a geophysical survey at the site was utilized).
5. Groundwater sample collection to determine the groundwater quality.
6. Analysis of groundwater and surface water quality.
7. Geohydrological Impact Assessment to identify the related groundwater and geological impacts and mitigation measures.
8. Groundwater and geological management, recommendations and conclusions.

4 DESKTOP STUDY

4.1 Location of Area

The area of investigation as seen in Figure 2 & Figure 3, is located approximately 34 km from Swartruggens in the North West Province, South Africa. The coordinates for this study are:

- Latitude: 25° 34' 38.79'' S & Longitude: 26° 54' 29.17'' E

The location of the investigation to the surrounding urban development is shown in Figure 3.

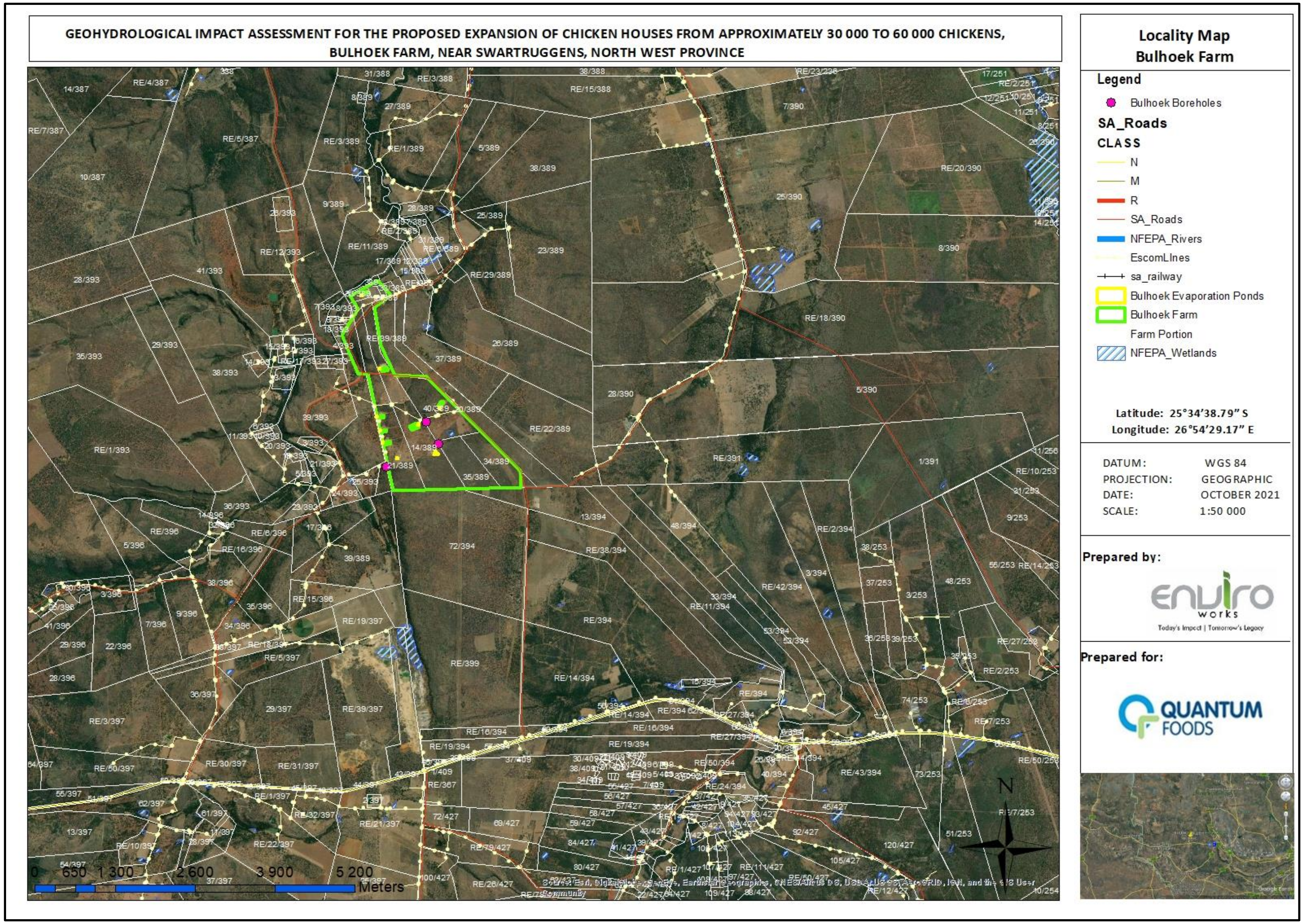


Figure 2. Locality map of Quantum Foods, Bulhoek Farm, Swartruggens, North West Province.

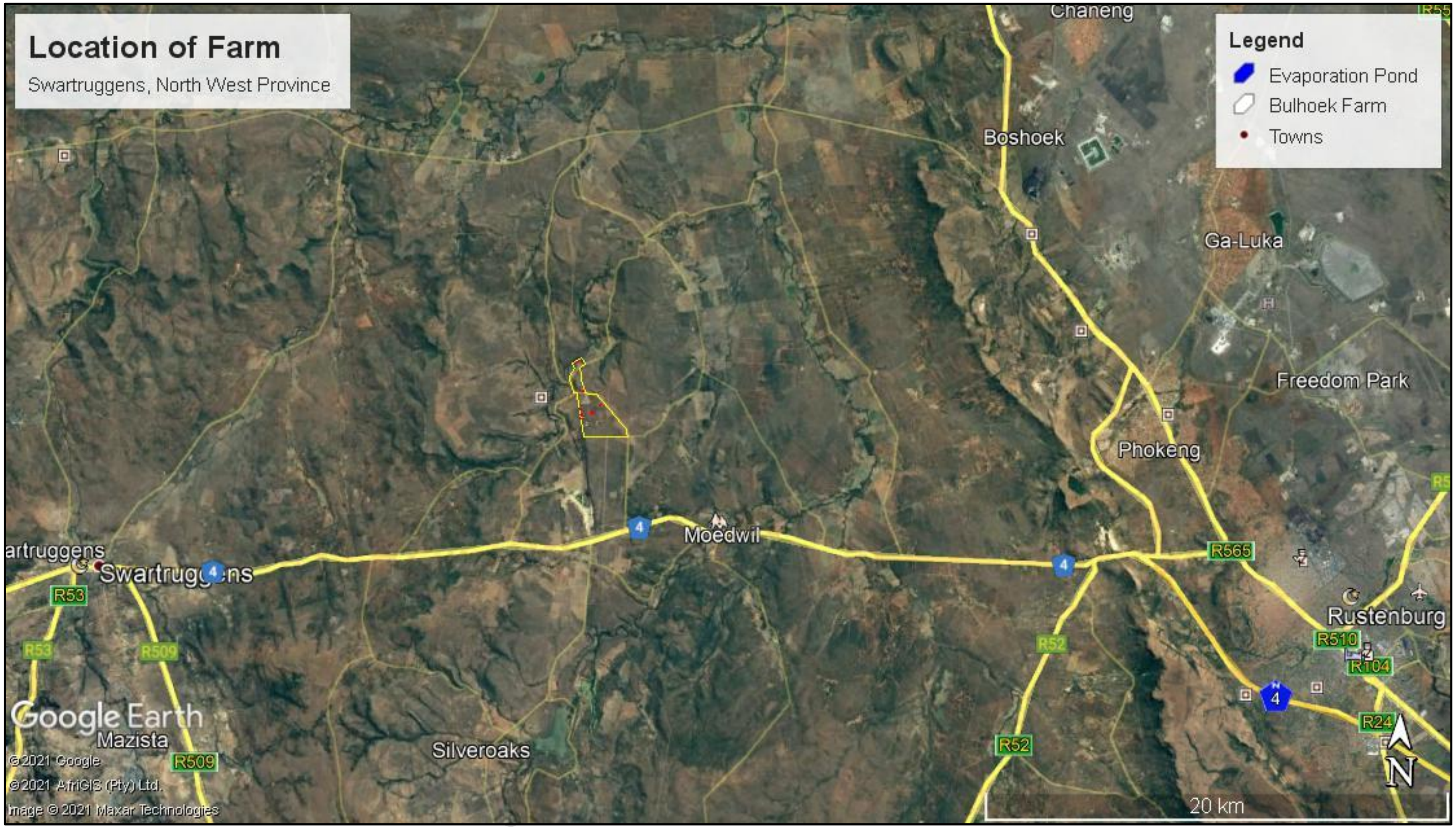
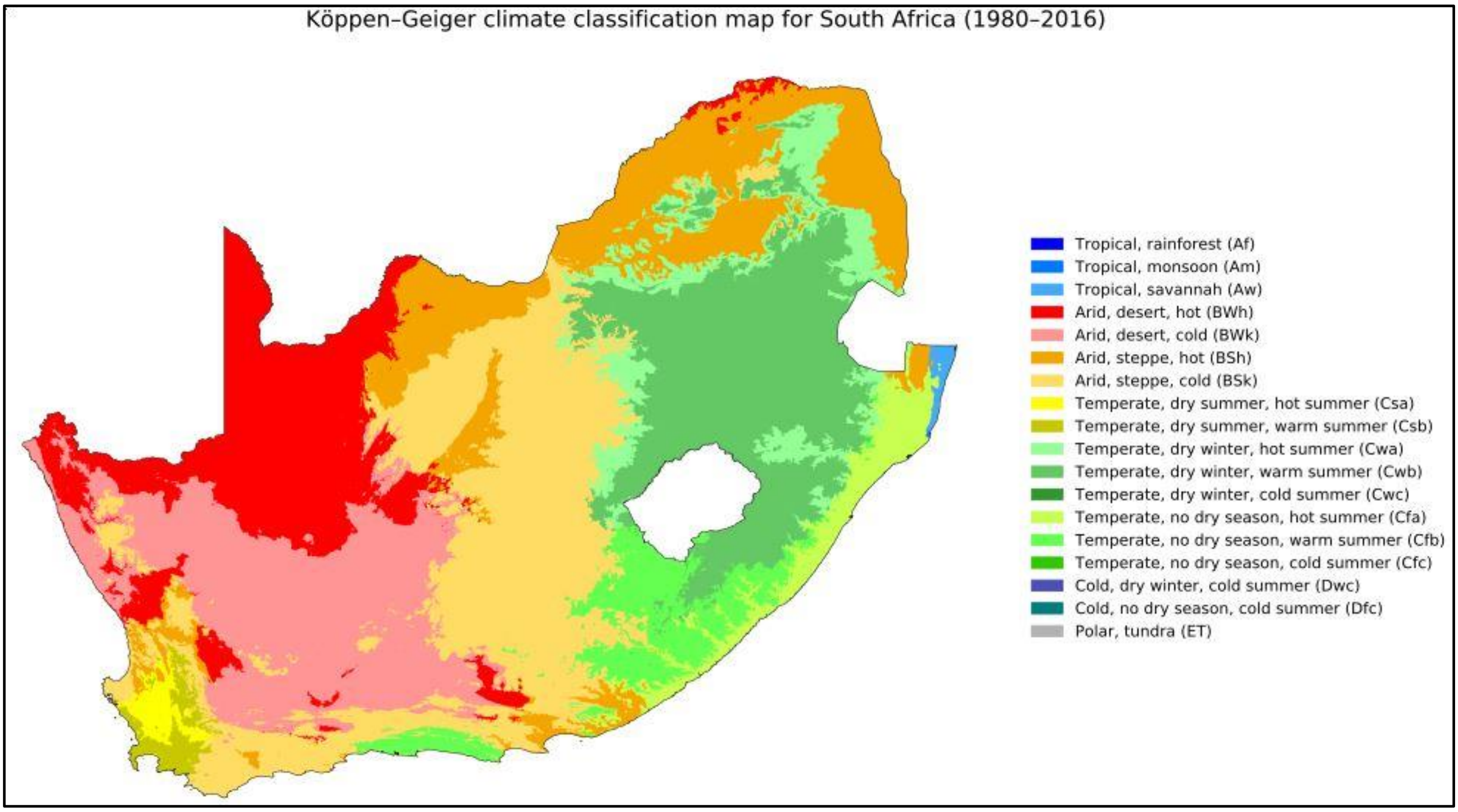


Figure 3. The location of Quantum Foods, Bulhoek Farm, Swartruggens, North West Province.

4.2 Climate

The Mean annual precipitation (MAP) for Quantum Foods, Bulhoek Farm, North West Province is approximately 600 - 750 mm, with most rainfall in the summer as seen in Figure 5. The average annual temperature is 18.30 °C (Mucina & Rutherford, 2006), which coincides with the average monthly temperatures of Rustenburg, North West Province as seen in Figure 6. Winters in this area are particularly very dry as seen in Figure 6.

Quantum Foods, Bulhoek Farm, North West Province has a typical subtropical highland climate. The climate is classified as Cwa (Temperate, dry winter, hot summer) by the Köppen-Geiger system (1980–2016) as seen in Figure 4.



The average monthly rainfall and temperature can be seen in Figure 5 & Figure 6.

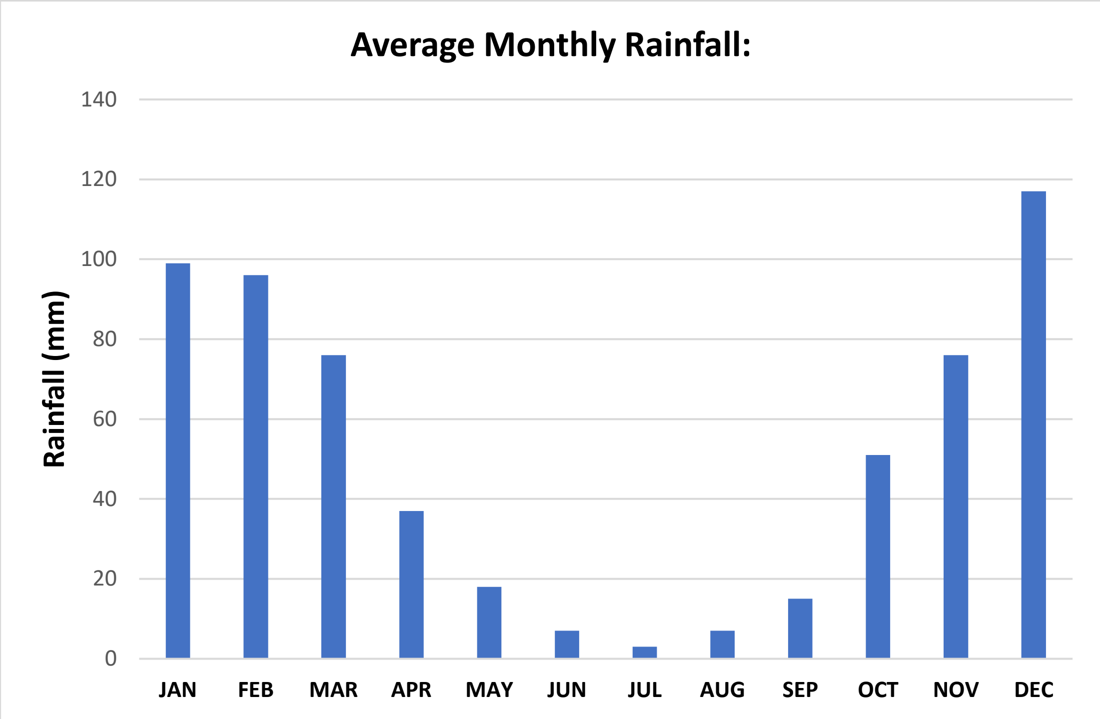


Figure 5. The average monthly rainfall of Rustenburg, North West Province (Climate-data.org, 2020).

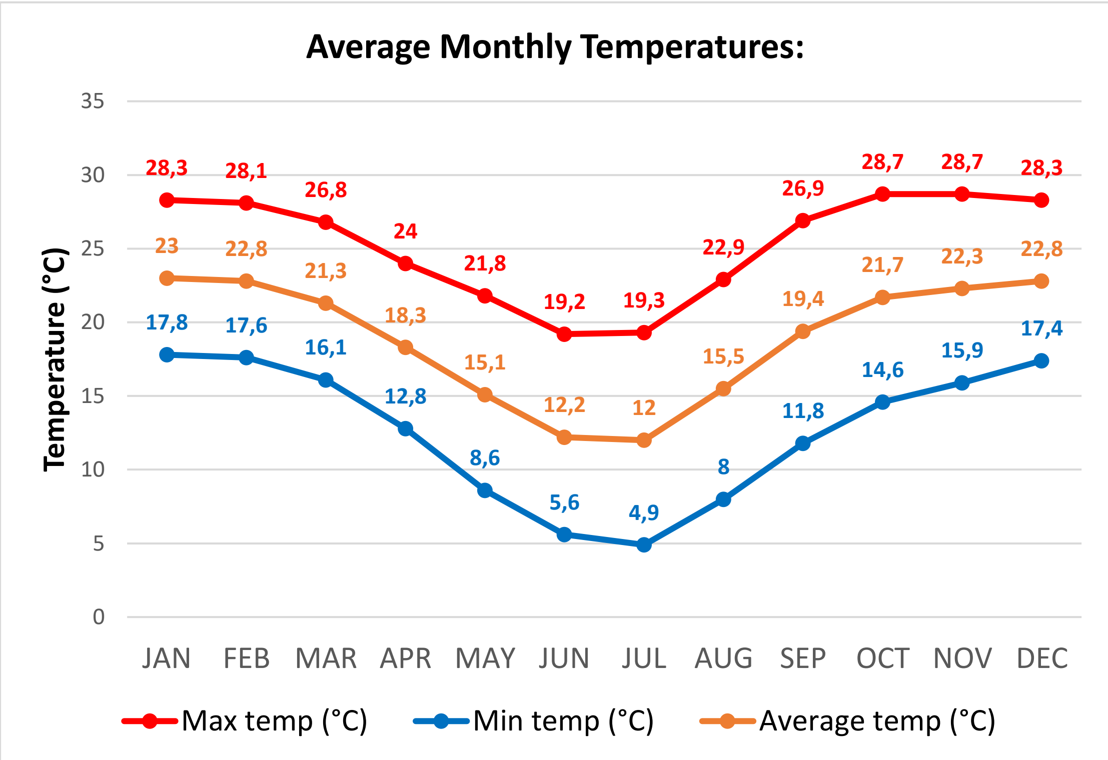


Figure 6. The average monthly temperatures of Rustenburg, North West Province (Climate-data.org, 2020).

4.3 Topography and Drainage

Topography with respect to the slope variability of the land surface plays an integral role in groundwater vulnerability because it controls the drainage and movement of water by means of concentrating flows in topographical depressions. The slope variation therefore determines the likelihood that contaminants will either runoff or infiltrate to the groundwater table (Musekiwa & Majola, 2011).

The topographical map of Quantum Foods, Bulhoek Farm, North West Province is shown in Figure 7, indicating that in general the surface drainage will occur in a Northern direction, towards the topographical depression which is the receiving water course of the Dwarspruit, this is due to the difference in elevation.

Figure 7 indicates the general surface drainage direction (represented by the black arrows) as well as the drainage direction into the receiving water course of the Dwarspruit.

The slope variation as indicated by Figure 7, in the area indicates that contaminants are likely runoff to the surrounding wetlands/ Dwarspruit, rather than infiltrate into the ground surface to the groundwater table, therefore decreasing the groundwater vulnerability.

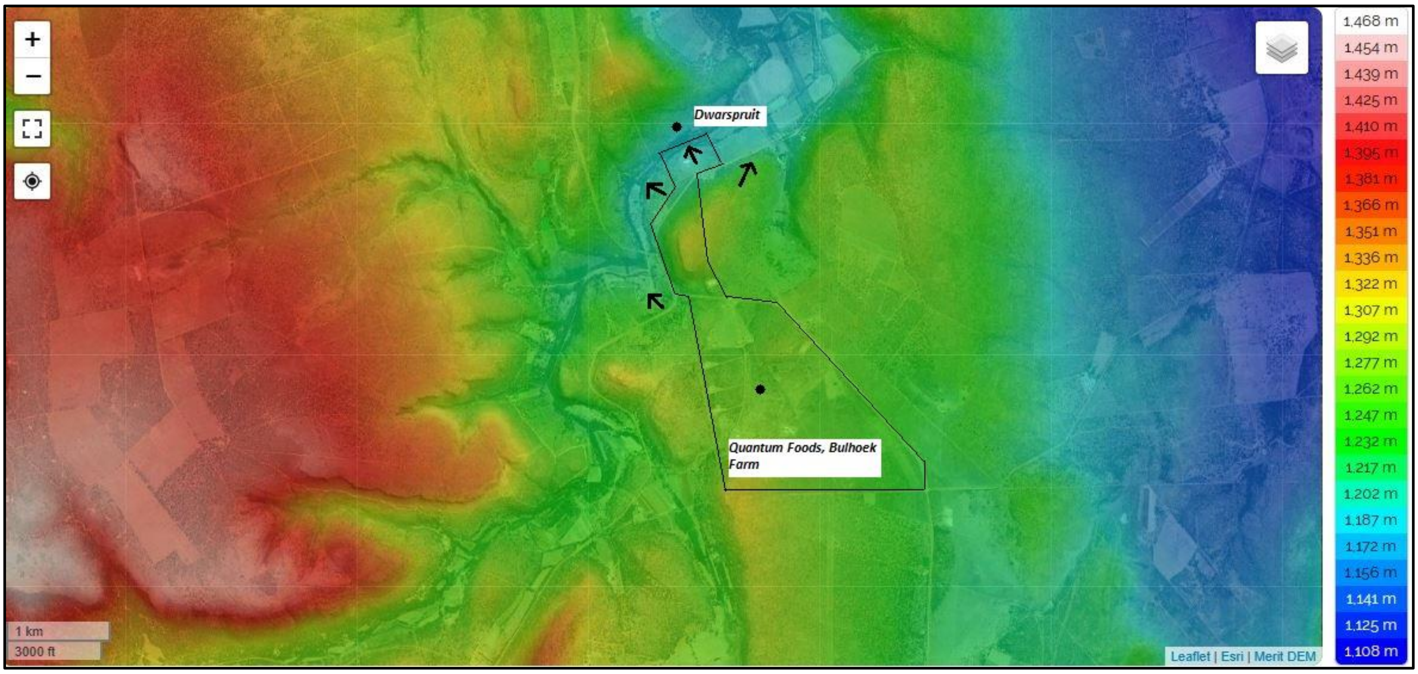


Figure 7. The topographical map of Quantum Foods, Bulhoek Farm, Swartruggens, North West Province, indicating the elevation (mamsl.) (Yamazaki, Topographic-map.com, 2021).

