Geohydrological assessment of the proposed quarries at Farm Klein Rivier 713 Portion 32 and Farm Buffelsbosch 742 Portion 14, Humansdorp

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EXECUTIVE SUMMARY

A mining right application is being submitted for two quarries near Humansdorp at the farm Klein Rivier 713 Portion 32 (Section 2) and the farm Buffelsbosch 742 Portion 14 (Section 1). Site Plan Consulting appointed GEOSS to conduct a geohydrological assessment of the proposed quarries, considering potential impacts on the surrounding boreholes, seeps and springs.

The two proposed quarry sites are located on the Peninsula Formation. In the area the Peninsula Formation has shown little faulting and fracturing and yields are very low (≤ 0.1 ℓ/s). Previous exploration drilling at the site didn't have water strikes down to a depth of 20 m but water has subsequently seeped into the boreholes. The water level within the quartzites of the Peninsula Formation, was found to range between 5.8 and 17 mbgl. The proposed quarry depth is 40 m which would be below the water table. Groundwater flow into the pit is expected to be very low based on the unfractured nature and low yields observed in the Peninsula Formation. Losses as a result of evaporation are therefore not considered to be significant and are not expected to impact the aquifer.

No boreholes have been identified down gradient and nearby the <u>Section 2 Quarry area on Klein Rivier 713 Portion 32</u>. The site is located on the contact zone between the Peninsula Formation and the Cedarberg Formation. This contact may represent a zone of preferential groundwater flow and this should be investigated further during further exploratory drilling.

<u>Section 1 Quarry area on Buffelsbosch 742 Portion 14</u> has abstraction boreholes located down gradient of the site. Gerber_S1 is a seep located nearby as well which flows into a dam used for stock watering. Gerber_BH2 and Gerber_BH1 are abstraction boreholes used for domestic supply and stock watering. It is not expected that the quarry will impact the abstraction at these sites based on the low transmissivity and storativity in the Peninsula Formation.

Groundwater quality in the Peninsula Formation in the area is of a very good quality and near to the proposed quarry section 1 boreholes are used for domestic supply. With the proposed quarry sites and associated activities related to the mining, stock piling and the processing plant facilities it will very important to ensure that no contamination takes place. Special attention must be give to hydrocarbon management and the prevention and containment of spillages from vehicles, machinery and storage facilities.

From the assessment of the hydrogeological setting of the proposed quarries it is concluded that the quarries are not expected to impact the borehole yields nearby. Evaporation losses are also not expected to be significant or to impact the water table in the surrounding area. Groundwater is currently of a very good quality, and it is important that no on site activities impact this.

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TABLE OF CONTENTS

LIST OF FIGURES AND MAPS

LIST OF TABLES

ABBREVIATIONS

BID	Background Information Document
EC	Electrical Conductivity
ℓ/s	litres per second
m	metres
mamsl	metres above mean sea level
mbch	metres below collar height
mg/l	milligrams per litre
mS/m	milliSiemens per meter
TDS	Total Dissolved Solids
TMG	Table Mountain Group
WGS84	Since the 1st January 1999, the official co-ordinate system for South Africa is based on the World Geodetic System 1984 ellipsoid, commonly known as WGS84, with the ITRF91 (epoch 1994.0) co-ordinates of the Hartebeesthoek Radio Astronomy Telescope used as the origin of this system. This new system is known as the Hartebeesthoek94 Datum.

GLOSSARY OF TERMS

Alkalinity: a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate.

Aquifer: a geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].

Borehole: includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from National Water Act (Act No. 36 of 1998)].

Confined aquifer: Groundwater below a layer of solid rock or clay is said to be in a confined aquifer. The rock or clay is called a confining layer. A borehole that goes through a confining layer is known as an artesian well. The groundwater in confined aquifers is usually under pressure. This pressure causes water in an artesian well to rise above the aquifer level. If the pressure causes the water to rise above ground level, the well overflows and is called a flowing artesian well.

Groundwater: water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.

Hydraulic conductivity: measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (in m/d)

Transmissivity: the rate at which a volume of water is transmitted through a unit width of aquifer under a unit hydraulic head (m^2/d); product of the thickness and average hydraulic conductivity of an aquifer.

Unconfined aquifer: these are sometimes also called water table or phreatic aquifers, because their upper boundary is the water table or phreatic surface. Typically (but not always) the shallowest aquifer at a given location is unconfined, meaning it does not have a confining layer between it and the surface. Unconfined aquifers usually receive recharge water directly from the surface, from precipitation or from a body of surface water (e.g., a river, stream, or lake) which is in hydraulic connection with it.

Water Table: the upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.

Cover Photo: The cover picture is taken from borehole Gerber_BH1 looking north east towards the seep Gerber_S1. This is about 400 m to the north east of the section 1 quarry site (Map 3, Appendix A). Gerber_S1 is a spring that seeps into the dam in the foreground of the picture. The eye of the spring is to the right of the picture where the trees are.

1. INTRODUCTION

A mining right application is being submitted for two quarries near Humansdorp (Map 1, Appendix A) at the farm Klein Rivier 713 Portion 32 (Section 2) and the farm Buffelsbosch 742 Portion 14 (Section 1) (Map 2, Appendix A). The material to be recovered is for building aggregate and armour stone§. Site Plan Consulting appointed GEOSS - Geohydrological and Spatial Solutions International (Pty) Ltd to conduct a geohydrological assessment of the proposed quarries, considering potential impacts on the surrounding boreholes, seeps and springs.

The sites are located in quaternary basin K90E which allows for 150m³ groundwater to be withdrawn per hectare per year (over the entire farm). Previous drilling at the sites for prospecting to depths of 20 m encountered no groundwater at the sites, but these boreholes have subsequently filled up with groundwater. The quarry depths will be to an average depth of 40 m in terms of this plan.

The Background Information Document (Site Plan Consulting, 2011) identified that potential impacts could arise from:

1. Exposure of groundwater to atmosphere through mining below the groundwater table may lead to excess evaporation of the groundwater.
2. Possible (but highly unlikely) pollution of groundwater through poor hydrocarbon management.

As part of the attenuation measures before mining a hydrocensus in the area was prescribed to measure ambient levels and yields.

2. SCOPE OF WORK

GEOSS submitted a proposal to complete the assessment and hydrocensus. The work involves a number of steps, namely:

Task 1: Obtain all relevant data to the project (i.e. obtain data from the National Groundwater Archive, Water Quality Management System and Water Information Management System), geological maps, geohydrological maps and any relevant consulting reports.

Task 2: Complete a site visit and complete a hydrocensus (i.e. visit all boreholes within 1 km of the quarries and measure yields and water quality (pH, EC, TDS and ORP). It is important to assess the importance of groundwater from a ecological and socio-economic perspectives.

Task 3: Analyze the data, using geohydrological methods.

Task 4: The findings will then be documented in a comprehensive report.

§ Large pieces of rock between 1 ton and 15 ton for sea or river defence. Commonly used at harbours etc.

3. SITE SETTING

The proposed quarry sites are presented in Map 2 (Appendix A), located on Buffelsbosch 742 portion 14 and Klein Rivier 713 portion 32. The area is characterised by an average annual rainfall of 673 mm, and a moderate climate with the average daily temperature ranging between 15 and 20 °C as presented in Figure 1. Rainfall is all year round but falls predominantly during winter.