4.4 GEOLOGY

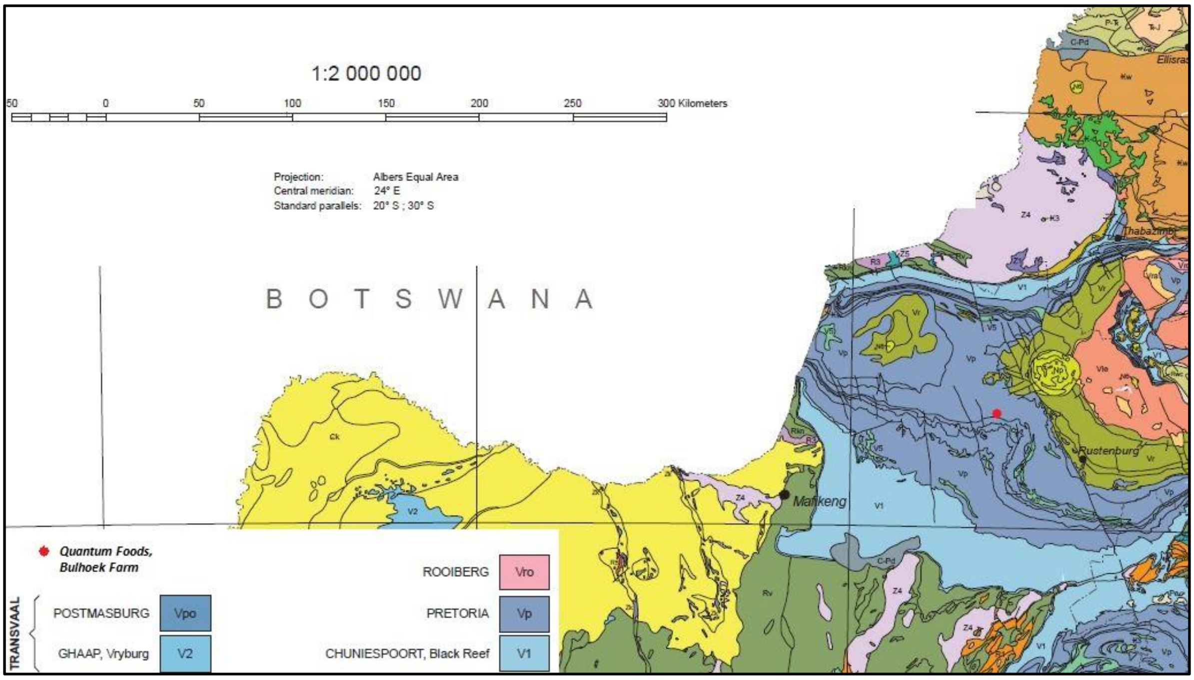
4.4.1 Regional Geology

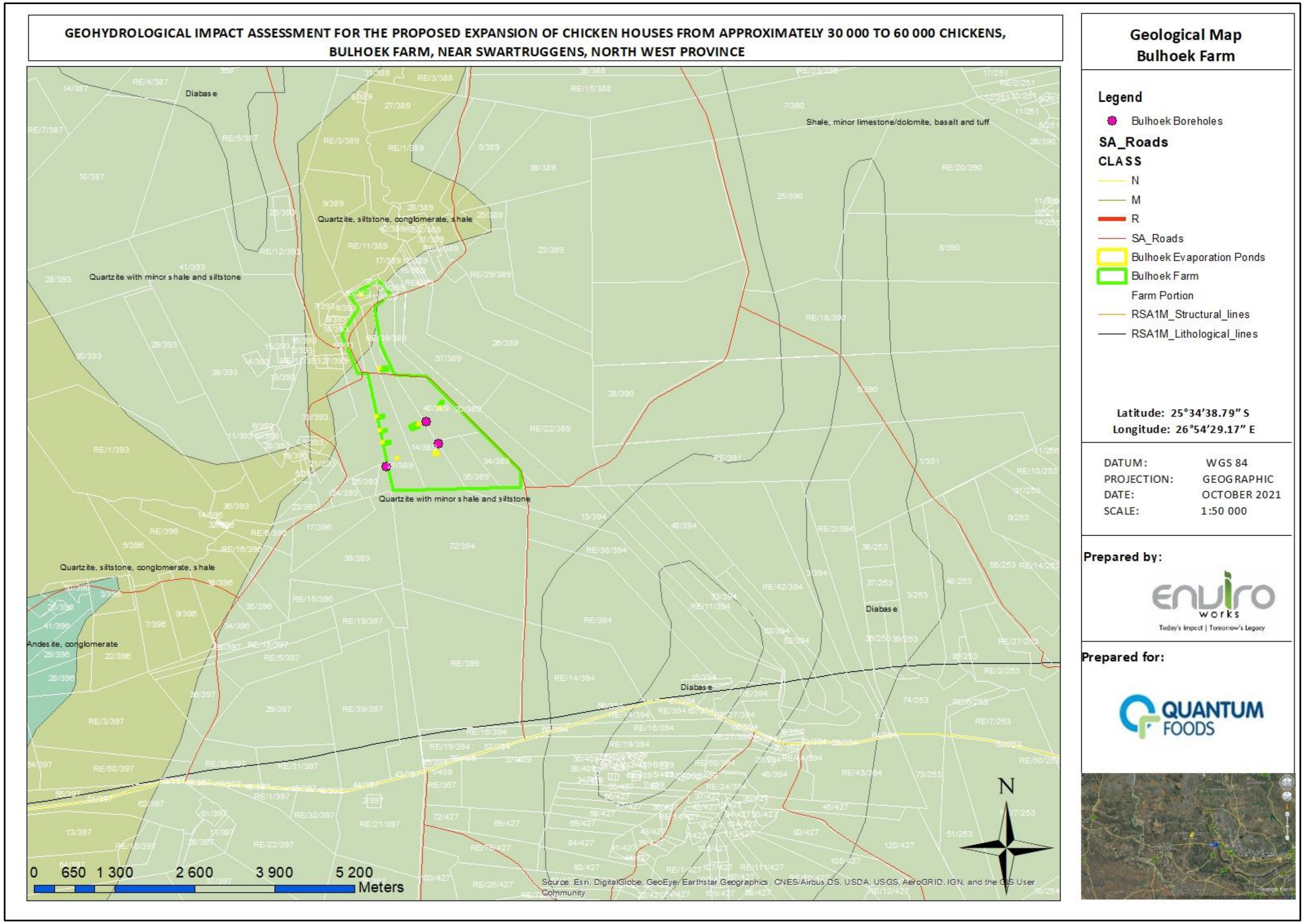
The study area is situated in the Transvaal Supergroup, Pretoria Group, Timeball Hill and Rooihoogte Formation which mainly consists out of sedimentary deposits that were deposited over the period 2 350 to 2 100 million years ago (McCarthy et al., 2005).

The Pretoria Group is dominated by a pile of sedimentary rocks which mainly consist of mudstones and quartzites. Some Basalts are present collectively up to 5 km thick. These deposits were deposited mainly under marine conditions ranging from muddy tidal flats (mudstones) to shallow-marine sands (Timeball Hill and Rooihoogte Formation) that today form the quartzites such as the Magaliesberg Mountains.

The Pretoria group consists of progressively finer sediments (more mudstone that quartzite) toward the South, indicating that the sediments were mainly supplied by the North or Northwest (McCarthy et al., 2005).

Figure 8 and 9 indicates the geology of Quantum Foods, Bulhoek Farm as per Geological map of South Africa (SANSA, 2015).




GEOHYDROLOGICAL IMPACT ASSESSMENT FOR THE PROPOSED EXPANSION OF CHICKEN HOUSES FROM APPROXIMATELY 30 000 TO 60 000 CHICKENS,
BULHOEK FARM, NEAR SWARTRUGGENS, NORTH WEST PROVINCE
Geological Map
Bulhoek Farm
Legend
Bulhoek Boreholes
SA_Roads
CLASS
N
M
R
SA_Roads
Bulhoek Evaporation Ponds
Bulhoek Farm
Farm Portion
RSA1M_Structural_lines
RSA1M_Lithological_lines
Latitude: 25°34'38.79" S
Longitude: 26°54'29.17" E
DATUM: WGS 84
PROJECTION: GEOGRAPHIC
DATE: OCTOBER 2021
SCALE: 1:50 000
Prepared by:
Prepared for:
Diabase
Shale, minor limestone/dolomite, basalt and tuff
Quartzite, siltstone, conglomerate, shale
Quartzite with minor shale and siltstone
Andesite, conglomerate
N
0 650 1 300 2 600 3 900 5 200
Meters
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

4.4.2 Local Geology

A site visit was performed on 22 September 2021 where it was determined that Quantum Foods, Bulhoek Farm, Swartruggens, North West Province is dominated by sedimentary rocks of the Pretoria Group (Daspoort and Strubenkop Formation). These sedimentary rocks mainly consist out of Quartzite, minor Shale, Conglomerate and Siltstone (CapeFarmMapper, 2021).

The investigation area consists predominantly of quartzite, minor shale, siltstone on the Southern side of the Bulhoek Farm and Quartzite, siltstone, conglomerate and shale on the Northern side of the Bulhoek Farm according to the geological map (Council for Geoscience, 2019) as seen in Figure 9.

Quartzite and metamorphosed rocks were observed in close proximity to the Witwatersrand Mountains on site as seen in Figure 10.

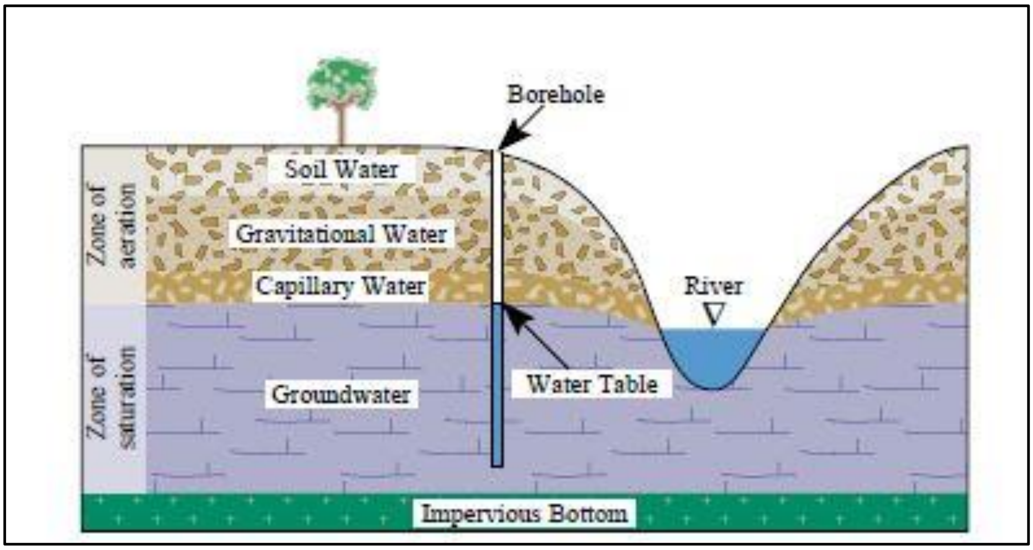
Figure 10. Quartzite and metamorphosed rocks on site.

5 GEOHYDROLOGY

5.1 Desktop Study

5.1.1 General groundwater understanding

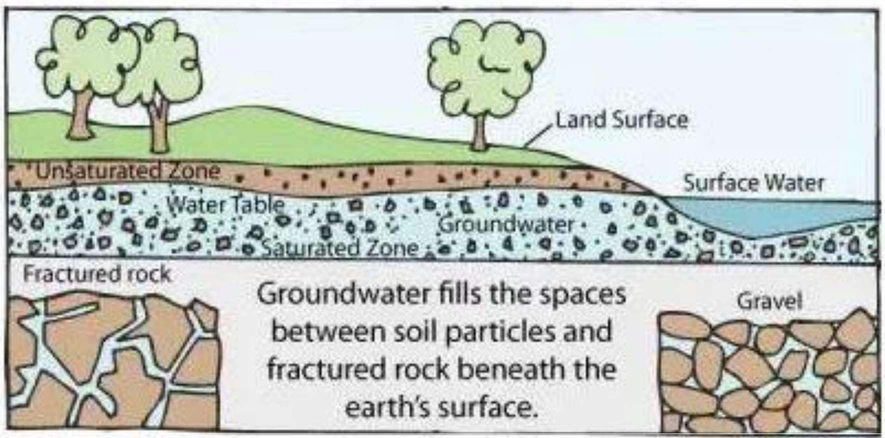
The concept of groundwater can be easily described as water found in the saturation zone. The saturation zone is found beneath the aeration (unsaturated) zone, which acts like a sponge that allows water to percolate to the zone of saturation (Kruseman & de Ridder, 1991). These two (2) zones are divided by the water table as shown in Figure 11.



The term aquifer can be defined as a geological formation that contains enough water to be used for economical uses such as domestic use *etc*. (van Tonder et al., 2001).

There are two (2) main type of aquifers namely, porous shallow weathered aquifers and deep fractured rock aquifers as shown in Figure 12. The porous shallow weathered aquifers consist of aggregates of individual grain particles such as sand, gravel, and silt, whereas fractured rock aquifers are geological formations where groundwater moves along fractures, joints, and other lithological discontinuities (Kruseman & de Ridder, 1991).

It is important to note that geology and groundwater are in very close relation to each other because the type of geology governs the flow of groundwater (van Tonder et al., 2001).



5.1.2 Importance of dolerite intrusions

According to literature, dolerite intrusions are of high importance for Geohydrological investigations with respect to groundwater exploration (Botha et al., 2004).

These dolerite intrusions are associated with fractures that are the main target for groundwater extraction. The presence of fractures along these linear intrusions can be explained by hot magma baking the surrounding sediments during the intrusion, that causes fractures to form in these sediments (Botha et al., 2004).

The importance of these dolerite intrusions can therefore be identified as (Botha et al., 2004):

1. The dolerite intrusions are highly magnetic and can be easily identified and traced with existing geophysical techniques.
2. The host rock is baked therefore creating the perfect condition for the formation of fractures in these sediments that act as preferential pathways for groundwater movement.

Thus, indicating that the underlaying geology determines the flow of groundwater through pathways created during deformation (Conrad & Murray, 2019).

5.2 Hydro-census

A site visit was conducted on 22 September 2021, which is in the summer. During a hydro-census the following information is collected within a one (1) km radius of the study area:

- The borehole coordinates.
- The static water levels to predict the groundwater flow direction.
- To determine the overall utilisation of groundwater in the vicinity of the facility.
- The recommended safe yields from the aquifer pumping tests.
- Photographs of the boreholes.
- Sample of the groundwater to determine the quality.

During the hydro-census three (3) boreholes were investigated within a one (1) km radius of the site, where the water levels, measurements and photos of the boreholes were taken. Some of the important information of the boreholes recorded during the hydro-census is shown in Table 4 below.

The general use of groundwater in the vicinity of the study area according to the IDP of Rustenburg are (IDP, 2017 – 2022):

- Rural utilisation
- Agriculture (irrigation)

Groundwater at the facility of Quantum Foods, Bulhoek Farm, Swartruggens is abstracted for the following uses:

- Drinking water for chickens;
- Human consumption after chemical treatment;
- Cleaning of chicken house; and,
- Domestic use (sanitation & showers).

Approximately 100 000 litre water per day is supplied from the three (3) boreholes to supply water for the chickens, human consumptions, domestic use and cleaning of the chicken houses.

Table 4. Hydro-census.

Borehole ID	Latitude	Longitude	SWL (mbgl)	Diameter of borehole (mm)	Property description	Sample taken?	Depth (m)	Casein height (cm)	Distance from site (m)	Comment
BULBH1	25° 35' 26.52'' S	26° 54' 24.27'' E	37.2	185	Bulhoek Farm	Yes	100 +	35	N/A	The borehole is equipped with a 1.5 Kw SVM 55/27 pump.
BULBH2	26° 1' 57.63'' S	27° 14' 18.09'' E	26.5	185	Bulhoek Farm	Yes	57.8	23.5	N/A	The borehole is equipped with a 1.5 Kw SVM 55/27 pump.
BULBH3	26° 1' 50.44'' S	27° 14' 8.98'' E	29.7	185	Bulhoek Farm	Yes	55.2	14.5	N/A	The borehole is situated within a pumping house on site.

5.2.1 BULBH1

The borehole is located in the South-Western region of the Bulhoek Farm and is equipped with a 1.5KW SVM7/20 Motor pump that has been installed at 73 meters deep. According to the Pump Test performed on 12 October 2021 by Tucana Solutions (Appendix B – Pump test BULBH01), the borehole delivers **54 432 litres per day**.

Groundwater is pumped from BULBH1 to a reservoir on site, from where the water is chemically treated. The water from the reservoir is used for:

- Drinking water for the chickens;
- Human consumption;
- Cleaning of Chicken houses; and,
- Domestic use (Sewage and Sanitation).

A photograph was taken of the borehole as seen in Figure 13.

A sample of the groundwater at BULBH1 was taken, prior to being treated chemically, to compare to SANS 241:2015 Drinking Water Standards.

5.2.2 BULBH2

The borehole is located in the South-Eastern region of the Bulhoek Farm and is equipped with a 1.5 Kw SVM 55/27 pump. According to the Pump Test performed on 06 October 2021 by Tucana Solutions (Appendix B – Pump test BULBH02), the borehole delivers **20 736 litres per day**.

Groundwater is pumped from BULBH2 to a reservoir on site, from where the water is chemically treated. The water from the reservoir is used for:

- Drinking water for the chickens;
- Human consumption;
- Cleaning of Chicken houses; and,
- Domestic use (Sewage and Sanitation).

A photograph was taken of the borehole as seen in Figure 14.

The relative locations in relation to the Bulhoek Farm is shown in Figure 17.

A sample of the groundwater at BULBH2 was taken, prior to being treated chemically, to compare to SANS 241:2015 Drinking Water Standards.

5.2.3 BULBH3

The borehole is located in the Southern region of the Bulhoek Farm and is equipped with a 2.2KW 4SD69/14 Motor pump that has been installed at 50 meters deep. The borehole is situated inside a pumping house on site as seen in Figure 16. According to the Pump Test performed on 13 October 2021 by Tucana Solutions (Appendix B – Pump test BULBH03), the borehole delivers **73 440 litres per day**.

Groundwater is pumped from BULBH3 to a reservoir on site, from where the water is chemically treated. The water from the reservoir is used for:

- Drinking water for the chickens;
- Human consumption;
- Cleaning of Chicken houses; and,
- Domestic use (Sewage and Sanitation).

A photograph was taken of the borehole as seen in Figure 15.

A sample of the groundwater at BULBH3 was taken, prior to being treated chemically, to compare to SANS 241:2015 Drinking Water Standards.

5.2.4 AQUIFER PUMPING TEST INFORMATION

5.2.4.1 BULBH1

An aquifer pumping test was performed on 12 October 2021 on BULBH1 (Appendix B – Pump test BULBH01).

The borehole was tested via a calibration test of approximately 60 minutes whereafter recovery to 95% of the water level was allowed before a Constant Rate test was performed. The Constant rate test was done at 55.8 mbgl., where the aquifer was pumped for approximately twenty four (24) hours.

It was concluded that the borehole delivers 54 432 L/d, which is **0.63 L/s**. The yield from the pumping test of BULBH1 does **not** coincides with the expected yield of 0.1 – 0.5 L/s of the Geohydrological Map (Figure 21 & 22).

The pumping test analysis sheet and raw data as provided from the pumping test contractor can be seen in Appendix B – Pump test BULBH01.

5.2.4.2 BULBH2

An aquifer pumping test was performed on 6 October 2021 on BULBH2 (Appendix B – Pump test BULBH02).

The borehole was tested via a calibration test of approximately 60 minutes whereafter recovery to 95% of the water level was allowed before a Constant Rate test was performed. The Constant rate test was done at 50 mbgl., where the aquifer was pumped for approximately twenty four (24) hours.

It was concluded that the borehole delivers 20 736 L/d, which is **0.24 L/s**. The yield from the pumping test of BULBH2 does coincides with the expected yield of 0.1 – 0.5 L/s of the Geohydrological Map (Figure 21 & 22).

The pumping test analysis sheet and raw data as provided from the pumping test contractor can be seen in Appendix B – Pump test BULBH02.

5.2.4.3 BULBH3

An aquifer pumping test was performed on 13 October 2021 on BULBH3 (Appendix B – Pump test BULBH03).

The borehole was tested via a calibration test of approximately 60 minutes whereafter recovery to 95% of the water level was allowed before a Constant Rate test was performed. The Constant rate test was done at 48 mbgl., where the aquifer was pumped for approximately twenty four (24) hours.

It was concluded that the borehole delivers 73 440 L/d, which is **0.85 L/s**. The yield from the pumping test of BULBH3 does **not** coincides with the expected yield of 0.1 – 0.5 L/s of the Geohydrological Map (Figure 21 & 22).

The pumping test analysis sheet and raw data as provided from the pumping test contractor can be seen in Appendix B – Pump test BULBH03.

Figure 13. BULBH1.

Figure 14. BULBH2.

Figure 15. BULBH3.

Figure 16. BULBH3 located within the pumping house.

Figure 17. Position of the boreholes of Quantum Foods, Bulhoek Farm, Swartruggens, North West Province

5.3 Groundwater Recharge

Recharge can be described as the process by which water is added to the zone of saturation of an aquifer and is therefore the vehicle for transporting contaminants to the groundwater table (Musekiwa & Majola, 2011).

The groundwater recharge into the vadose zone (unsaturated zone) in the study area is average (10 mm - 50 mm per year) as shown in Figure 18, which indicates that the groundwater vulnerability decreases with respect to the groundwater recharge rate.

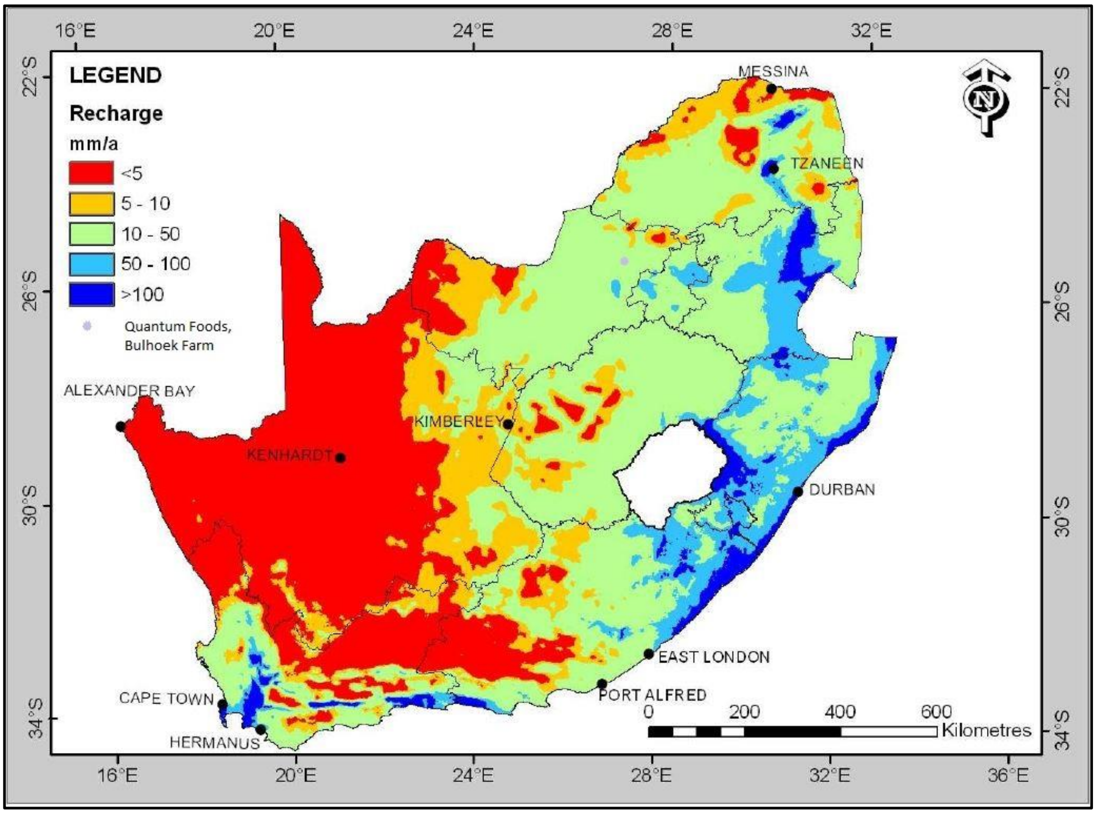


Figure 18. Groundwater recharge of South Africa (Musekiwa & Majola, 2011).