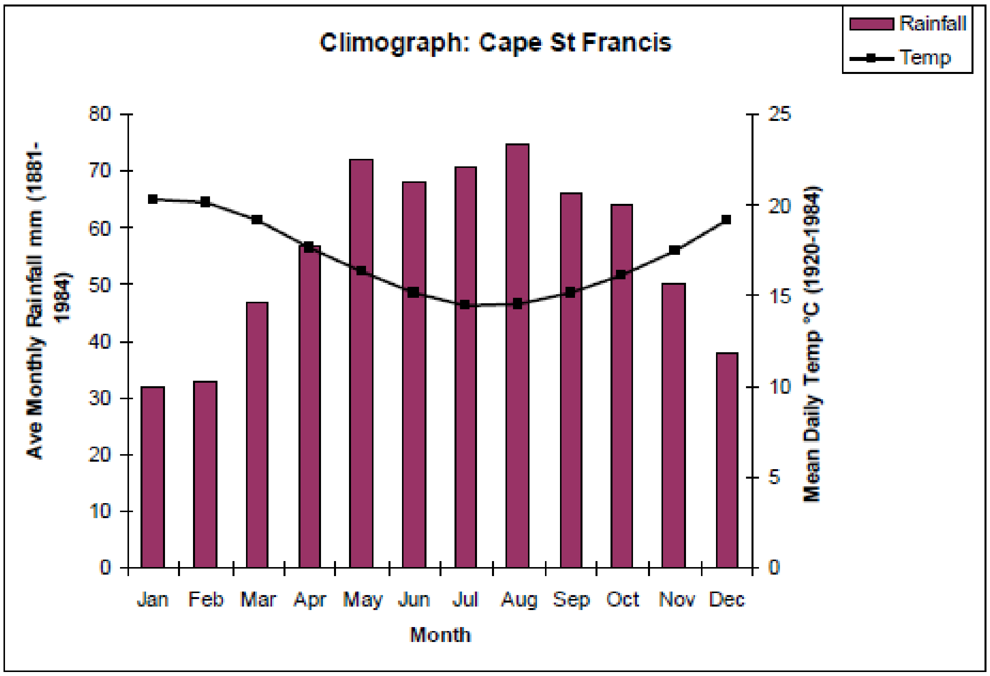

Figure 1. Long term average monthly rainfall and daily temperature (Background information document, 2011).

3.1 Geology

A geology map of the area is presented in Map 4 (Appendix A), taken from the 1:250 000 geology map Cape Town 3318. Both the proposed quarry sites are situated on the Peninsula Formation (Op) which is to be mined. Just to the north east of the quarry sites are younger formations of the Table Mountain Group, namely the Cedarberg (Oc) and Goudini Formations (Sg).

The Peninsula Formation is thick and consists of largely thick bedded, coarse-grained quartzitic sandstone (Theron et al, 1992). The sandstones hard and resistant and outcrop in the study area, and specifically the quarry areas. The Peninsula Formation is overlain by the Cedarberg Formation, composed of shale, siltstone and silty sandstone.

The Cedarberg Formation is relatively thin but is very extensive and consistent. The Cedarberg formation does not outcrop in the area due to its softer more argillaceous nature.

The Goudini Formation is the oldest member of the Nardouw Subgroup, and consists of quartzose sandstone which is reddish brown when weathered. The Goudini Formation is thick and overlies the Cedarberg Formation to the north east of the quarry sites. No outcrop of the Goudini Formation is evident in the field.

The thickness of the formations in the study area are presented in Table 1. Based on the mapped geological outcrop, dip and dip direction the thickness of the formations were calculated. The Peninsula Formation thickness was taken from Meyer (1998). All measured thickness' are within acceptable limits with the exception of the Goudini formation which is thicker than it's reported thickness (Meyer, 1998). This may be simply due to a greater formation thickness near the coast than previously reported, or be a result of parasitic folding in the study area.

Table 1. Table Mountain Group formations in the study area and their thickness'.

Formation	General Lithology	Thickness (m)
Baviaanskloof Formation (Nardouw Subgroup)	Feldspathic sandstone with some shale	170
Skurweberg Formation (Nardouw Subgroup)	Feldspathic quartzose sandstone	300
Goudini Formation (Nardouw Subgroup)	Quartzose sandstone	860
Cedarberg Formation	Shale and siltstone	50
Peninsula Formation	Quartzitic sandstone	1500 (Meyer, 1998)

Structurally the area is folded with south east and northwest trending folds. One kilometre south west of Quarry section 1 is the fold axis of a regional south east plunging antiform in which the Peninsula Formation is preserved along the hinge zone. The quarry zones are towards the hinge zones of the fold, and the Peninsula, Cedarberg and Goudini Formations dip towards the north east in the study area. The dip is about 40 degrees at the quarry sites, and increases to about 50 degrees at the Goudini Skurweberg contact. No significant faulting is evident in the area, although folding related fractures are expected. The compressional tectonics related to the inner part of the hinge zone may mean that there is little fracturing in the Peninsula Formation.