5.4 Water management in the area of investigation

The area of investigation is situated in the Crocodile West and Marico Water Management Area (WMA) (Statistics South Africa, 2010). The land use in area is characterised by sprawling urban, agricultural, and mining activities (DWAF, 2004). The facility is situated in the quaternary catchment A22D.

The Crocodile West and Marico WMA consists of the following rivers (Statistics South Africa, 2010):

- Crocodile River;
- Marico River;
- Magalies River;
- Pienaars River;
- Apies River
- Elands River; and,
- Klip Spruit.

The current surface water quality of the Crocodile West and Marico Water Management Area is influenced by the overall activities in the catchment area, which include (Statistics South Africa, 2010):

- Urbanisation (Main activity influencing surface water quality);
- Irrigation;
- Mining and bulk industrial activities;
- Return flows from irrigation;
- Runoff from mining and industrial activities;
- Urban areas; and,
- Power generation.

5.5 Water quality

5.5.1 Prevailing surface water quality

The current state of the surface water quality in quaternary catchment A22D has been influenced by numerous activities (DWS, 2014). These activities are (Statistics South Africa, 2010):

- Mining and mine dewatering;
- Seepage from tailings dams;
- Personal services; and,
- Agricultural activities.

Under present conditions, the surface water quality in quaternary catchment A22D does comply with the SANS 241:2015 specifications, which indicates that the surface water quality is **suitable** for human consumption due to the fact that raw water is treated by water treatment plants in the vicinity associated with the Magalies River and surrounding steams (Magalies Water, 2018/2019).

5.5.2 Prevailing groundwater quality

Large dolomitic groundwater aquifers are present along the Southern part of the Crocodile West and Marico WMA. These aquifers are mainly utilised for urban and irrigation purposes (Statistics South Africa, 2010).

The general use of groundwater in the vicinity of Quantum Foods, Bulhoek Farm, Swartruggens are (Statistics South Africa, 2010):

- Domestic use in urban and rural areas;
- Irrigation (agriculture); and,
- Drinking water for game.

The groundwater quality as per Geohydrological map of South Africa indicates that the electrical conductivity (EC) of the groundwater is **0 – 70 mS/m**, which is a good quality for using groundwater as drinking water with respect to EC values (Figure 21 - Barnard, 1999).

5.5.3 Groundwater samples

Three (3) groundwater samples were taken in the vicinity of Quantum Foods, Bulhoek Farm. These samples were taken on 22 September 2021.

Please note that no surface water samples were taken in the near vicinity of Bulhoek Farm as surface water was not present on 22 September 2021 in the Dwarspruit.

5.5.4 Groundwater quality analysis

5.5.4.1 BULBH1

The groundwater quality according to the groundwater quality analysis report, samples taken on 22 September 2021 (Appendix A – BH 1) indicated the following:

In comparison to the SANS 241:2015 Drinking water standards, the groundwater from BULBH1 is suitable for human consumption according to the Microbial results (Appendix A – BH 1) which indicate that the Heterotrophic plate count & total coliforms are below the allowable limit for human consumption.

The macro chemical parameters result from the groundwater taken prior to chemical treatment from BULBH1 are below the SANS:2015 standards and are therefore recommended for usage prior to treatment.

5.5.4.2 BULBH2

The groundwater quality according to the groundwater quality analysis report, samples taken on 22 September 2021 (Appendix A – BH 2) indicated the following:

In comparison to the SANS 241:2015 Drinking water standards, the groundwater from BULBH2 is **not** recommended for human consumption according to the Microbial results (Appendix A – BH 2) which indicate that the total coliforms are above the allowable limit for human consumption. It is therefore not recommended that groundwater from BULBH2 be used for human consumption prior to be chemically treated for total coliforms.

The macro chemical parameters result from the groundwater taken prior to chemical treatment from BULBH2 are below the SANS:2015 standards and are therefore recommended for usage prior to treatment.

5.5.4.3 BULBH3

The groundwater quality according to the groundwater quality analysis report, samples taken on 22 September 2021 (Appendix A – BH 3) indicated the following:

In comparison to the SANS 241:2015 Drinking water standards, the groundwater from BULBH3 is suitable for human consumption according to the Microbial results (Appendix A – BH 3) which indicate that the total Heterotrophic plate count & coliforms are below the allowable limit for human consumption.

The macro chemical parameters result from the groundwater taken prior to chemical treatment from BULBH3 are below the SANS:2015 standards, although the Total Hardness of the groundwater is above the allowable limit. It is therefore recommended that the borehole water from BULBH3 is treated for Total Hardness prior to utilization to prevent damage to pumps etc. Kindly note that the Total Hardness that is above the allowable limit does not have any direct health effects.

5.6 Groundwater vulnerability

The term groundwater vulnerability is a dimensionless, relative, and non-measurable property that is based on the concept that certain land areas are more vulnerable to groundwater contamination than others. Groundwater vulnerability is therefore important to aid in groundwater management and protection (Musekiwa & Majola, 2011).

The DRASTIC method has been identified as the most appropriate method for groundwater vulnerability determination since the method is for regional applications, thus evaluating the pollution potential of large areas (Musekiwa & Majola, 2011).

The method is assessed using the following parameters:

D - The depth to the groundwater table

R - The net recharge of the area

A - The aquifer media

S - The soil media

T - The overall topography of the area

I - The impact of the vadose zone

C - The hydraulic conductivity of the aquifer

The DRASTIC method has the following assumptions (Musekiwa & Majola, 2011):

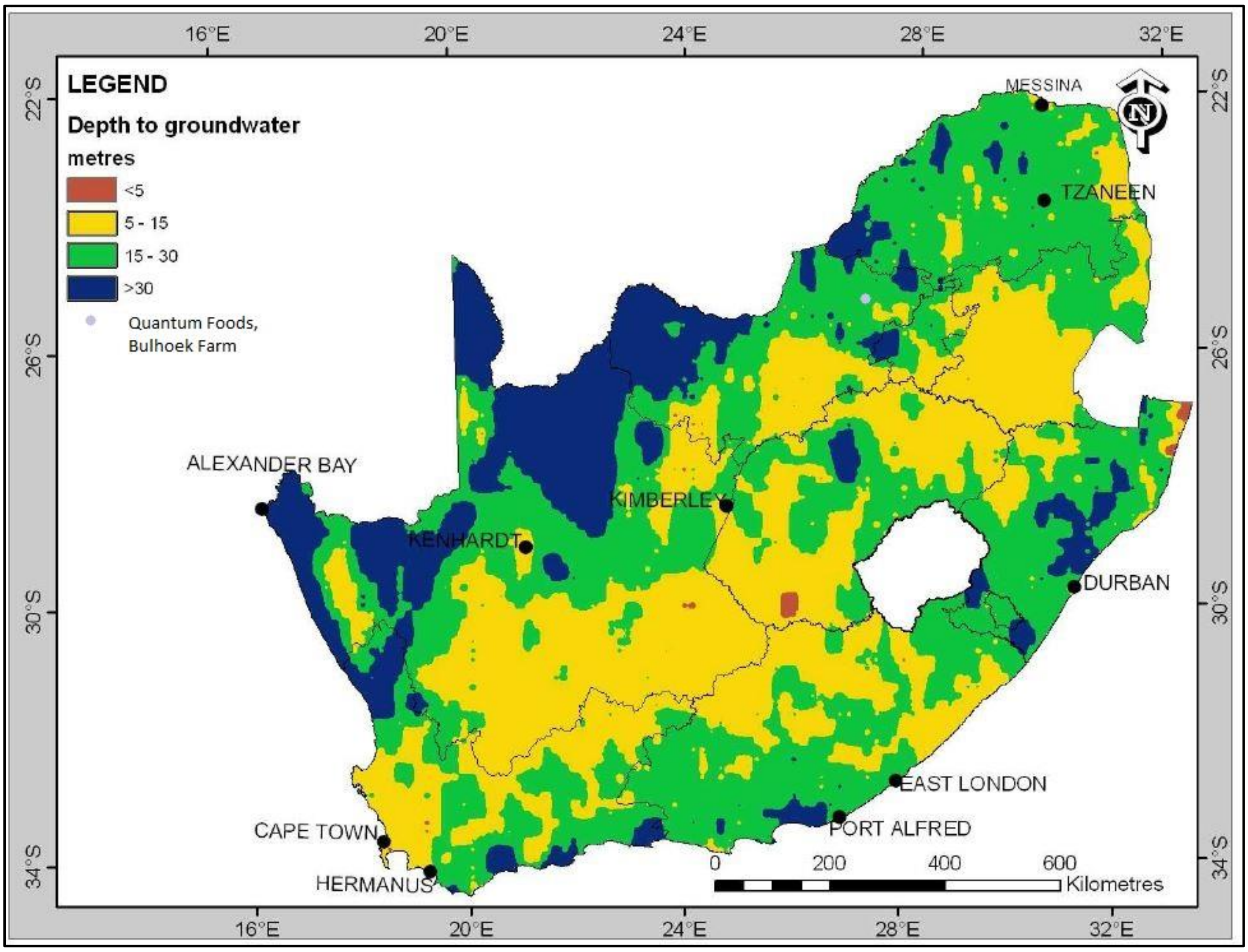
- All contaminants are introduced at the land surface;
- Precipitation is the mechanism whereby contaminants are introduced into the groundwater;
- The contaminants have the same mobility as water; and,
- The evaluated area is 0.4 km^2 or more.

This method was applied in the vicinity of Quantum Foods, Bulhoek Farm, North West Province, to identify certain conditions to classify the groundwater vulnerability.

5.6.1 Depth to groundwater table

The depth to the groundwater table is the relative distance that a potential contaminant travels to reach the saturated zone (Musekiwa & Majola, 2011). Therefore, the shallower the groundwater table, the shorter the flow path for the contaminate to reach the aquifer, thus increasing the vulnerability of the groundwater to be contaminated (Musekiwa & Majola, 2011).

Figure 19 indicates that the groundwater table in the area is 15 - 30 mbgl., indicating that groundwater pollution probability with respect to the depth of the groundwater table is low. This corresponds partly to the static water levels obtained for the boreholes on 22 September 2021 during the hydro-census (Table 4). Some of the water levels are deeper that 30 mbgl., therefore confirming that the groundwater pollution probability with respect to the depth of the groundwater table is low.



5.6.2 Net recharge of the area under investigation

The groundwater recharge in the area is discussed in Section 5.3.

5.6.3 Aquifer media & classification

The type of aquifer plays an important role in groundwater vulnerability with respect to the Geohydrological composition of the aquifer. Therefore, the more fractured and weathered an aquifer, the higher the permeability of the rock which the aquifer consists of, thus increasing the vulnerability of contaminants to contaminate groundwater (Musekiwa & Majola, 2011).

According to the Geohydrological map of South Africa as seen in Figure 21 & 22, the aquifer present in the vicinity of the area is classified as a fractured rock aquifer. These fractures create preferential flow paths for groundwater which enables contaminants to infiltrate into the groundwater table.

It is evident that the study area has possible dolerite intrusions, please refer to Section 6, which are often associated with highly weathered zones around these intrusions. These weathered zones act as preferential pathways for groundwater to move and store, thereby increasing the permeability of an aquifer (Kruseman & de Ridder, 1991).

Thus, the aquifer in the vicinity of the area of investigation can be identified as a weathered fractured rock aquifer, which indicates that the groundwater vulnerability is very high due to the high permeability associated with the aquifer.

5.6.4 Soil media and impact of the vadose zone

The soil composition determines the rate of recharge and contaminant transport, for example a composition of high clay content lessen the potential for groundwater contamination due to low permeability, whereas sandy soils have a much higher permeability, therefore a higher vulnerability (Musekiwa & Majola, 2011).

According to the Geohydrological map of South Africa (Figure 21) and the Geological Map of South Africa (Figure 9), the geology in the vicinity of the study area consists of the Pretoria Supergroup which consist mainly of meta-arenaceous rocks (quartzite) and predominantly meta-argillaceous rocks (slate and hornfels). These rocks have low permeability indicating the groundwater vulnerability potential is low.

5.6.5 Topography of the area

The topography in the vicinity of the area is discussed in Section 4.3.

5.6.6 Hydraulic conductivity of the aquifer

The hydraulic conductivity of an aquifer is a measure of the aquifer's ability to transport water when a hydraulic gradient is present. The hydraulic conductivity therefore controls the velocity of groundwater and contaminants that are transported via groundwater, which indicates that a high hydraulic conductivity increases the vulnerability of groundwater to become contaminated (Musekiwa & Majola, 2011).

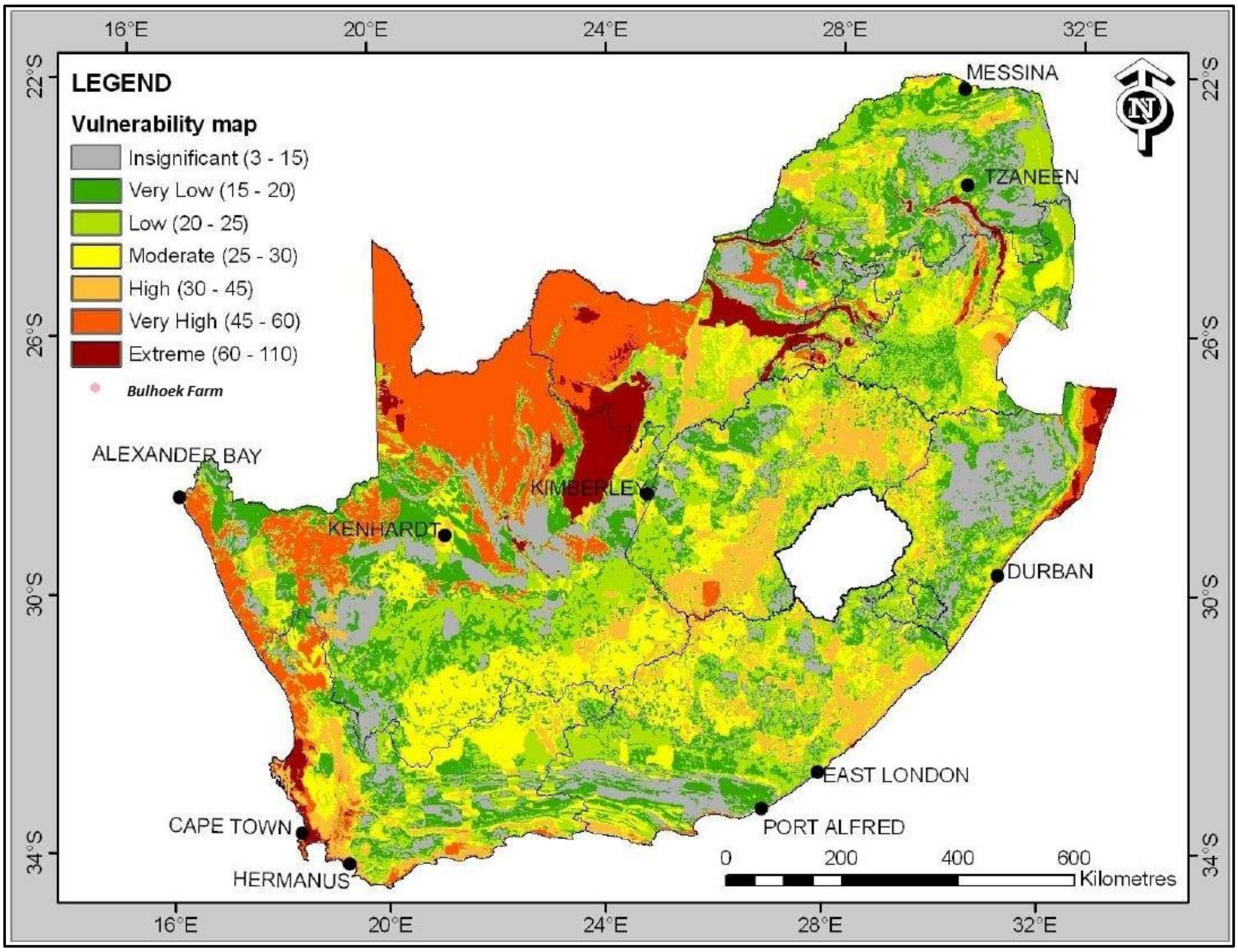
The type of geology and aquifer therefore determines the hydraulic conductivity, which in this case is a weathered, fractured aquifer, indicating that the hydraulic conductivity is low, thus decreasing the groundwater vulnerability (Musekiwa & Majola, 2011).

5.6.7 Groundwater vulnerability conclusion

Taking the seven (7) parameters investigated during the DRASTIC method into account, the following can be concluded with respect to the groundwater vulnerability:

PARAMETER	**-**	**GROUNDWATER VUNERABILITY CONCLUSION**
D	-	Low
R	-	Low
A	-	Very High
S	-	Low
T	-	Low
I	-	Low
C	-	Low

The overall groundwater vulnerability in the vicinity of Quantum Foods, Bulhoek Farm, North West Province, is **Low**, however any groundwater contamination concerns can be lessened by implementing the recommendations and mitigation measures as recommended in Section 12.



This classification of the Groundwater Vulnerability coincides with Figure 20, where the vulnerability is classified as **Insignificant to Very Low** (Musekiwa & Majola, 2011).

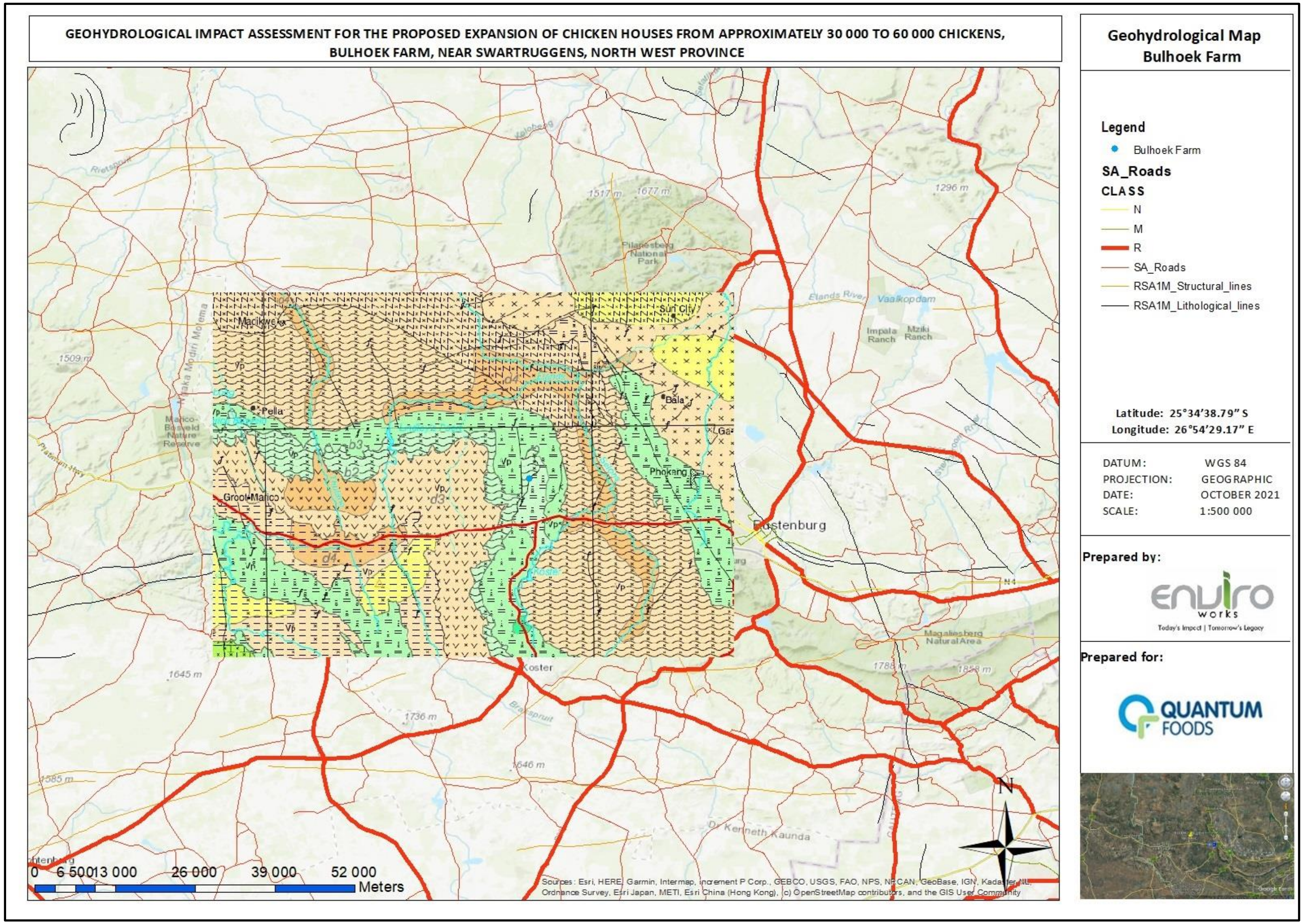
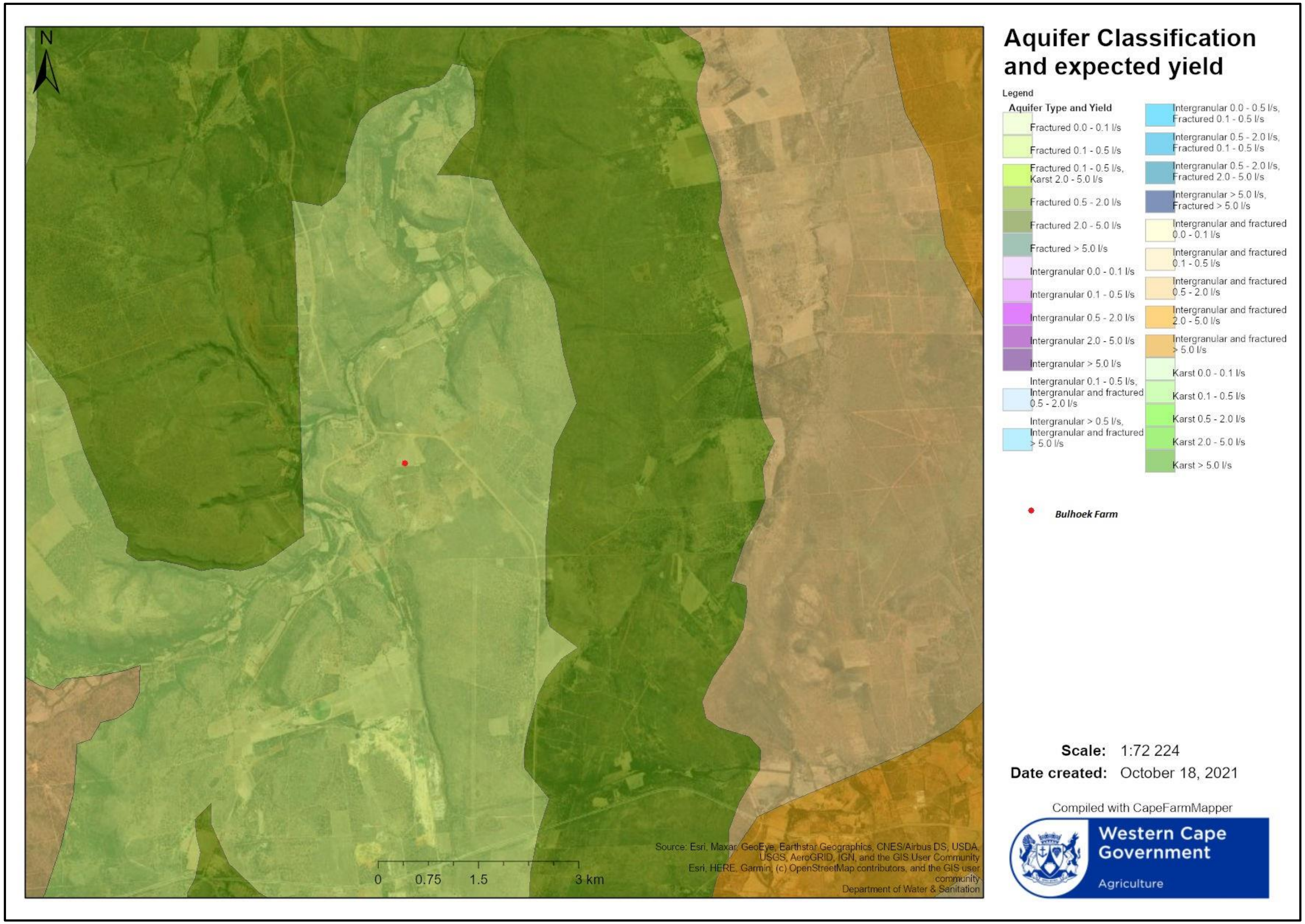


Figure 21. Geohydrological map (Johannesburg, 2526), indicating the Geohydrology in the vicinity of the Bulhoek Farm (Barnard, 1999).


Aquifer Classification and expected yield
Legend
Aquifer Type and Yield
Fractured 0.0 - 0.1 l/s
Fractured 0.1 - 0.5 l/s
Fractured 0.1 - 0.5 l/s, Karst 2.0 - 5.0 l/s
Fractured 0.5 - 2.0 l/s
Fractured 2.0 - 5.0 l/s
Fractured > 5.0 l/s
Intergranular 0.0 - 0.1 l/s
Intergranular 0.1 - 0.5 l/s
Intergranular 0.5 - 2.0 l/s
Intergranular 2.0 - 5.0 l/s
Intergranular > 5.0 l/s
Intergranular 0.1 - 0.5 l/s, Intergranular and fractured 0.5 - 2.0 l/s
Intergranular > 0.5 l/s, Intergranular and fractured > 5.0 l/s
Intergranular 0.0 - 0.5 l/s, Fractured 0.1 - 0.5 l/s
Intergranular 0.5 - 2.0 l/s, Fractured 0.1 - 0.5 l/s
Intergranular 0.5 - 2.0 l/s, Fractured 2.0 - 5.0 l/s
Intergranular > 5.0 l/s, Fractured > 5.0 l/s
Intergranular and fractured 0.0 - 0.1 l/s
Intergranular and fractured 0.1 - 0.5 l/s
Intergranular and fractured 0.5 - 2.0 l/s
Intergranular and fractured 2.0 - 5.0 l/s
Intergranular and fractured > 5.0 l/s
Karst 0.0 - 0.1 l/s
Karst 0.1 - 0.5 l/s
Karst 0.5 - 2.0 l/s
Karst 2.0 - 5.0 l/s
Karst > 5.0 l/s
Bulhoek Farm
N
0 0.75 1.5 3 km
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Department of Water & Sanitation
Scale: 1:72 224
Date created: October 18, 2021
Compiled with CapeFarmMapper
Western Cape Government
Agriculture

6 GEOPHYSICS

The purpose of the geophysical survey is to detect and delineate geological structures and features that could potentially act as or be associated with preferential pathways for groundwater migration and contaminant transport. The Aeromagnetic map of South Africa (Figure 24) provides the magnetic intensity and delineates geological features as well as determine the need of a geophysical survey to be conducted at the site.

6.1 Introduction

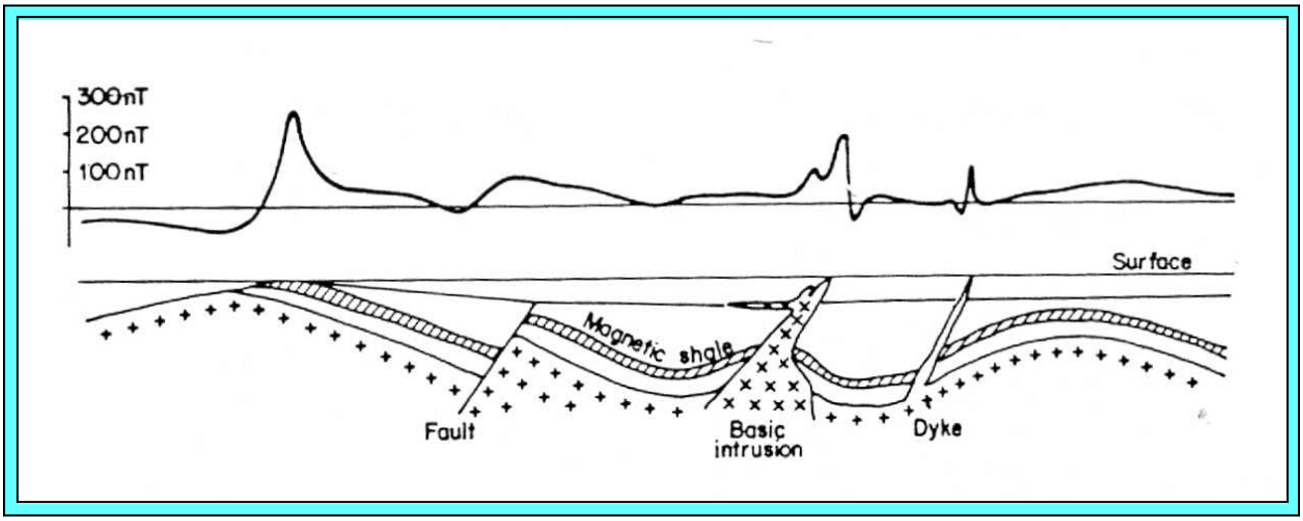
A geophysical survey is considered one of the most cost effective, non-intrusive methods to investigate subsurface properties (Roux, 1980).

The geophysical survey includes a desktop study of the study area's geophysical properties followed by a ground geophysical survey using the magnetic method.

The magnetic method is a passive method that uses the Earth's magnetic field as the source of energy to measure the relative magnetic permeability of different materials. Any magnetic material can become magnetized by the earth's magnetic field where it becomes an induced magnetic field and will therefore be different than that of the earth's magnetic field. The difference in these magnetic fields are recorded in nT (nanotesla) and are referred to as anomalies (Roux, 1980).

Geological features such as dolerite intrusions have a high magnetic permeability and will therefore result in anomalies (Roux, 1980). Thus, the aim in using the magnetometer is to detect possible dolerite intrusions which are ideal in the exploration for groundwater (Woodford & Chevallier, 2002).

According to Mariita (2007) geological features such as dykes, faults and lava flows contain magnetic properties which causes magnetic anomalies as seen in Figure 23.



6.2 Aeromagnetic map

A geophysical aeromagnetic map of the study area as seen in Figure 24 was used as a preliminary tool to detect any magnetic structures in the vicinity of Quantum Foods, Bulhoek Farm, North West Province.

Figure 24 indicates that magnetic features do appear in the vicinity of the study area, a magnetic ground survey was done along the relative position where the evaporation ponds are to be installed to determine whether dolerite features are present.

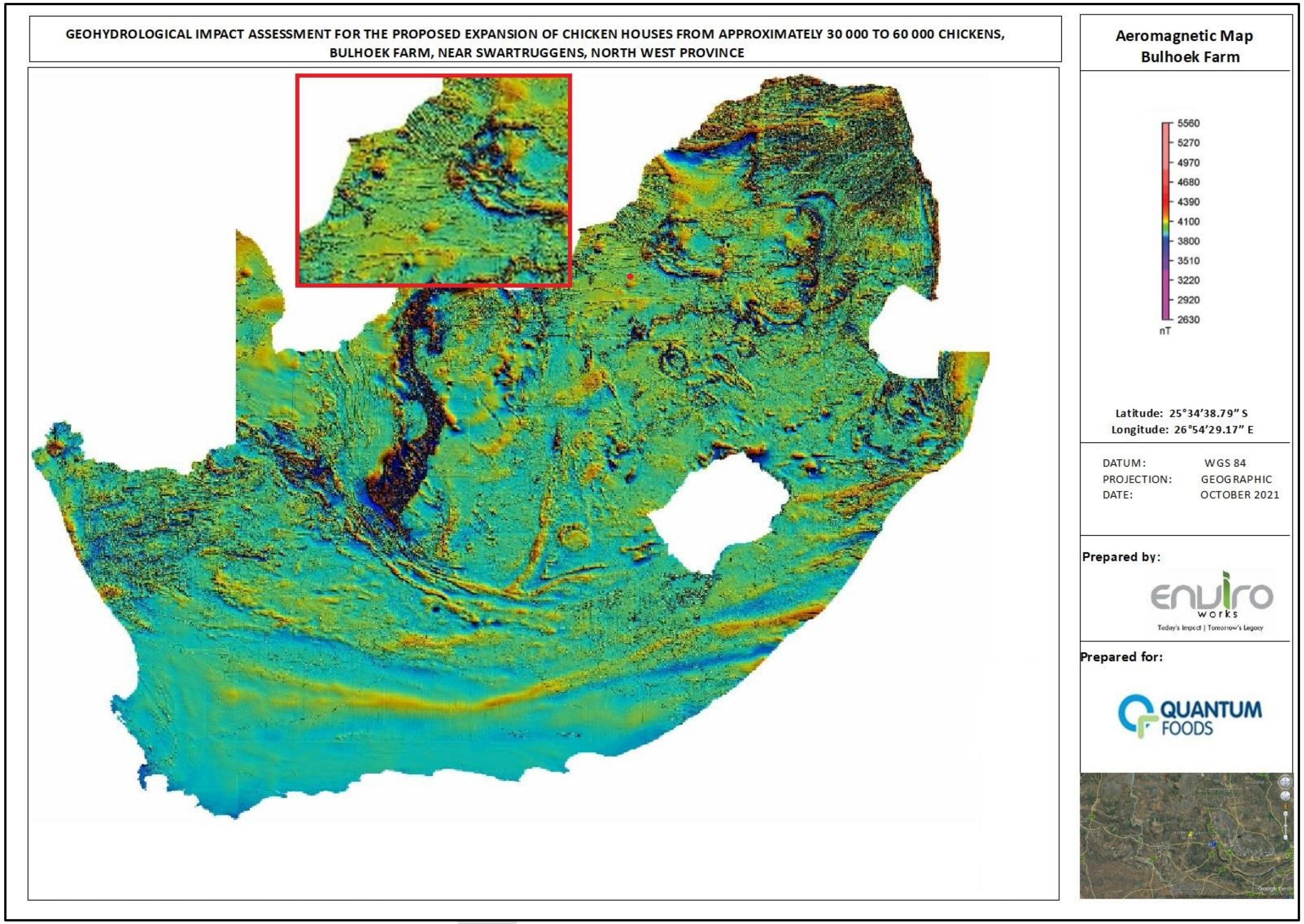


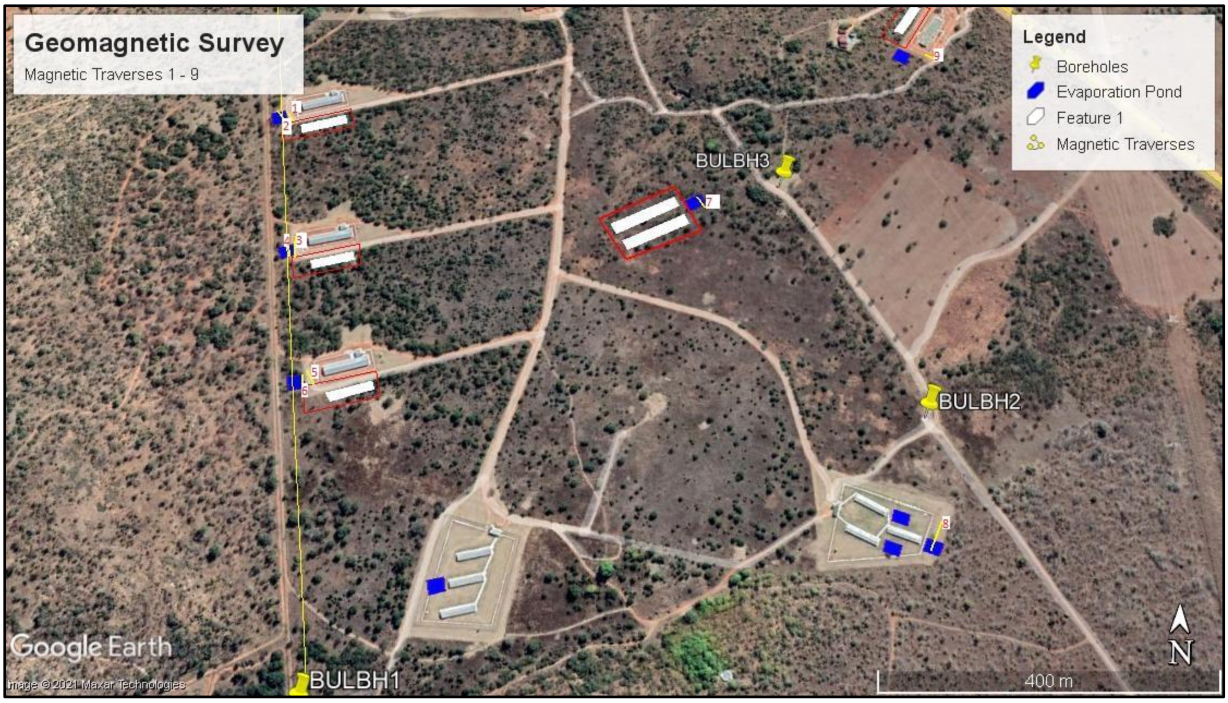
Figure 24. **Aeromagnetic map of** Bulhoek Farm, North West Province **(Council of Geoscience, 2019).**

6.3 Magnetic field survey

A geophysical field survey was performed on 22 September 2021 where the G5 magnetometer was used to record the magnetic readings over traverses at the site of investigation.

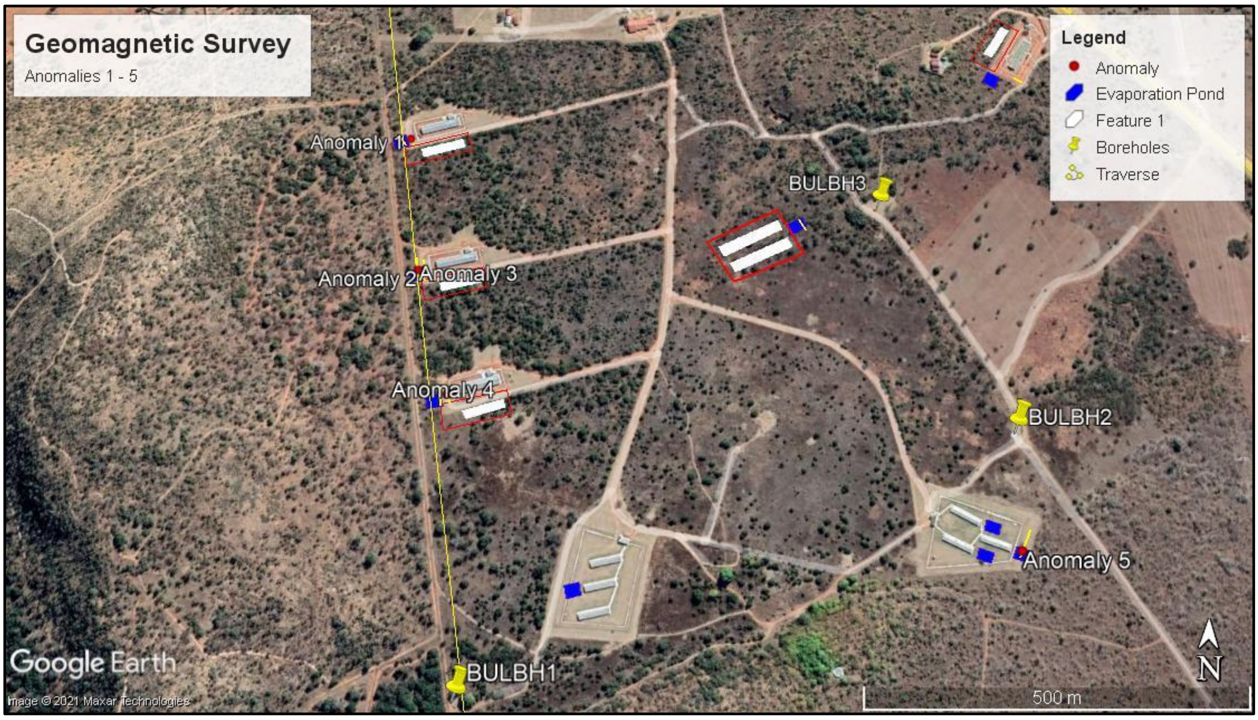
The field survey was conducted at "areas of concern" which is where the evaporation ponds are proposed to be constructed on site.

The magnetic field survey consisted of ten (10) traverses as indicated in Figure 25 & 26.

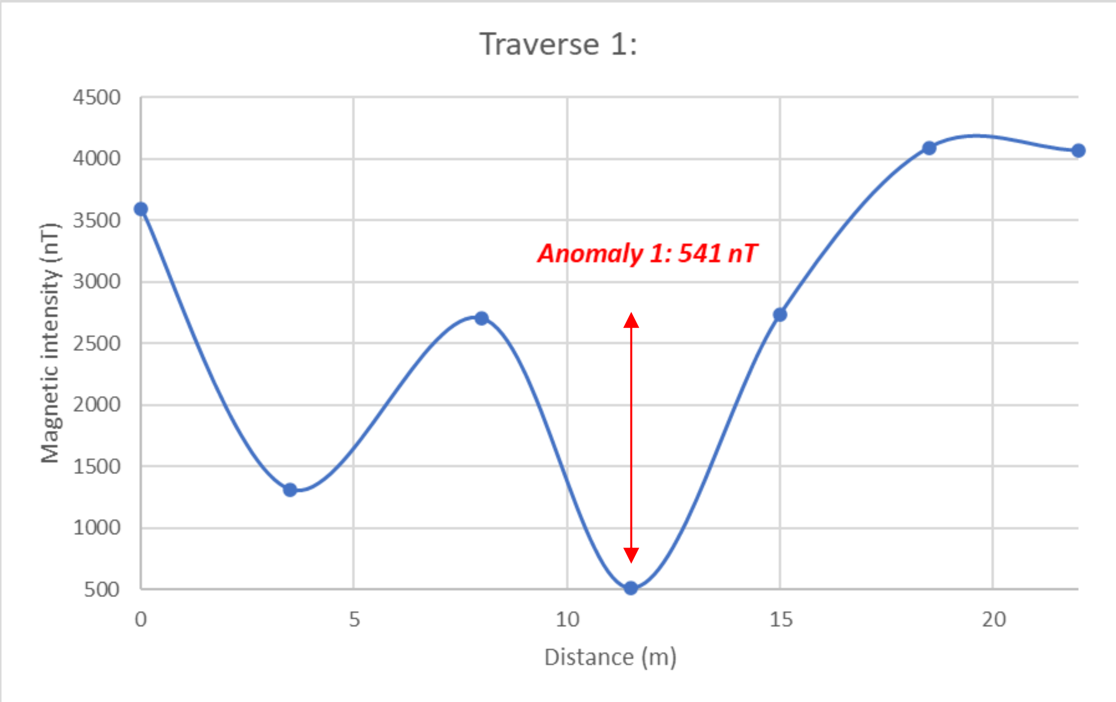


The outcome of the magnetic field survey is shown in the Figures below, note that the regional magnetic field has been removed to make the identification of the magnetic anomalies easier to interpret.

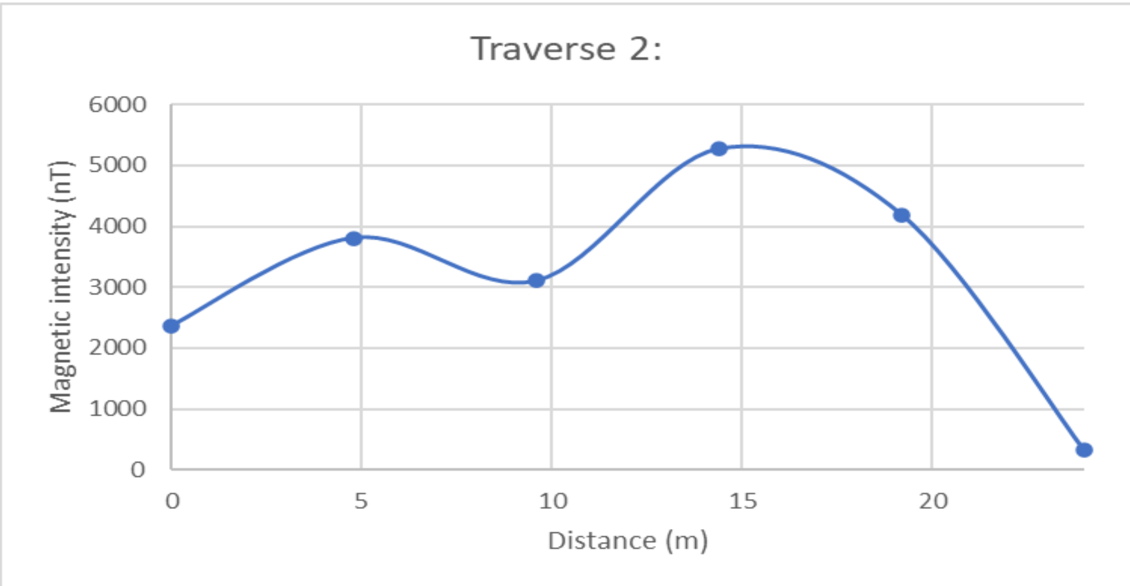
The anomalies will be discussed in the Figures below and the positions have been identified as seen in Figures 27 & 28.



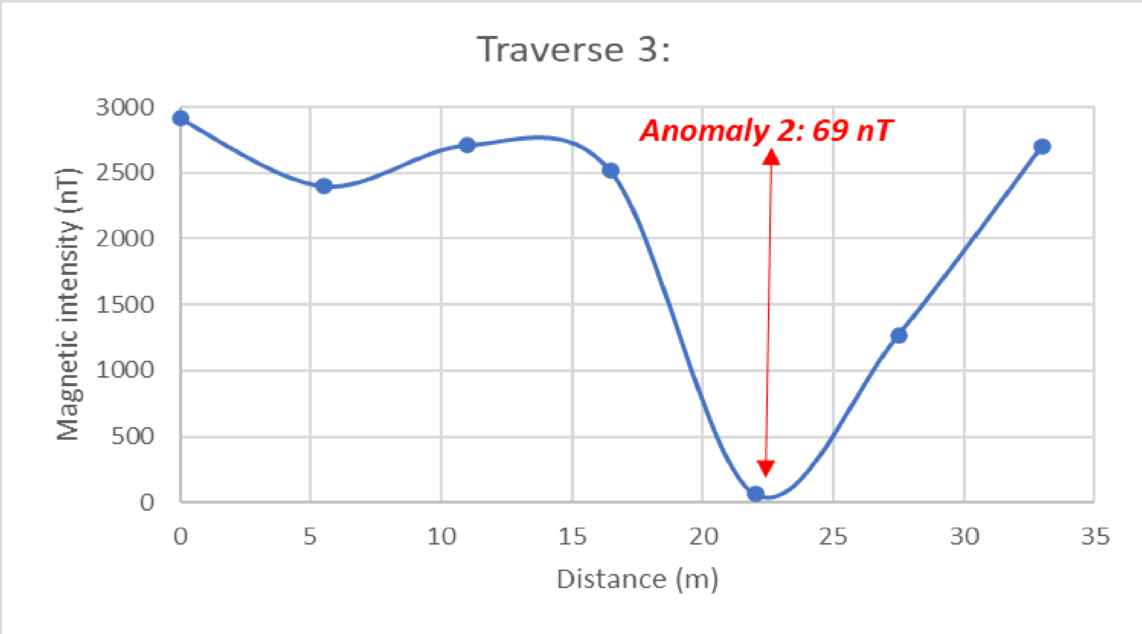
It can be concluded from Traverse 1 (Figure 29) that one (1) significant anomaly (Anomaly 1) was identified at 11.5 m. Anomaly 1 has a magnetic intensity of 541 nT and it is unlikely that this anomaly can be indicative of an intrusive dolerite/magnetic feature. Please note that this magnetic survey was done next to an existing chicken house with metal structures, electric fence and metal components which can be the reason for the magnetic noise in the background.



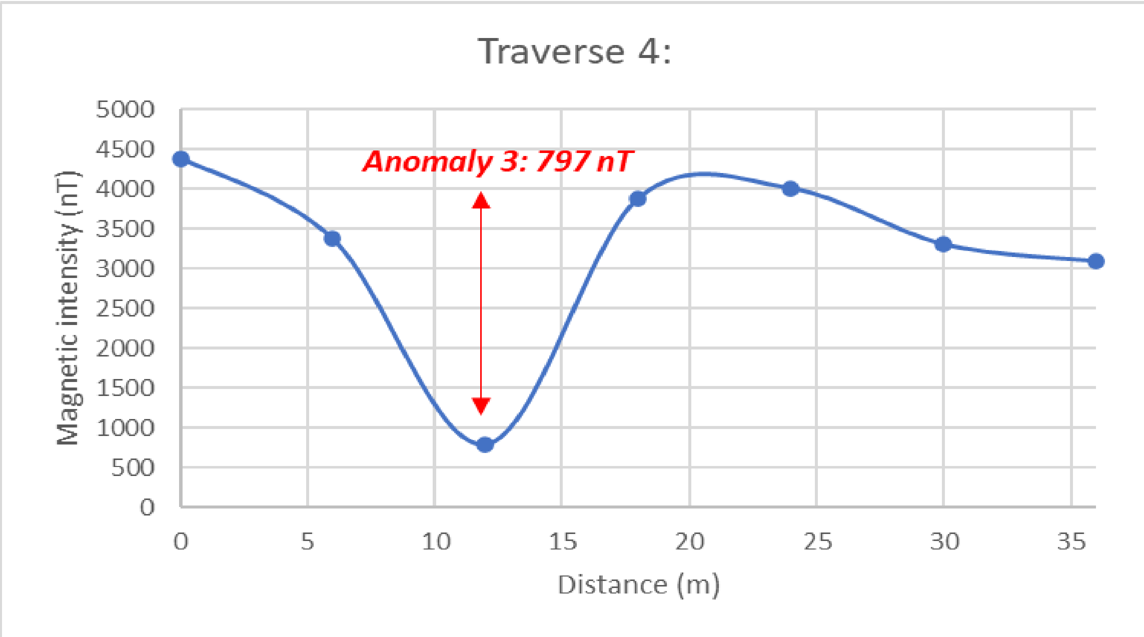
It can be concluded from Traverse 2 (Figure 30) that no significant anomalies were identified. Please note that this magnetic survey was done next to an existing chicken house with metal structures, electric fence and metal components which can be the reason for the magnetic noise in the background.



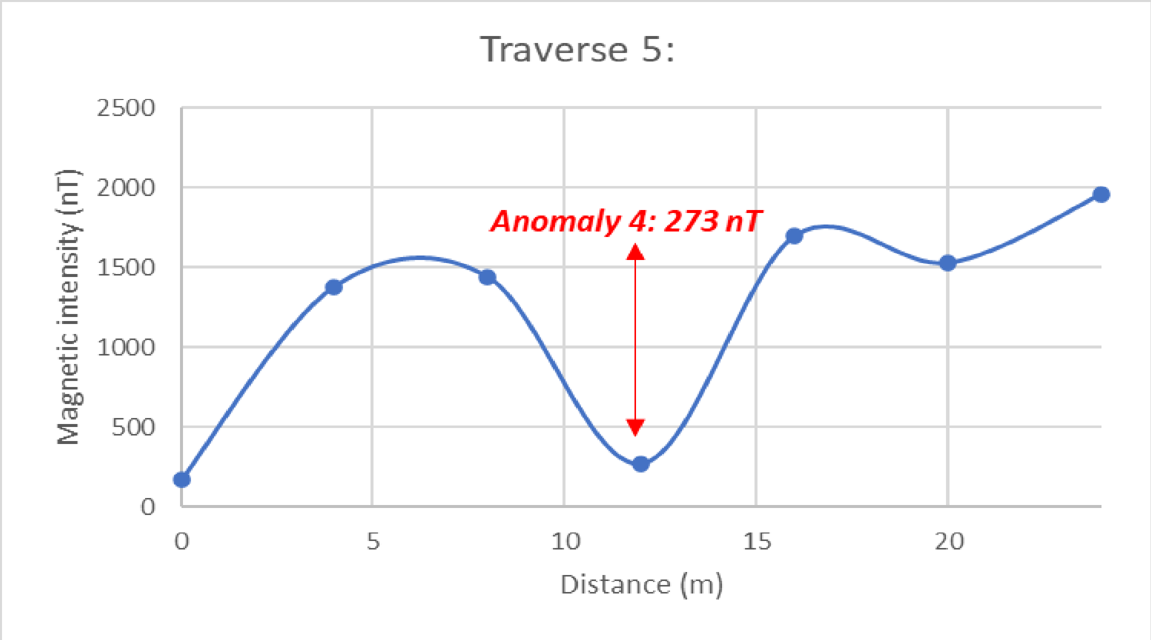
It can be concluded from Traverse 3 (Figure 31) that one (1) significant anomaly (Anomaly 2) was identified at 22 m with a magnetic intensity of 69 nT. The change in magnetic intensity can be indicative of an intrusive dolerite/ magnetic feature.



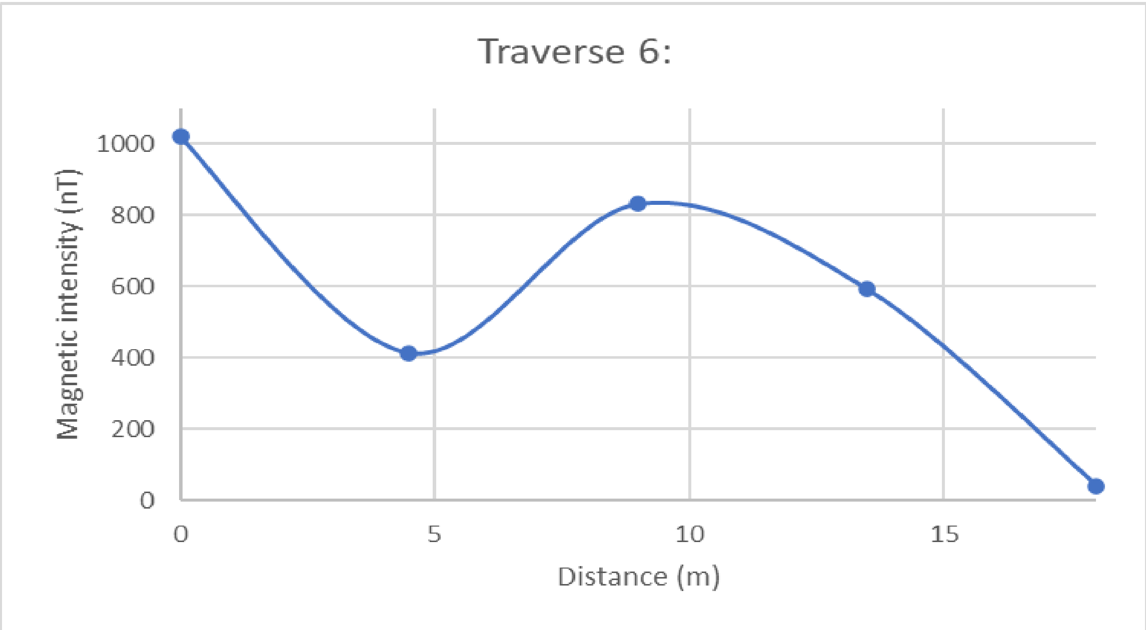
It can be concluded from Traverse 4 (Figure 32) that one (1) significant anomaly (Anomaly 3) was identified at 12 m with a magnetic intensity of 797 nT. The change in magnetic intensity can be indicative of an intrusive dolerite/ magnetic feature.



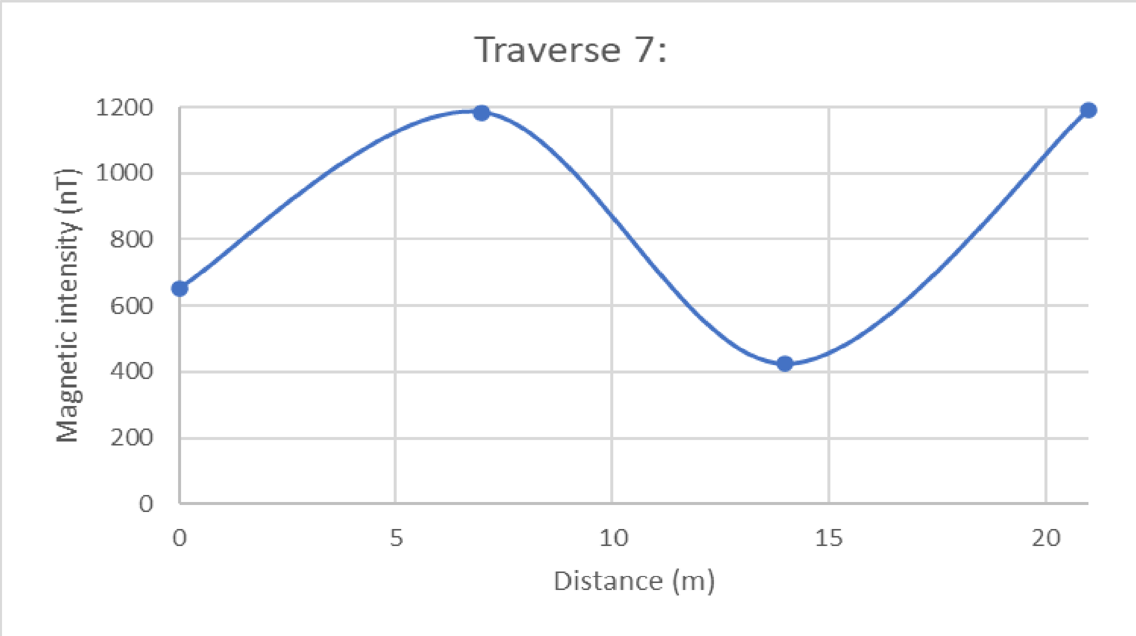
It can be concluded from Traverse 5 (Figure 33) that one (1) significant anomaly (Anomaly 4) was identified at 12 m. Anomaly 4 has a magnetic intensity of 273 nT and it is unlikely that this anomaly can be indicative of an intrusive dolerite/magnetic feature. Please note that this magnetic survey was done next to an existing chicken house with metal structures, electric fence and metal components which can be the reason for the magnetic noise in the background.



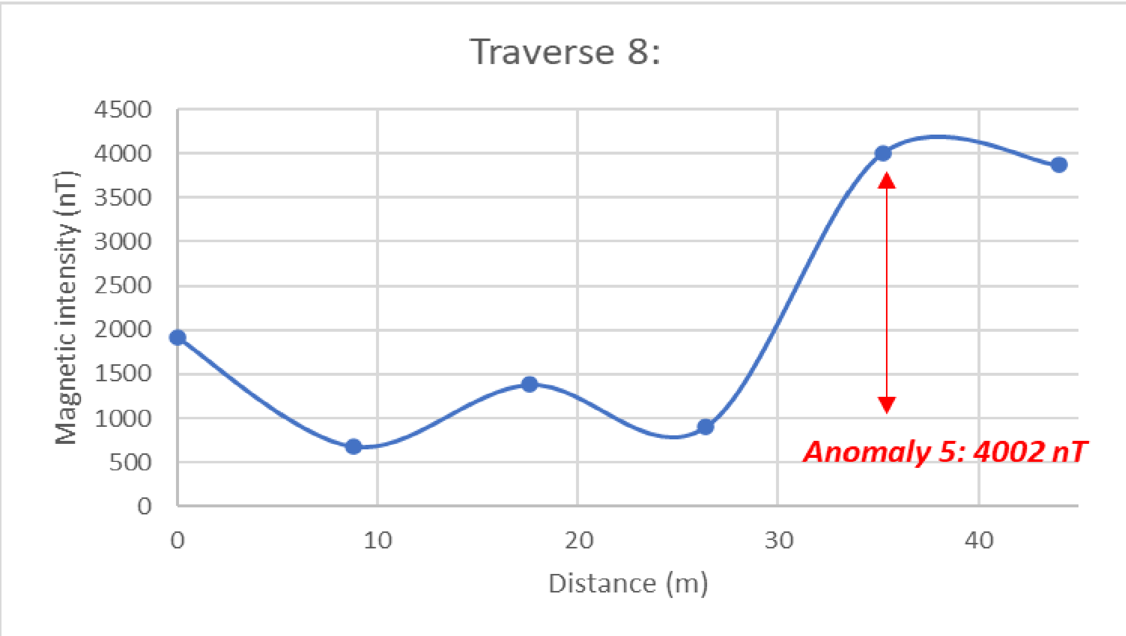
It can be concluded from Traverse 6 (Figure 34) that no significant anomalies were identified. Please note that this magnetic survey was done next to an existing chicken house with metal structures, electric fence and metal components which can be the reason for the magnetic noise in the background.



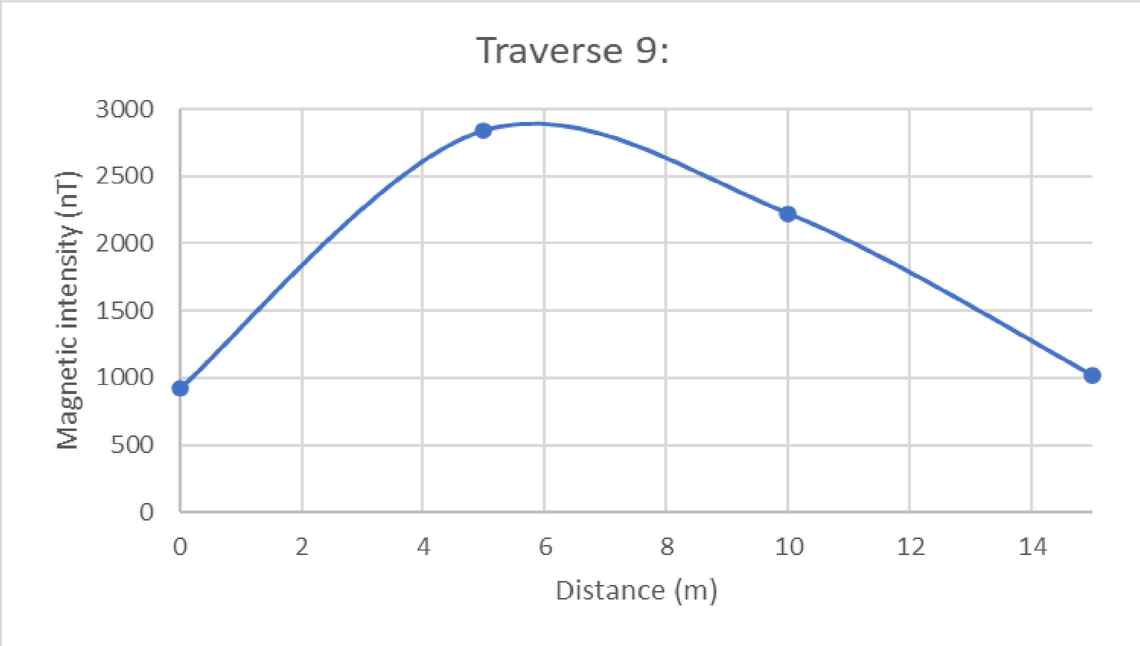
It can be concluded from Traverse 7 (Figure 35) that no significant anomalies were identified. Please note that this magnetic survey was done next to an existing chicken house with metal structures, electric fence and metal components which can be the reason for the magnetic noise in the background.



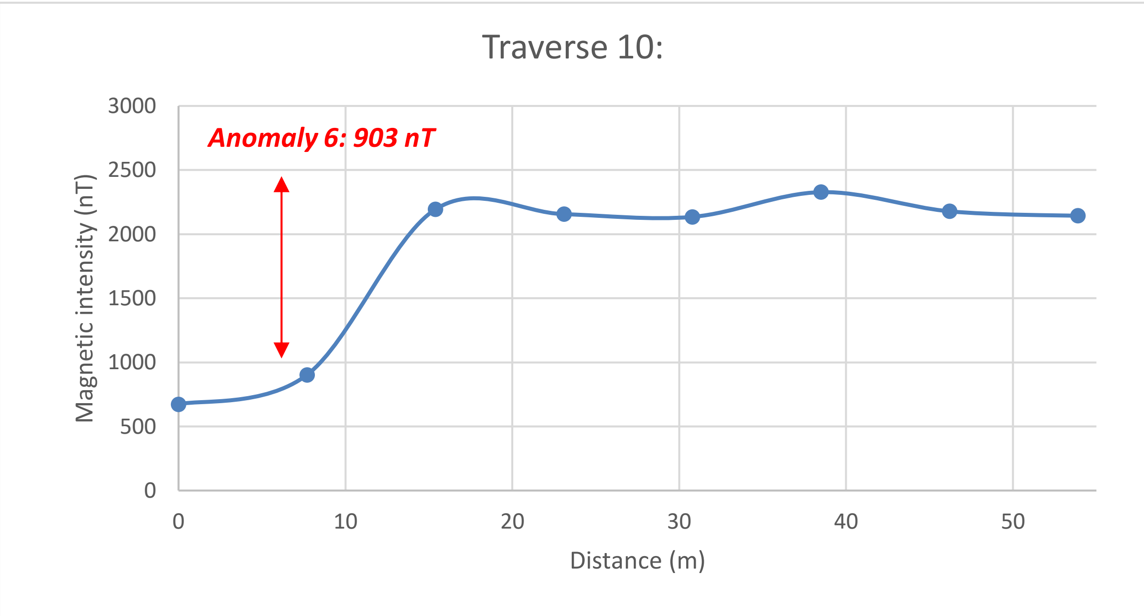
It can be concluded from Traverse 8 (Figure 36) that one (1) significant anomaly (Anomaly 5) was identified at 35.2 m. Anomaly 5 has a magnetic intensity of 4002 nT. Due to the magnitude of the magnetic intensity in respect to the other identified anomalies, it is likely that this anomaly can be indicative of an intrusive dolerite/magnetic feature.



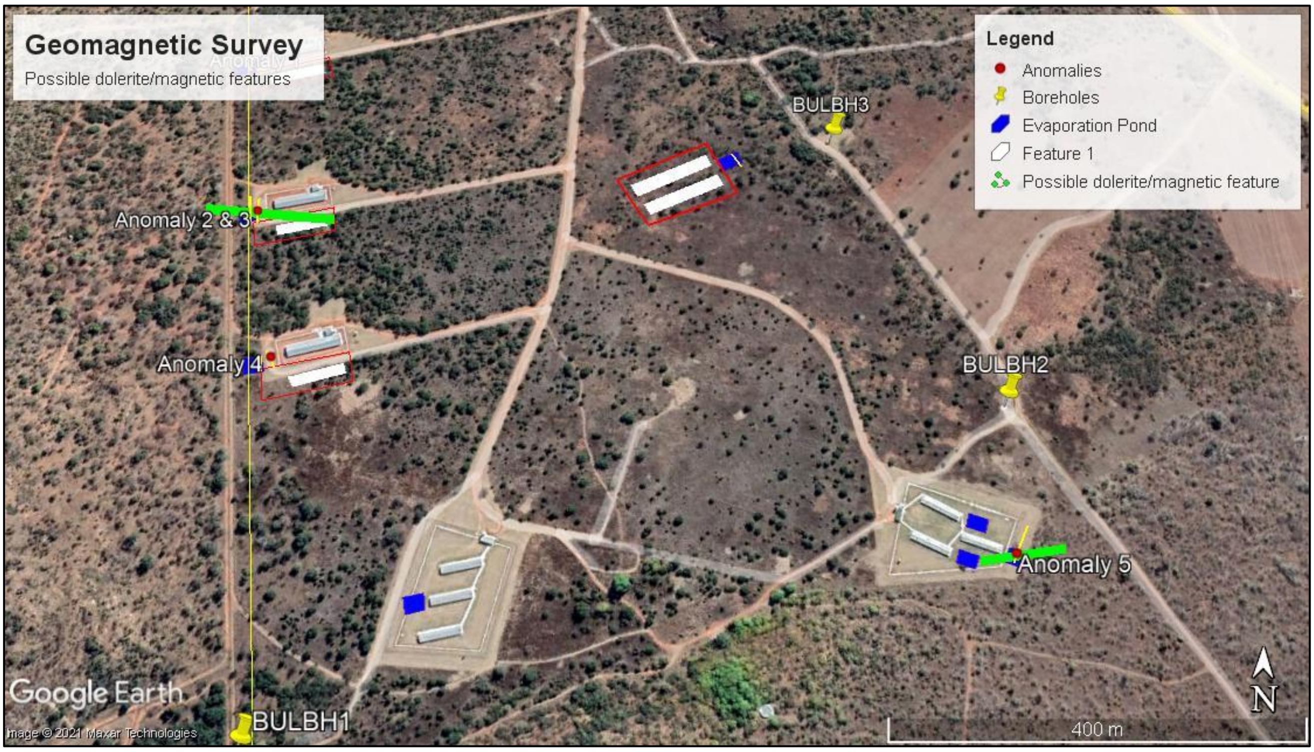
It can be concluded from Traverse 9 (Figure 37) that no significant anomalies were identified. Please note that this magnetic survey was done next to an existing chicken house with metal structures, electric fence and metal components which can be the reason for the magnetic noise in the background.



It can be concluded from Traverse 10 (Figure 38) that one (1) significant anomaly (Anomaly 6) was identified at 7.7 m. Anomaly 6 has a magnetic intensity of 903 nT and it is unlikely that this anomaly can be indicative of an intrusive dolerite/magnetic feature due to the close proximity that this magnetic traverse was done to the electric fence. Please note that this magnetic survey was done next to an existing chicken house with metal structures, electric fence and metal components which can be the reason for the magnetic noise in the background.



From the analysis of the magnetic field data and the significant anomalies identified from the ten (10) traverses the following two (2) possible intrusive dolerite/ magnetic features can be identified as indicated by the green lines in Figure 39, which can act as a preferential pathway for contaminants to contaminate groundwater.



6.4 Geophysical conclusion

The aeromagnetic data obtained in the vicinity of the site as discussed in Section 6.2 coincides with the information obtained from the magnetic field survey performed at the site. Two (2) possible intrusive dolerite/ magnetic features have been identified by the magnetic survey. However, no dolerite outcrops were observed on site during the site visit. The possible presence of a dolerite intrusion increases the vulnerability of the groundwater with respect to groundwater contamination.

Due to the presence of the evaporation ponds in close proximity to the possible intrusive dolerite/ magnetic features, the evaporation ponds and septic tanks should be designed and constructed to include a synthetic liner or geotextile liner approved by the DWS and have at least two (2) monitoring boreholes, one (1) upstream from the facility and the other downstream of the facility, on site to ensure that leakage from the evaporation ponds do not occur. The groundwater quality should be assessed bi-annually during the operation of the evaporation ponds.

Kindly take note that the Geophysical Survey was performed at the previous evaporation ponds positions prior to the distribution of the revised layout map that indicate the new positions of the evaporation ponds as indicated by Figures 1, 40 & 41 . However, this does not change the fact that intrusive features are expected in the vicinity of the proposed development. Thus, the proposed recommendations as mentioned in Section 12 should still be implemented.

Figure 40. The new positions of the evaporation ponds, Southern side of the farm, Bulhoek Farm.

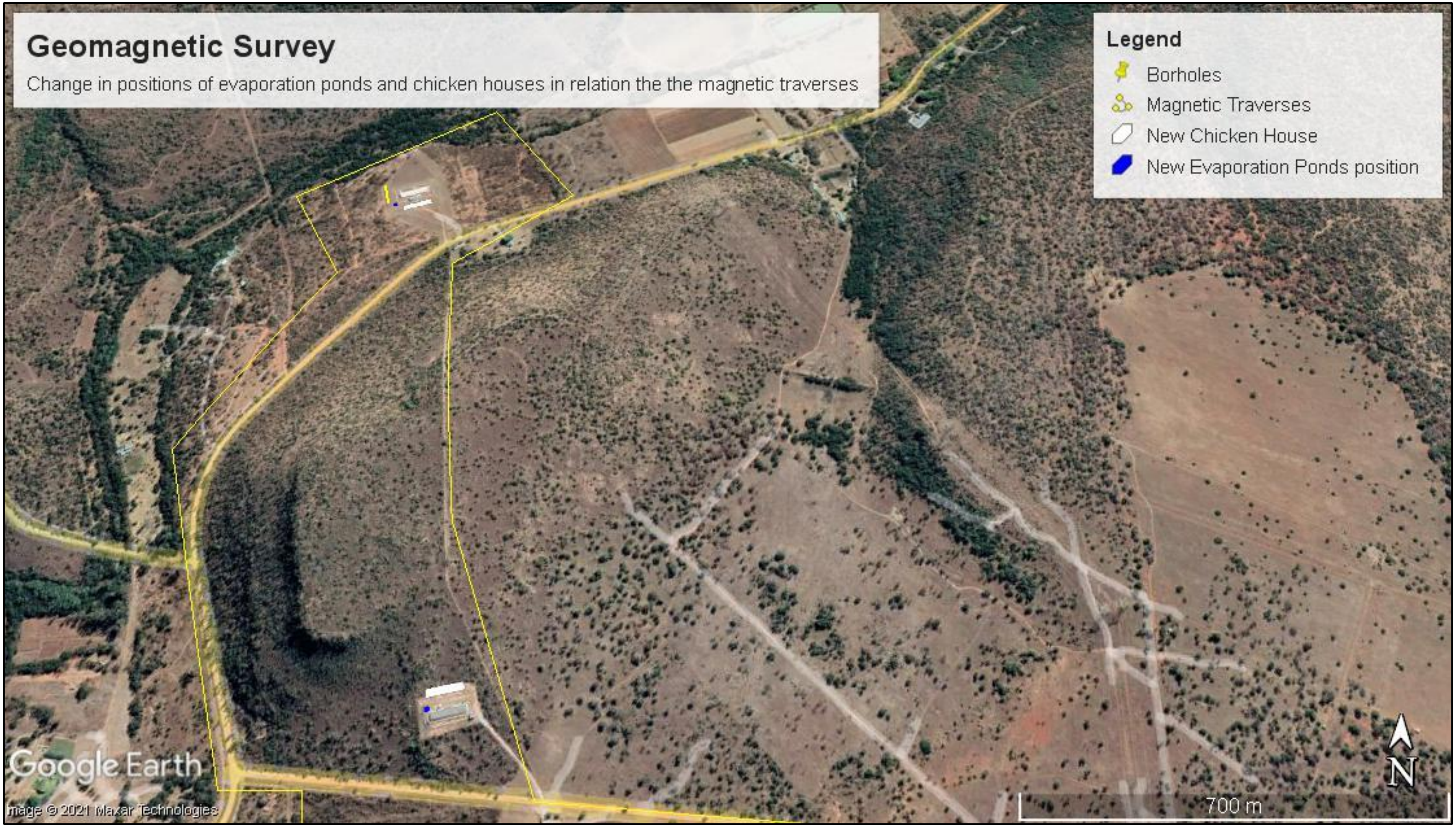


Figure 41. The new positions of the evaporation ponds, Northern side of the Farm, Bulhoek Farm.

7 GEOHYDROLOGICAL IMPACT ASSESSMENT

Table 5. Geohydrological Impact Assessment.

Planning, Design and Construction phase	**Site Layout**		**No-Go Alternative**
	Before Mitigation	**After Mitigation**	
POTENTIAL GEOHYDROLOGICAL AND GEOLOGICAL IMPACTS:			
Nature of impact: Infiltration of effluent and chemicals that have the potential to change the quality of the groundwater.	**Activity:** Dolerite found in the study area can create a potential impact where a preferential path can be created where the potential leachate from the evaporation ponds and septic tanks from the facility can pollute the groundwater by changing the quality of the groundwater. This dolerite intrusions can bake the surrounding geology and cause the geology to weather which increases the permeability for contaminants.		The definite pollution of groundwater can cause Quantum Foods, Bulhoek Farm's EA and associated licenses to be reviewed.
Magnitude:	6	4	-
Duration:	4	2	-
Extent:	2	2	-
Irreplaceable:	3	2	-
Reversibility:	3	1	-
Probability:	3	3	-
Total SP:	54	33	-
Significance rating:	M	L	-
Cumulative impact:	-	-	-
Proposed Mitigation:	• Groundwater monitoring to prevent groundwater contamination, through means of prevention when detected early enough. • The facility should be kept clean and tidy at all times. • Any waste generated should be disposed of accordingly in registered waste (landfill) sites and not dumped on site or the surrounding area. • All surfaces that are associated with waste should have impermeable surfaces. • Stormwater and runoff should be diverted and managed to not come in contact with any waste generated on site.		N/A

Planning, Design and Construction phase	Site Layout		No-Go Alternative
	Before Mitigation	After Mitigation	
POTENTIAL GEOHYDROLOGICAL AND GEOLOGICAL IMPACTS:			
Nature of impact: Infiltration of effluent and chemicals that have the potential to change the quality of the groundwater.	**Activity:** Taking the site-specific properties such as: • Recharge (average); • Rainfall (average rainfall MAP: 600 - 750 mm); • Temperature (average annual temperature of 18.30°C); • Topography and drainage (Northern drainage – towards topographical depression – Dwarspruit); • Water table (deep water table of 15 - 30 mbgl. – swl BULBH1 37.2 mbgl); • Fractured weathered aquifer (very high permeability); • Groundwater vulnerability (Insignificant to very low), and, • Groundwater quality (good quality with respect to EC Values).		The definite pollution of groundwater can cause Quantum Foods, Bulhoek Farm's EA and associated licenses to be reviewed.
Magnitude:	4	4	-
Duration:	4	3	-
Extent:	2	2	-
Irreplaceable:	2	2	-
Reversibility:	2	2	-
Probability:	2	1	-
Total SP:	28	13	-
Significance rating:	L	L	-
Cumulative impact:	-	-	-
Proposed Mitigation:	• Groundwater monitoring to prevent groundwater contamination, through means of prevention when detected early enough. • The facility should be kept clean and tidy at all times. • Any waste generated should be disposed of accordingly in registered waste (landfill) sites and not dumped on site or the surrounding area. • All surfaces that are associated with waste should have impermeable surfaces. • Stormwater and runoff should be diverted and managed to not come in contact with any waste generated on site. • All evaporation ponds and septic tanks associated with the facility should be lined with a synthetic liner or any other liner approved by the Department of Water and Sanitation (DWS) to ensure that any possible leachate from the evaporation ponds and septic tanks do not pollute the groundwater.		N/A

	• Due to the presence of possible intrusive dolerite/ magnetic features, the proposed facility should have at least two (2) monitoring boreholes, one (1) upstream from the facility and the other downstream of the facility, on site to ensure that leakage from the evaporation ponds and septic tanks do not occur. The groundwater quality should be assessed bi-annually during the operation of the evaporation ponds.	

The scales to be used to assess these variables and to define the rating categories are tabulated in the tables below:

7.1 Impact assessment methodology

For each potential impact, the EXTENT (spatial scale), MAGNITUDE, DURATION (time scale), PROBABILITY of occurrence, IRREPLACEABLE loss of resources and the REVERSIBILITY of potential impacts must be assessed by the specialist by using the results of their specialist studies. The assessment of the above criteria will be used to determine the significance of each impact, with and without the implementation of the proposed mitigation measures. The scales to be used to assess these variables and to define the rating categories are tabulated in Table 6 & Table 7 below.

Table 6. Evaluation components, ranking scales, and descriptions (criteria).

Evaluation component	Ranking scale and description (criteria)
MAGNITUDE of NEGATIVE IMPACT (at the indicated spatial scale)	**10 - Very high**: Bio-physical and/or social functions and/or processes might be *severely* altered. **8 - High**: Bio-physical and/or social functions and/or processes might be *considerably* altered. **6 - Medium**: Bio-physical and/or social functions and/or processes might be *notably* altered. **4 - Low** : Bio-physical and/or social functions and/or processes might be *slightly* altered. **2 - Very Low**: Bio-physical and/or social functions and/or processes might be *negligibly* altered. **0 - Zero**: Bio-physical and/or social functions and/or processes will remain *unaltered.*
MAGNITUDE of POSITIVE IMPACT (at the indicated spatial scale)	**10 - Very high (positive)**: Bio-physical and/or social functions and/or processes might be *substantially* enhanced. **8 - High (positive)**: Bio-physical and/or social functions and/or processes might be *considerably* enhanced. **6 - Medium (positive)**: Bio-physical and/or social functions and/or processes might be *notably* enhanced. **4 - Low (positive)**: Bio-physical and/or social functions and/or processes might be *slightly* enhanced. **2 - Very Low (positive)**: Bio-physical and/or social functions and/or processes might be *negligibly* enhanced. **0 - Zero (positive)**: Bio-physical and/or social functions and/or processes will remain *unaltered.*
DURATION	**5 - Permanent** **4 - Long term**: Impact ceases after operational phase/life of the activity > 60 years. **3 - Medium term**: Impact might occur during the operational phase/life of the activity – 60 years. **2 - Short term**: Impact might occur during the construction phase - < 3 years. **1 - Immediate**
EXTENT (or spatial scale/influence of impact)	**5 - International**: Beyond National boundaries. **4 - National**: Beyond Provincial boundaries and within National boundaries. **3 - Regional**: Beyond 5 km of the proposed development and within Provincial boundaries. **2 - Local**: Within 5 km of the proposed development. **1 - Site-specific**: On site or within 100 m of the site boundary. **0 -** None

IRREPLACEABLE loss of resources	**5 – Definite** loss of irreplaceable resources. **4 – High** potential for loss of irreplaceable resources. **3 – Moderate** potential for loss of irreplaceable resources. **2 – Low** potential for loss of irreplaceable resources. **1 – Very low** potential for loss of irreplaceable resources. **0 - None**
REVERSIBILITY of impact	**5 –** Impact **cannot** be reversed. **4 – Low** potential that impact might be reversed. **3 – Moderate** potential that impact might be reversed. **2 – High** potential that impact might be reversed. **1 –** Impact **will be** reversible. **0 –** No impact.
PROBABILITY (of occurrence)	**5 - Definite**: >95% chance of the potential impact occurring. **4 - High probability**: 75% - 95% chance of the potential impact occurring. **3 - Medium probability**: 25% - 75% chance of the potential impact occurring **2 - Low probability**: 5% - 25% chance of the potential impact occurring. **1 - Improbable**: <5% chance of the potential impact occurring.
Evaluation component	**Ranking scale and description (criteria)**
CUMULATIVE impacts	**High**: The activity is one of several similar pasts, present or future activities in the same geographical area, and might contribute to a very significant combined impact on the natural, cultural, and/or socio-economic resources of local, regional, or national concern. **Medium**: The activity is one of a few similar pasts, present or future activities in the same geographical area, and might have a combined impact of moderate significance on the natural, cultural, and/or socio-economic resources of local, regional, or national concern. **Low**: The activity is localised and might have a negligible cumulative impact. **None**: No cumulative impact on the environment.

Once the evaluation components have been ranked for each potential impact, the significance of each potential impact will be assessed (or calculated) using the following formula:

- **SP (Significance Points) = (Magnitude + Duration + Extent + Irreplaceable + Reversibility) x Probability.**

The maximum value is 150 SP (significance points). The unmitigated and mitigated scenarios for each potential environmental impact should be rated as per Table below.

Table 7. Definition of significance ratings (positive and negative).

Significance Points	Environmental Significance	Description
125 – 150	**Very high (VH)**	An impact of very high significance will mean that the project cannot proceed, and that impacts are irreversible, regardless of available mitigation options.
100 – 124	**High (H)**	An impact of high significance which could influence a decision about whether or not to proceed with the proposed project, regardless of available mitigation options.
75 – 99	**Medium-high (MH)**	If left unmanaged, an impact of medium-high significance could influence a decision about whether or not to proceed with a proposed project. Mitigation options should be relooked.

40 – 74	**Medium (M)**	If left unmanaged, an impact of moderate significance could influence a decision about whether or not to proceed with a proposed project.
<40	**Low (L)**	An impact of low is likely to contribute to positive decisions about whether or not to proceed with the project. It will have little real effect and is unlikely to have an influence on project design or alternative motivation.
+	**Positive impact (+)**	A positive impact is likely to result in a positive consequence/effect and is likely to contribute to positive decisions about whether or not to proceed with the project.

8 GROUNDWATER MONITORING SYSTEM

8.1 Groundwater and surface water monitoring system

The groundwater and surface water background quality has been discussed in Section 5.5 as analysed in Appendix A (groundwater quality analysis).

8.2 Monitoring parameters

Appendix A indicates the background groundwater quality parameters that should be monitored over time by a qualified Geohydrologist Bi-annually during the operational phase of the evaporation ponds to ensure that if groundwater contamination from Quantum Foods, Bulhoek Farm, takes place that mitigation measures are put in place. As stated, these parameters should be monitored at least twice a year during the operational phase of evaporation ponds and analysed according to the upper limits and ranges of the water standards as stipulated by the DWS – please refer to Appendix A. The laboratory analysis techniques will have to comply with SABS guidelines, therefore, the laboratories must be accredited.

These parameters are:

- Heterotrophic plate count;
- Total coliform bacteria;
- Faecal coliform bacteria;
- EC (Electrical Conductivity);
- TDS (Total Dissolved Salts);
- TSS (Total Suspended Solids);
- M-Alk as CaCO3;
- Ca & Mg Hardness;
- Calcium as Ca;
- Ammonia as N;
- Chloride as Cl;
- Fluoride as F;
- Magnesium as Mg;
- Nitrate as N;
- Potassium as K;
- Sodium as Na;
- Sulphate as SO_4;
- Aluminium as Al;
- Arsenic as;
- Boron as B;
- Cadmium as Cd;
- Cobalt as Co;

- Chromium as Cr;
- Copper as Cu;
- Cyanide as CN^- (free);
- Iron as Fe;
- Lead as Pb;
- Manganese as M;
- Selenium as Se; and,
- Zinc as Zn.

8.3 Groundwater monitoring boreholes

At least two (2) monitoring boreholes should be developed in the area, one (1) upstream from the facility and another downstream from the facility to ensure that groundwater quality can be monitored with reference to the facility, manure, evaporation ponds and septic tanks on site. The quality should be assessed at least twice a year by a qualified Geohydrologist.

A groundwater monitoring plan should be drafted which include an early warning system to highlight contamination, should it occur and should also include a mitigation plan if/when groundwater contamination occurs. The water monitoring plan should be revised on a regular basis to incorporate the changes in the water flow regime.

9 GROUNDWATER AND SURFACE WATER ENVIRONMENTAL MANAGEMENT PROGRAMME

9.1 Current groundwater and surface water conditions

The current groundwater and surface water quality conditions have been discussed in Section 5.5.1 & 5.5.2. The results of the chemical analysis of the groundwater can be seen in Appendix A and Section 5.5.4.

9.2 Predicted impacts of the facility on groundwater and surface water

The waste and potential predicted contaminants associated with the facility are:

- The operation of the facility;
- Septic tanks on site;
- General waste on site (estimated to be insignificant to very low);
- Manure; and,
- Evaporation ponds.

The runoff in the vicinity of Quantum Foods, Bulhoek Farm, is high. Therefore, if runoff from the facility occurs it creates the potential that the contaminants from the facility are transported to the receiving water course in the topographical depression (Dwarspruit and surrounding wetlands) and could potentially contaminate the surface water. The current state of the surface water is discussed in Section 5.5.1.

The predicted impact of the facility on groundwater can be that the aquifer present is a fractured, weathered aquifer (increases the permeability of the aquifer) and potential dolerite intrusions (creates preferential pathways for contaminant transport) which indicates that the potential for the aquifer to become contaminated is very high, however the infiltration potential of the contaminant to the deep groundwater table is low. Thus, the overall predicted impact on the groundwater quality is low if the mitigation measures and recommendations are considered.

Note that the current state of the groundwater quality is suitable for human consumption prior to treatment , excluding groundwater from BULBH2 which is not suitable for human consumption and must be treated prior to utilisation as drinking water. Groundwater monitoring is essential to determine whether the facility causes any additional contamination to the groundwater with regards to the evaporation ponds and septic tanks.

The septic tanks should be serviced at least weekly, the evaporation ponds and septic tanks should have a synthetic liner or geotextile liner approved by the DWS and have at least two (2) monitoring boreholes on site, one (1) upstream from the facility and the other downstream of the facility, to ensure that leakage from the septic tanks and evaporation ponds does not occur. A leak monitoring device is advised for each septic tank to ensure that if any leakages should occur that they are detected early enough to mitigate.

9.3 Mitigation measures

Taking the predicted potential impacts of the facility and associated infrastructure on surface water, geology and groundwater into account the following mitigation measures must be implemented as recommended from the Geohydrological Specialist:

- The facility should be kept clean and tidy at all times;
- Any waste generated should be disposed of accordingly in registered waste (landfill) sites and not dumped on site or the surrounding area;
- All surfaces that are associated with waste and manure should have impermeable surfaces;
- Stormwater and runoff should be diverted and managed to not come in contact with any waste generated on site;
- Proper waste management during all phases of the activity, as well as storm water management, will have to be strictly enforced and monitored. This is to prevent any litter, rubble, or possible pollution to enter the watercourses downstream of the site and the surrounding environment in general;
- Water drainage should be properly planned and addressed to drain water from the site and prevent any accumulation on site;
- Provision of adequate on-site sewerage management;
- Groundwater from BULBH2 should be treated chemically prior to be used for human consumption;
- Groundwater from BULBH3 should be treated for the total harness of the water prior to utilisation to protect groundwater pumping equipment etc.;
- Appoint a qualified Geohydrologist to monitor groundwater quality, this should be implemented throughout the lifespan on the activity. The quality analysis should be done bi-annually during the operational phase of the evaporation ponds;
- Sewerage and sanitation facilities should be regularly maintained and checked;
- The septic tanks and evaporation ponds should be lined with a synthetic liner or any other liner that has been approved by the DWS to ensure that no potential leachate pollutes the groundwater;
- Due to the presence possible intrusive dolerite/ magnetic features, the septic tanks should be serviced at least weekly.
- The facility should have at least two (2) monitoring boreholes, one (1) upstream from the facility and the other downstream of the facility, on site to ensure that leakage from the septic tanks and evaporation ponds do not occur.
- A leak monitoring device is advised for each septic tank on site to ensure that any leakages are detected early enough to mitigate.
- The principle of reduce, re-use and recycle should be followed;
- Avoid the use of concrete lined channels for storm water management as this can increase the speed of water. This in turn increases erosion potential that can cause erosion on site and in channels and increase siltation downstream. If concrete-lined channels are used; they should end in silt traps;
- Regular inspections will be undertaken of any access roads and stormwater management drains for signs of erosion and sedimentation;
- Regularly inspect all vehicles for leaks. Re-fuelling of vehicles must take place on a sealed surface area surrounded by berms to prevent ingress of hydrocarbons into topsoil;
- If any spills occur, they should be immediately cleaned up;

- If water is sprayed on the surfaces for any reason during the construction completion process, utmost care must be taken to ensure the runoff water does not pollute the watercourses;
- A stormwater cut-off drain should be constructed between the facility and the watercourses to ensure that storm water flowing through the facility cannot flow into the watercourses. The water from the cut-off drain must be collected in a sedimentation pond before entering the aquatic system;
- No dirty water runoff from the construction and decommissioning site must be permitted to reach the watercourse;
- Spill kits must be stored on site: In case of accidental spills of oil, petroleum products *etc.*, good oil absorbent materials must be on hand to allow for the quick remediation of the spill. The kits should also be well marked and all personnel should be educated to deal with the spill. Vehicles must be kept in good working order and leaks must be fixed immediately on an oil absorbent mat. The use of a product such as Sunsorb is advised;
- Proper toilet facilities must be available during construction and decommissioning. The impact of human waste on the system is immense. Chemical toilets must be provided and should always be well serviced and spaced as per occupational health and safety laws, and placed outside the 1:100 year flood lines;
- Water tanks should be regularly checked for structural integrity, if present; and,
- Emergency response plan should be in place for failure of water tank structures on site, if present.

10 POST CLOSURE MANAGEMENT PLAN

With respect to groundwater, geology and the surface water predicted potential impacts, the following remediation measure must be considered when the facility suspends all activities and the facility closes.

- On completion of works, the area must be rehabilitated by suitable landscaping, levelling, topsoil dressing, land preparation, alien plant eradication and where ascribed for by the ECO, vegetation establishment;
- Boreholes should be sealed off to prevent damage to the borehole and potential rubble to be thrown into the boreholes;
- Clear and completely remove from site all construction structures and temporary infrastructure;
- Rehabilitation structures must be inspected regularly for the accumulation of debris, blockages, instabilities, and erosion with concomitant remedial and maintenance actions;
- Topsoil backfilling must be undertaken when the soil is dry, and not following any recent rainfall events;
- The replacement of topsoil should be sought in situ with construction where possible, or as soon as construction in an area has be completed;
- Topsoil must be returned to the same site from where it was stripped; and,
- All re-growth of invasive vegetative material will be monitored by the developer for one (1) year;
  All disturbed areas must be re-vegetated with indigenous vegetation suitable to the area.

11 CONCLUSION

Taking all the different aspects and their limitations that were investigated during the Geohydrological Impact Assessment into account the following conclusions can be made:

- In case of overflow or spillage the effluent from the facility can flow to the topographical depression, which is the Dwarspruit/ the surrounding wetlands.
- The predicted impact of the facility on groundwater can be that the aquifer present is a fractured, weathered aquifer (increases the permeability of the aquifer) and potential dolerite intrusions (creates preferential pathways for contaminant transport) which indicate that the potential for the aquifer to become contaminated is high, however the infiltration potential of the contaminant to the deep

groundwater table is low. Thus, the overall predicted impact on the groundwater quality is low if the mitigation measures and recommendations are considered.

- The current state of the groundwater quality is suitable for human consumption prior to treatment , excluding groundwater from BULBH2 which is not suitable for human consumption and must be treated prior to utilisation as drinking water.
- Groundwater from BULBH3 should be treated for the total harness of the water prior to utilisation to protect groundwater pumping equipment etc.

12 RECOMMENDATIONS

The following recommendations should be adhered to in terms of mitigation measures:

- Monitoring boreholes should be developed in the area to ensure that groundwater quality can be monitored with regards to the septic tanks and evaporation ponds on site, two (2) boreholes are advised, one (1) upstream from the facility and another downstream of the facility.
- Groundwater from the borehole BULBH2 should be chemically treated prior to human consumption and utilisation;
- Groundwater from BULBH3 should be treated for the total harness of the water prior to utilisation to protect groundwater pumping equipment etc.;
- Surface water quality should be monitored to ensure that surface water contamination from the facility does not take place;
- A groundwater monitoring plan should be drafted which include an early warning system to highlight contamination, should it occur and should also include a mitigation plan if/when groundwater contamination occurs;
- The water monitoring plan should be revised on a regular basis to incorporate the changes in the water flow regime;
- Laboratory analysis techniques will comply with SABS guidelines. Laboratories must be accredited;
- Data must be stored electronically. It is suggested that a well-known database such as WISH, Aqua base or Access be used. A backup of the data base must be stored in a safe place. Backups should be made every time the database is updated;
- On the completion of every sampling run a monitoring report must be completed. Included in the report must be time series trends, Piper and Durov diagrams. These will be used to determine if there are any changes in the system. These changes must be flagged and explained in the report;
- The facility should be kept clean and tidy at all times;
- Any waste generated should be disposed of accordingly in registered waste (landfill) sites and not dumped on site or the surrounding area;
- All surfaces that are associated with waste and manure should have impermeable surfaces;
- Stormwater and runoff should be diverted and managed to not come in contact with any waste generated on site;
- Proper waste management during all phases of the activity, as well as storm water management, will have to be strictly enforced and monitored. This is to prevent any litter, rubble, or possible pollution to enter the watercourses downstream of the site and the surrounding environment in general;
- Water drainage should be properly planned and addressed to drain water from the site and prevent any accumulation on site;
- Provision of adequate on-site sewerage management;
- Appoint a qualified Geohydrologist to monitor groundwater, this should be implemented throughout the lifespan on the activity. The quality analysis should be done bi-annually during the operational phase of the evaporation ponds;
- Sewerage and sanitation facilities should be regularly maintained and checked;
- The principle of reduce, re-use and recycle should be followed;

- Avoid the use of concrete lined channels for storm water management as this can increase the speed of water. This in turn increases erosion potential that can cause erosion on site and in channels and increase siltation downstream. If concrete-lined channels are used; they should end in silt traps;
- Regular inspections will be undertaken of any access roads and stormwater management drains for signs of erosion and sedimentation;
- Regularly inspect all vehicles for leaks. Re-fuelling of vehicles must take place on a sealed surface area surrounded by berms to prevent ingress of hydrocarbons into topsoil;
- If any spills occur, they should be immediately cleaned up;
- If water is sprayed on the surfaces for any reason during the construction completion process, utmost care must be taken to ensure the runoff water does not pollute the watercourses;
- A stormwater cut-off drain should be constructed between the facility and the watercourses to ensure that storm water flowing through the facility cannot flow into the watercourses. The water from the cut-off drain must be collected in a sedimentation pond before entering the aquatic system;
- No dirty water runoff from the construction and decommissioning site must be permitted to reach the watercourse;
- Spill kits must be stored on site: In case of accidental spills of oil, petroleum products *etc.*, good oil absorbent materials must be on hand to allow for the quick remediation of the spill. The kits should also be well marked and all personnel should be educated to deal with the spill. Vehicles must be kept in good working order and leaks must be fixed immediately on an oil absorbent mat. The use of a product such as Sunsorb is advised;
- Proper toilet facilities must be available during construction and decommissioning. The impact of human waste on the system is immense. Chemical toilets must be provided and should always be well serviced and spaced as per occupational health and safety laws, and placed outside the 1:100 year flood lines;
- The proposed septic tanks and evaporation ponds should be lined with a synthetic liner or any other liner that has been approved by the DWS to ensure that no potential leachate pollutes the groundwater;
- Due to the presence of possible intrusive dolerite/ magnetic features, the septic tanks should be serviced at least weekly;
- A leak monitoring device is advised for the septic tanks to ensure that any leakages are detected early enough to mitigate.
- Should it be decided to irrigate fields with the wash water from the chicken houses, the water will need to be tested to ensure that it meets the minimum requirements. If the wash water quality does not comply with the minimum requirements, water should be treated prior to irrigation.
- Water tanks should be regularly checked for structural integrity on site, if present; and,
- Emergency response plan should be in place for failure of water tank structures, if present.

In conclusion, Quantum Foods, Bulhoek Farm, near Swartruggens, North West Province, poses a low risk in terms of groundwater contamination potential and a low risk in surface water contamination potential, but any risks can be decreased by taking the above-mentioned recommendations and mitigation measures mentioned in the report into account.

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14 APPENDIX A – GROUNDWATER QUALITY ANALYSIS

iWATER

KNOWLEDGE TO ENVIRONMENTAL SOLUTIONS

WATER QUALITY REPORT

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1. INTRODUCTION TO IWATER

iWater has recognized the need for directing the **specific analyses** selected, followed by accurate analysis to support clients to achieve compliance in their environmental management strategies. We offer a selection of quality tests for any type of environmental or waste sample. We do not select standard packages but use expert advice to support the client to decide on the most appropriate tests to create a comprehensive understanding of the site compliancy**. iWater operates its own in-house laboratory and development centre, but data is also independently verified with aligned SANAS accredited partners**.

iWater's qualified and expert staff is always available to assist any client to understand chemical and microbial results, while our knowledge, as well as international experts, are geared to remedy any situation. Monitoring is only a tool to support effective resource management, therefore iWater is a leader in supplying innovative sustainable solutions for water and soil remediation. Since each client has a unique blend of contamination each site receives a tailor-made solution, thereby adding specific value with lowered risk and costs, using environmentally friendly options.

2. SAMPLING AND ANALYSIS

The results discussed in this report are from a sampling completed in September 2021 by Rolene Lubbe from Enviroworks. These samples were analysed by an independent SANAS accredited laboratory within 48 hours after sampling.

2.1 Site

Google Earth maps were supplied by Rolene Lubbe (Enviroworks) and indicates the three borehole sampling points, at Bulhoek farm, Schweizer Reineke, North West. The water from the boreholes is transported to a reservoir where it is treated with chemicals before it is available as drinking water and usage in chicken broiler houses.

Figure 1: Google Earth map of the borehole sampling points at Bulhoek farm.

3. RESULTS AND DISCUSSIONS

3.1 Microbial composition

Table 1: Microbial results of provided September 2021 samples in grey shading.

Determinant	Units	SANS 241:2015	Risk	September 2021		
				BH1	BH2	BH3
Heterotrophic / Standard plate count	CFU/ml	< 1000	Operational	**0**	**41**	**288**
Total coliforms	CFU/100 ml	10	Operational	**<1**	**36**	**8**
Faecal coliforms	CFU/100 ml	0		**<1**	**<1**	**<1**
E. coli	CFU/100 ml	0	Acute Health Micro	**<1**	**<1**	**<1**
[1]According to SANS 241 : (2015) Drinking water standards (<1 taken as 0)						

The data are compared to SANS241:2015 standards for drinking water. It is noted that it is only BH2 that fail the criteria for drinking water qualities as set by the SANS 241:2015 guidelines.

3.2 Chemical composition

Table 2: Chemical results of provided September 2021 samples in grey shading.

Determinants	Units	SANS:2015	September 2021		
			BH1	BH2	BH3
Alkalinity	mg $CaCO_3$/L		**110**	**99.8**	**145**
pH	pH units	≥5.0 - ≤9.7	**7.38**	**7.44**	**7.76**
Total Hardness	mg/L	120-180 Hard Water	**102**	**118**	**140**
Electrical conductivity	mS/m	170	**22.9**	**26.1**	**31.0**
Total Dissolved Solids (TDS)	mg/L	<1200	**113**	**145**	**149**

Turbidity	NTU	1-5	**0.40**	**0.47**	**0.30**
Chemical Oxygen Demand (COD)	mgO_2/L	<75	**7.0**	**11.0**	**11.0**
Ammonia as N	mg/L	<1.5	**< 0.45**	**< 0.45**	**< 0.45**
Calcium as Ca	mg/L	<150	**16.2**	**14.6**	**15.9**
Chloride as Cl	mg/L	<300	**2.41**	**3.07**	**1.74**
Fluoride as F	mg/L	<1.5	**<0.09**	**<0.09**	**<0.09**
Magnesium as Mg	mg/L	<70	**15.0**	**19.9**	**24.4**
Nitrate as N	mg/L	<12	**<0.35**	**8.82**	**2.62**
Ortho Phosphate	mg/L	<10	**< 0.03**	**< 0.03**	**< 0.03**
Potassium as K	mg/L	<50	**0.43**	**0.37**	**0.44**
Sodium as Na	mg/L	<200	**5.96**	**5.42**	**4.59**
Sulphate as SO_4	mg/L	<500	**6.64**	**2.29**	**3.24**
Aluminium as Al	mg/L	<0.03	**< 0.01**	**< 0.01**	**< 0.01**
Arsenic as As	mg/L	<0.1	**< 0.01**	**< 0.01**	**< 0.01**
Chromium as Cr	mg/L	<0.5	**< 0.01**	**< 0.01**	**< 0.01**
Cobalt as Co	mg/L	<0.05	**< 0.01**	**< 0.01**	**< 0.01**
Copper as Cu	mg/L	<2.0	**< 0.01**	**< 0.01**	**< 0.01**
Iron as Fe	mg/L	<0.3 - 2.0	**0.08**	**0.06**	**0.31**
Lead as Pb	mg/L	<0.01	**< 0.01**	**< 0.01**	**< 0.01**
Manganese as M	mg/L	<0.1	**< 0.01**	**< 0.01**	**< 0.01**
Molybdenum as Mo	mg/L	< 0.07	**< 0.01**	**< 0.01**	**< 0.01**
Zinc as Zn	mg/L	<5.0	**< 0.01**	**< 0.01**	**< 0.01**

The chemical parameters are of no concern and falls within the upper limits set by the SANS241:2015 for drinking water.

BH3 water can be considered as hard; however, this does not have any direct health effects.

This report only reflects the analysis and safety for the batch water source of the supplied water sample.

15 APPENDIX B – PUMPING TEST INFORMATION

Yield Test Report

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24 October 2021

FINAL YIELD TESTING ANANLYSIS OF THREE BOREHOLES AT BULHOEK FARM, SWARTRUGGENS IN THE NORTHWEST PROVINCE

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DEFENITIONS & ABREVIATIONS

Abbreviation/ Term	Definition
Aquifer	An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (fractured rock, gravel, sand, or silt) from which groundwater can be usefully extracted by use of a borehole.
BH	Borehole
CFU	Colony forming unit is an estimate of viable bacterial or fungal numbers
Confined	A confined aquifer is bordered at the top and sometimes at the bottom by confining beds (layers of impermeable materials such as clay which impede the movement of water into and out of the aquifer).
Draw down	The difference between the rest water level and the water level during an abstraction or recovery period.
Mbgl	Meters below ground level
mamsl	Meters above mean sea level
Recovery	The way in which water replenish in a borehole under natural hydraulic pressure.
Storativity	The aquifer storativity, S, is defined as the change in water volume per unit aquifer area, A (m^2), per unit change in head.
Transmissivity	The rate at which groundwater flows horizontally in an aquifer. Measured in m^2/d
Unconfined	Unconfined aquifers are also called water table aquifers, because their upper boundary is the water table.
Yield test	A scientific test performed on a borehole in order to determine the safe and sustainable yield as well as aquifer parameters.

INTRODUCTION

Tucana Solutions was appointed by *Enviroworks* to perform long term pump and recovery tests on 3 identified boreholes at Bulhoek operations in the Swartruggens area in the Northwest Province.

According to the Groundwater Harvest Potential Map of the Republic of South Africa (DWAF 1996) the average yield of successful boreholes in the Swartruggens Area vary between 0.8 and 1.5l/s.

The area is situated on a minor aquifer system.

GENERAL SCOPE

AQUIFER TESTING

The procedure that is followed in order to determine the aquifer parameters and the long term sustainable yield of the borehole are described below. The different portions of the test involve:

- Calibration test
- Constant discharge test
- Recovery monitoring

CALIBRATION TEST

This type of test involves the determination of the actual rate of inflow into the borehole from the surrounding geological formations. It is achieved by abstracting water at a higher rate than it is replenished. Eventually it is only the water that enters the borehole from the aquifer that is abstracted. If this rate of abstraction is measured, it represents the rate at which the water enters the borehole from the aquifer, i.e., the actual yield of the aquifer.

The normal duration of a calibration test is 60 minutes. After the termination of the calibration test, enough time is allowed for the water level to recover at least 95%.

CONSTANT RATE DISCHARGE TEST

The constant discharge test is used to

- determine an aquifer's hydraulic parameters like transmissivity and storativity (if an observation well exists)

- compile a conceptual model of the aquifer's hydraulic scenario, for example the presence of impermeable or recharge boundaries.

The test involves monitoring the drawdown in the borehole while the abstraction rate is constant over the duration of the test. A description of the various methods used to analyse the data obtained from constant discharge tests can be found in Kruseman and De Ridder (1991). The duration of the constant rate test may be determined by the information and level of reliability required (Weaver, 1993).

The type of test and its duration shall be selected to suit the level of reliability required, which is a function of the water user's dependence on the borehole(s) and of the consequences (usually financial) of borehole failure (SANS 10299-4). Thus, a borehole for the watering of livestock needs a much shorter duration of test than a borehole for the irrigation of apple orchards or one that supplies an entire factory. In general, the test will run for about eight hours for boreholes to be equipped with hand, solar or wind driven pumps, and for forty-eight to seventy-two hours for boreholes to be equipped with electricity or diesel driven pumps, which are to be operated on a daily basis.

RECOVERY TEST

The results gained from the recovery test are used to determine the aquifer parameters and to determine how rapidly the water level recovers and whether the storativity values vary throughout the aquifer (Driscoll, 1986). The recovery test is done after a calibration test, step-drawdown test or a constant discharge test (or both), as required by the project geohydrologist. (SANS 10299-4)

It can also give an indication of the extent of the aquifer, or the extent and connectiveness of fractures. At the end of the pumping test (constant discharge test or step-drawdown test (or both)), switch off the pump and immediately start collecting residual drawdown readings at the relevant time intervals, until,

1. the water level recovers to less than 5 % of the total drawdown during the constant discharge test, or

2. at least three readings taken in succession are identical, or

3. a time equal to the total time taken for the constant discharge test has elapsed.

In order to establish whether the aquifer has been significantly dewatered during the constant discharge test, and in order to accurately apply the recovery test data for estimating sustainable borehole yields, it may be preferable to monitor recovery water levels for at least the same duration as the constant discharge test.

Recovery Test Method (Kirchner, 1991): This method involves calculating the maximum number of hours a borehole should be pumped each day at the tested rate, and it is based on the time it takes for the water level in a pumped borehole to return to the original rest water level (prior to pumping). Borehole water level measurements during the recovery period following a constant discharge pump test are plotted on semi-log graph paper against the time since pumping began (t), divided by the time since pumping was stopped (t').

The following formula is then used to determine the maximum number of hours (h) a borehole should be pumped for each day, at the pumping rate of the preceding test:

$h = 24 - (24/x)$

where: x = the x-axis intercept of the residual drawdown versus recovery plot (t/t') on semilog graph paper after a constant discharge pumping test. Residual drawdown is the water level in a borehole after pumping was terminated.

Extrapolations may also produce a t/t' value which is less than one, which gives a negative yield recommendation using the abovementioned equation. Under these circumstances it does not necessarily mean that the borehole cannot yield anything at all on a sustainable basis. Rather it indicates that partial dewatering of the aquifer took place during the constant discharge test, or that the aquifer is bounded by formations with relatively low permeabilities. While these may be good reasons to be cautious in recommending a long-term abstraction rate, they are not reasons to abandon the borehole altogether. In cases where rapid recovery occurs due to leakage from overlying material or variations in storativity, relatively high t/t' values may be obtained. This results in the calculation of large yield values. Since the extent of storage in these horizons is not taken into account, the sustainability of these yields would be uncertain.

It is also necessary to examine the assumption that recovery time is related to the preceding pumping rate. Does a borehole that was pumped at a low rate, relative to its potential, require just as long to recover than if it was pumped at a higher rate? If a low rate was selected, a low-pressure gradient would be induced in the fractures, which would limit the rate of replenishment from the surrounding matrix. Consequently, similar t/t' intercept values may be obtained irrespective of the preceding pumping rate.

The implication is that a much lower yield value would be calculated relative to that which would have been calculated from a high pumping rate recovery test. The application of this method should possibly be restricted to tests where the pumping rate is close to the borehole's capacity and where the recovery is complete.

LOCATION

The maps below indicate location of the boreholes that was tested.

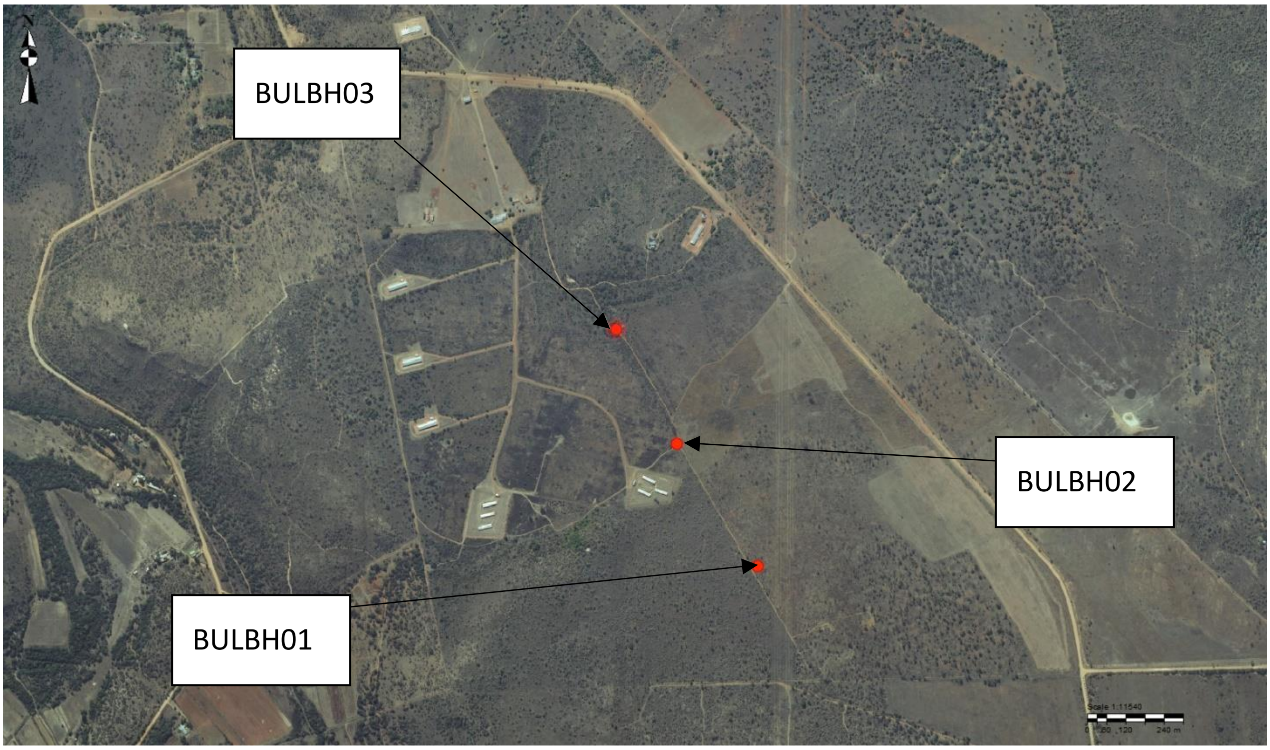


Figure 1: Location of boreholes at the Bulhoek operations

The details of the boreholes that was tested are summarised in the table below;

Name	Lat	Long	Static Water Level(mbgl)	BH Depth (mbgl)	Comments
BULBH01	-25.590748	26.906845	37.2	100+	1.5kW/ SVM70/20 pump @73m
BULBH02	-25.587362	26.914383	26.5	57.8	1.5kW/ SVM55/20 pump @ 43m
BULBH03	-32.309369	24.540708	29.7	55.2	2.2kW pump @ 50m

Table 1: Borehole Details

PUMP TEST ANALYSIS – BULBH01

The following data was recorded:

Start date of test: 12/10/2021

Borehole Depth: 100+m below ground level

Water level: 37.2 m below ground level

Test pump intake: 93 m below ground level

Available draw down (to pump): 55.8 m

Abstraction rate: 1.39 l/s

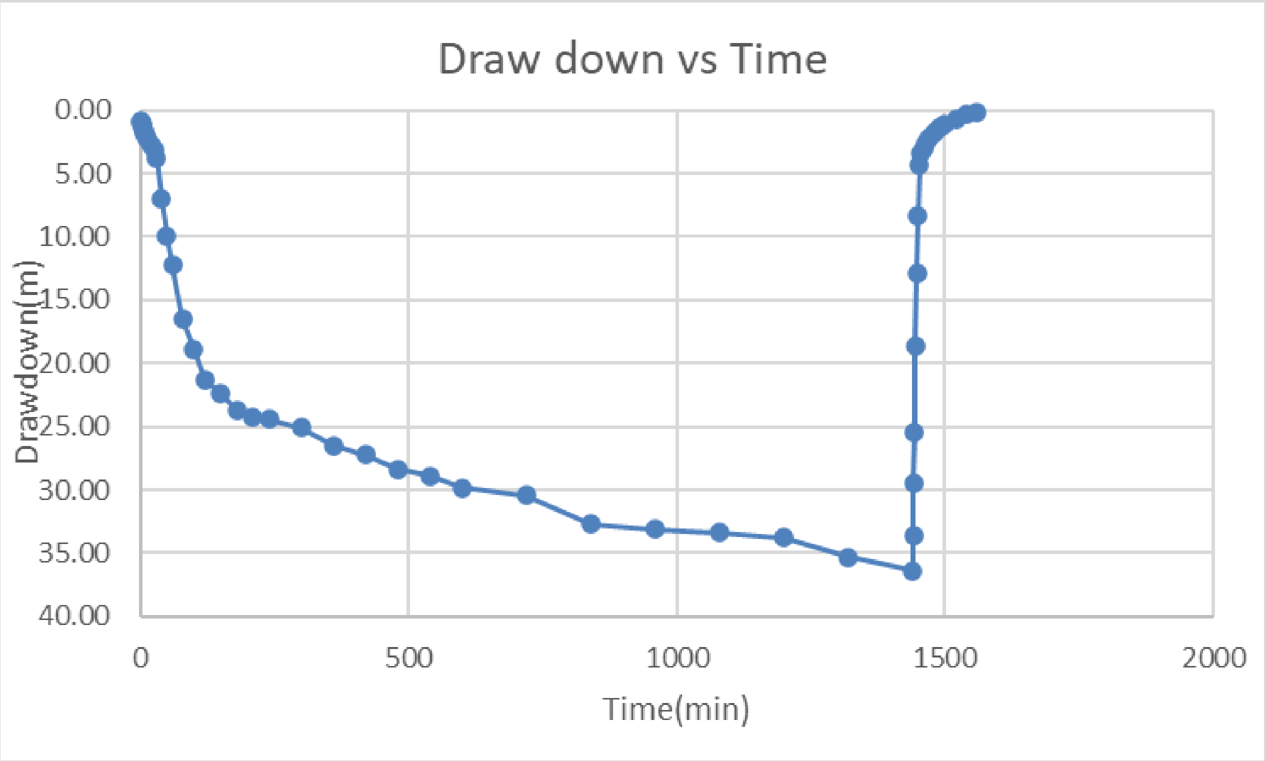


Figure 2: Draw down versus time (Pump & Recovery Data)-BULBH01

CONSTANT RATE PUMP AND RECOVERY TEST CONSTANT RATE TEST

After the calibration test and recovery an average abstraction rate of 1.39 l/s was selected for the long-term test pumping. The final draw down after 24 hours was 36.4 m. The transmissivity as calculated by the Cooper-Jacob method is 8.5 m^2/d.

RECOVERY

During the recovery monitoring the water level recovered to 37.36 mbgl (99 % recovery) within 20 min, which indicate average recovery. According to the recovery data a transmissivity of 8.8 m^2/d could be estimated.

SAFE YIELD ESTIMATION

The safe yield was estimated on the basis of the constant yield test. According to the FC method calculations the sustainable yield for BULBH01 is 0.63 l/s (2 268 l/hr) on a 24-hr pump cycle. A total of 54 432 litres per day is available at the above-mentioned rate and duty cycle.

The recommended depth of the pump intake is 80 meters below ground level and the dynamic water level is 62 mbgl.

WATER QUALITY

No water samples were collected.

PUMP TEST ANALYSIS – BULBH02

The following data was recorded:

Start date of test: 06/10/2021

Borehole Depth: 57.8m below ground level

Water level: 26.5 m below ground level

Test pump intake: 50 m below ground level

Available draw down (to pump): 23.5 m

Abstraction rate: 0.5 l/s

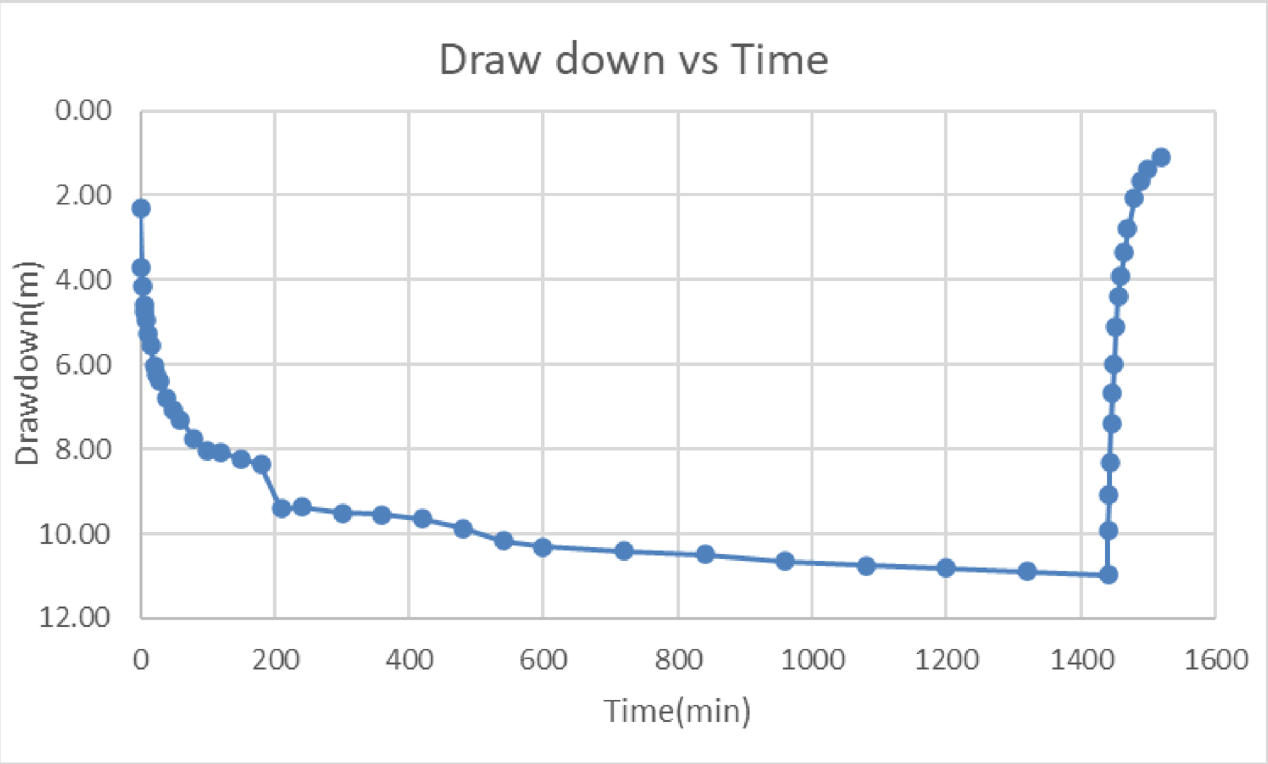


Figure 3: Draw down versus time (Pump & Recovery Data)- BULBH02

CONSTANT RATE PUMP AND RECOVERY TEST CONSTANT RATE TEST

After the calibration test and recovery an average abstraction rate of 0.5 l/s was selected for the long-term test pumping. The final draw down after 24 hours was 10.97 m. The calculated transmissivity is 3 m^2/d.

RECOVERY

During the recovery monitoring the water level recovered to 27.59 mbgl (95 % recovery) within 1.33 hours, which indicate average/good recovery. According to the recovery data a transmissivity of 2.5 m^2/d could be estimated.

SAFE YIELD ESTIMATION

The safe yield was estimated on the basis of the constant yield test. According to the FC method calculations the sustainable yield for BULBH02 is 0.24 l/s (864 l/hr) on an 24-hr pump cycle. A total of 20 736 litres per day is available at the above-mentioned rate and duty cycle.

The recommended depth of the pump intake is 50 meters below ground level and the dynamic water level of 37 mbgl should not be exceeded.

WATER QUALITY

No water sample was requested.

PUMP TEST ANALYSIS – BULBH03

The following data was recorded:

Start date of test: 13/10/2021

Borehole Depth: 55.2m below ground level

Water level: 29.7 m below ground level

Test pump intake: 48 m below ground level

Available draw down (to pump): 18.3 m

Abstraction rate: 2.33 l/s

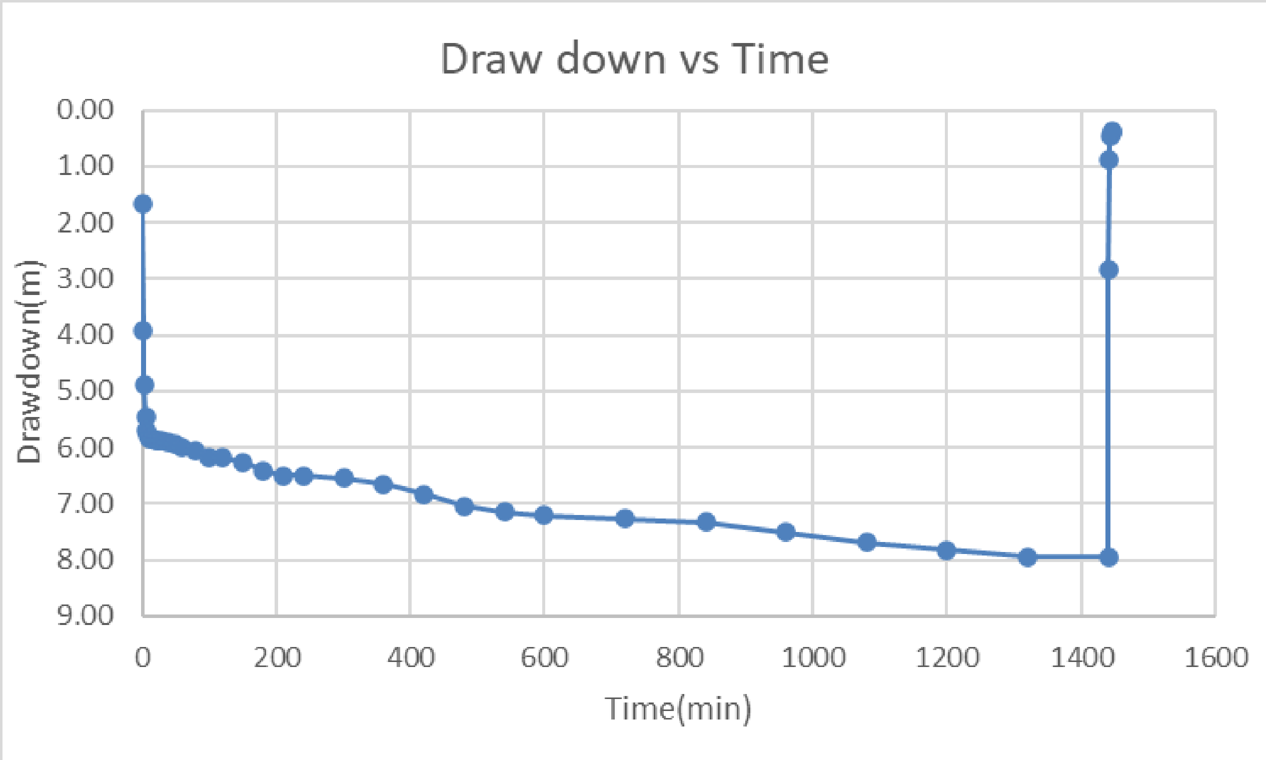


Figure 4: Draw down versus time (Pump & Recovery Data)-BULBH03

CONSTANT RATE PUMP AND RECOVERY TEST CONSTANT RATE TEST

After the calibration test and recovery an average abstraction rate of 2.23 l/s was selected for the long-term test pumping. The final draw down after 24 hours was 7.94 m. The calculated transmissivity is 20.9 m^2/d.

RECOVERY

During the recovery monitoring the water level recovered to 30.09 mbgl (99 % recovery) within 7 min, which indicate rapid recovery. According to the recovery data a transmissivity of 28.1 m^2/d could be estimated.

SAFE YIELD ESTIMATION

The safe yield was estimated on the basis of the constant yield test. According to the FC method calculations the sustainable yield for BULBH03 is 0.85 l/s (3060 l/hr) on an 24hr pump cycle. A total of 73 440 litres per day is available at the above-mentioned rate and duty cycle.

The recommended depth of the pump intake is 50 meters below ground level and the dynamic water level of 37 mbgl should not be exceeded.

WATER QUALITY

No water sample was requested

CONCLUSIONS & RECOMMENDATIONS

It must be noted that the boreholes were tested separately from any other boreholes therefore no calculations or estimation can be made on the effect of simultaneous abstraction from boreholes.

The combined effect of the abstraction of groundwater from the aquifer as well as the seasonal influence of rainfall recharge and other external factors on the aquifer must be monitored in the long term to determine such impacts on these boreholes. The abstraction management must be optimised with these influences in mind. Management and monitoring of the borehole are absolutely crucial in order to develop the resource sustainably.

For water level monitoring purposes, it is recommended that a 32mm HDPE pipe be strapped to the riser main to allow access with a dip meter.

The daily pump cycle, as recommended must not be exceeded and adequate controls must be installed to prevent "dry running" or over stressing of the aquifer.

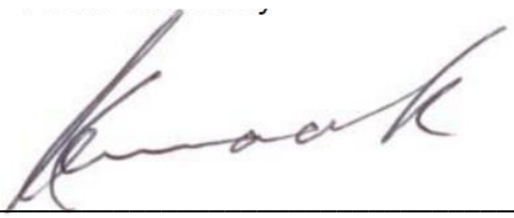
It is recommended that timers as well as water level probes be installed with the correct size pump to yield the recommended rate at the outlet.

The boreholes should be secured from objects or contamination entering at ground level. Based on the results of the analysis of the pump test data and the stated uncertainties the following abstraction rates can be recommended.

Name	Lat	Long	Pump Rate (l/s)	Duty Cycle (hrs pumped/hrs rest)	Available Volume (m^3/d)
BULBH01	-25.590748	26.906845	0.63	24/0	54.43
BULBH02	-25.587362	26.914383	0.24	24/0	20.74
BULBH03	-32.309369	24.540708	0.85	24/0	73.44
Total					148.61

Table 2: Management Recommendations

For proper management, water level monitoring must be implemented and recorded on a monthly basis. An automatic water level logger is recommended for this purpose.



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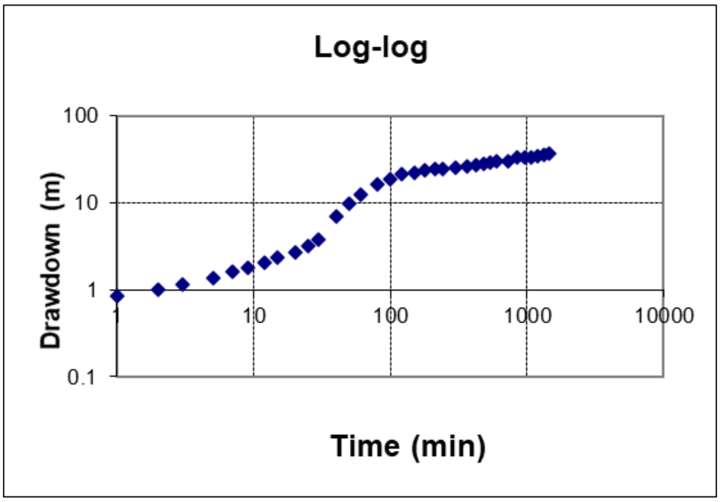
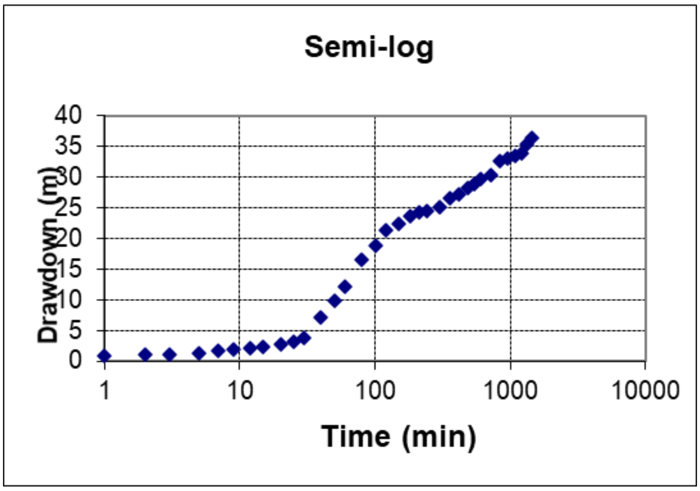
Appendix A

BULBH01

Summary	Main	BULBH1					
Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	Basic FC	0.23	0.16	6	1.2	2.20E-03	25.0
☐	Advanced FC			6	1.2	1.00E-03	25.0
☑	FC inflection point	0.52	0.31				24.8
☑	Cooper-Jacob	0.75	0.49		8.5	7.87E-06	25.0
☐	FC Non-Linear	2.49	2.20		34.0	5.06E-03	25.0
☑	Barker	1.04	1.63	K_f = 100	S_s =	2.11E-04	25.0
	Average Q_sust (l/s)	0.63	0.34	b = 0.20	Fractional dimension n =	2.00	

Recommended abstraction rate (L/s)	0.63	for 24 hours per day





Raw Test Data

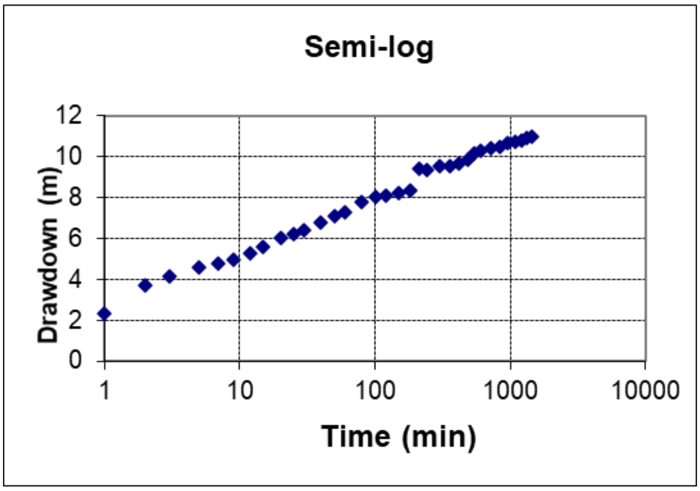
Time(s)	WL(mbgl)
0	37.20
1	38.04
2	38.21
3	38.34
5	38.57
7	38.82
9	39.00
12	39.25
15	39.56
20	39.92
25	40.35
30	40.97
40	44.26
50	47.12
60	49.43
80	53.70

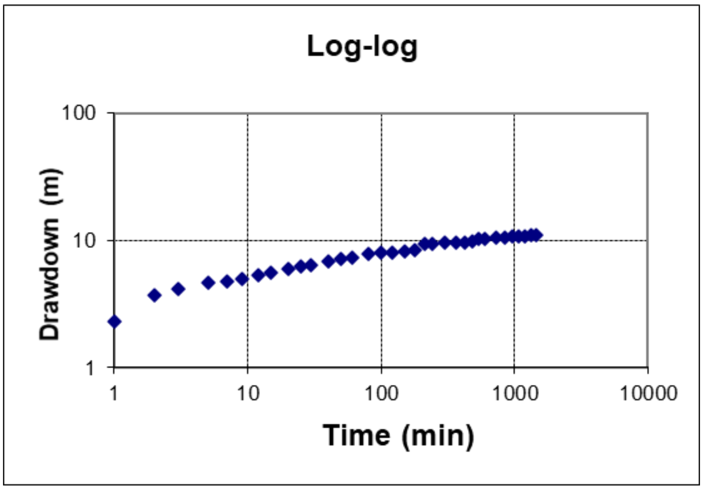
100	56.07
120	58.47
150	59.61
180	60.91
210	61.42
240	61.64
300	62.31
360	63.68
420	64.45
480	65.53
540	66.08
600	67.00
720	67.60
840	69.89
960	70.29
1080	70.56
1200	70.98
1320	72.47
1440	73.60
1441	70.85
1442	66.61
1443	62.59
1445	55.77
1447	50.11
1449	45.55
1452	41.56
1455	40.60
1460	40.16
1465	39.76
1470	39.44
1480	38.95
1490	38.58
1500	38.31
1520	37.88
1540	37.58
1560	37.36

BULBH02

Summary		Main		KBBH02			
Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☐	Basic FC	0.22	0.13	3	1.7	9.90E-04	20.0
☐	Advanced FC			3	1.7	1.00E-03	20.0
☑	FC inflection point	0.21	0.09				9.6
☑	Cooper-Jacob	0.28	0.18		3.0	4.90E-04	20.0
☐	FC Non-Linear						20.0
☑	Barker	0.25	0.16	K_f = 192	S_s =	2.11E-04	20.0
	Average Q_sust (l/s)	0.24	0.04	b = 0.04	Fractal dimension n =	1.91	

Recommended abstraction rate (L/s)	0.24	for 24 hours per day





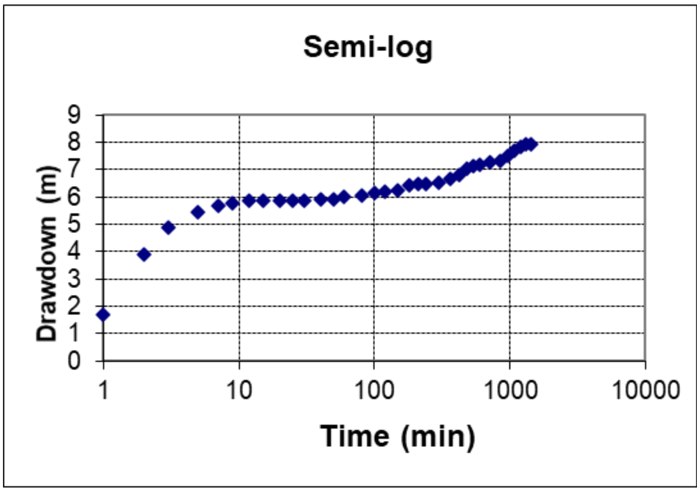
Time(s)	(m above logger)
0	21.51
1	19.20
2	17.81
3	17.37
5	16.91
7	16.77
9	16.55
12	16.25
15	15.95
20	15.49
25	15.29
30	15.12
40	14.71
50	14.43
60	14.20
80	13.75
100	13.46
120	13.43
150	13.28
180	13.15

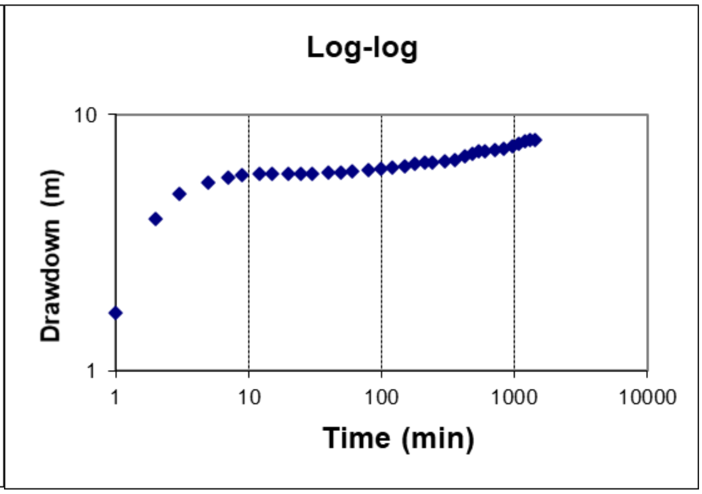
210	12.10
240	12.15
300	12.00
360	11.97
420	11.87
480	11.64
540	11.34
600	11.20
720	11.09
840	11.02
960	10.85
1080	10.76
1200	10.70
1320	10.62
1440	10.54
1441	11.58
1442	12.42
1443	13.19
1445	14.12
1447	14.85
1449	15.52
1452	16.40
1455	17.13
1460	17.61
1465	18.17
1470	18.72
1480	19.43
1490	19.85
1500	20.12
1520	20.42

BULBH03

Summary	Main	BULBH03					
Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	Basic FC	0.68	0.37	72	12.3	1.10E-03	9.0
☐	Advanced FC			72	12.3	1.00E-03	9.0
☑	FC inflection point	1.01	0.39				6.6
☑	Cooper-Jacob	0.83	0.53		20.9	1.16E-03	9.0
☐	FC Non-Linear						9.0
☑	Barker	0.90	0.63	K_f = 198	S_s =	2.12E-04	9.0
	Average Q_sust (l/s)	0.85	0.14	b = 0.09	Fractal dimension n =	2.04	

Recommended abstraction rate (L/s)	0.85	for 24 hours per day





Time(s)	(m above logger)
0	16.30
1	14.62
2	12.39
3	11.41
5	10.85
7	10.61
9	10.52
12	10.45
15	10.44
20	10.42
25	10.43
30	10.41
40	10.39
50	10.37
60	10.29
80	10.24
100	10.13
120	10.12

150	10.04
180	9.89
210	9.80
240	9.80
300	9.76
360	9.65
420	9.47
480	9.26
540	9.15
600	9.10
720	9.04
840	8.97
960	8.79
1080	8.62
1200	8.47
1320	8.36
1440	8.36
1441	13.45
1442	15.41
1443	15.82
1445	15.90
1447	15.91