3.2 Geohydrology

The Peninsula Formation is generally regarded as a significant aquifer. The very high quartz content in the sandstone renders it very brittle and far more prone to fracturing than ductile deformation. It is largely anisotropic, and groundwater flow and recharge is controlled by networks of fissures, joints, and fractures. Lithologically controlled springs are common in the TMG when impeding shale layers (such as the Cedarberg Formation) force groundwater to the surface.

Groundwater quality in the TMG is excellent, with Electrical Conductivities ranging between 5 and 70 mS/m (Meyer, 2001). The groundwater generally has a dominant Na Cl nature.

4. FIELD PROCEDURE

A field visit was conducted on 24 and 25 May 2012. This included familiarisation with the area, conducting a hydrocensus within 1 km of the two proposed sites, sampling and measuring field chemistry of the wetlands and boreholes, visiting the proposed quarry sites and characterising the geohydrology of the area.

Numerous boreholes were visited and information obtained from land owners, the sites visited are presented in Map 3 (Appendix A). Where possible a water level was measured and field chemistry analysed. Table 2 presents the results and information obtained. While access to the farm Penny Sands was not permitted by the owner Roy Seeney information about a dry borehole drilled on his property was obtained from a neighbouring landowner – the borehole coordinates are therefore only an approximate.

Table 2. Hydrocensus borehole locations and details.

Site	Type	Date	time	lat (WGS84)	long (WGS84)	elevation (mamsl)	WL (mbgl)	Pump/ rest	BH depth (mbgl)	BH yield (l/s)
Crouse_BH1	Borehole	24-May-12	15:15	-34.14983	24.72295	138	27.74	rest	110	~ 0.1
Gerber_BH1	Borehole	24-May-12	12:30	-34.15253	24.74361	103	24.2	pump	100	0.11
Gerber_BH2	Borehole	24-May-12	13:15	-34.15113	24.74429	99	2.875	rest	65	3.33
Gerber_S1	Spring	24-May-12	12:50	-34.15263	24.7449	95	0	rest	-	-
Gerber_S2	Spring	24-May-12	14:20	-34.13208	24.7176	87	0	rest	-	-
Knott_BH1	Borehole	24-May-12	13:45	-34.14510	24.74253	86	5.45	rest	50	11.11
Knott_BH2	Borehole	24-May-12	13:55	-34.14516	24.74249	84	5.631	rest	~ 100	<1
PennySands	Borehole	25-May-12		-34.14275	24.72269	123			100	0.1
Quarry1_P	Exploration Borehole	25-May-12	12:50	-34.14191	24.7279	108	6.67	rest	23.47	<0.1
Quarry1_V	Exploration Borehole	25-May-12	12:38	-34.14408	24.72815	123	16.885	rest	17	<0.1
Quarry1_W	Exploration Borehole	25-May-12	12:40	-34.14351	24.72805	120	-		5	Ex
Quarry2_C	Exploration Borehole	25-May-12	13:47	-34.15490	24.73879	117	8.93	rest	9	<0.1
Quarry2_F	Exploration Borehole	25-May-12	13:55	-34.15469	24.73786	116	9.6	rest	19.57	<0.1
Quarry2_H	Exploration Borehole	25-May-12	14:05	-34.15505	24.73713	118			7.58	<0.1
Quarry2_I	Exploration Borehole	25-May-12	14:12	-34.15537	24.73736	117	8.425	rest	21	<0.1
Quarry2_J	Exploration Borehole	25-May-12	14:25	-34.15597	24.73777	117	5.87	rest	17	<0.1
Quarry2_K	Exploration Borehole	25-May-12	14:40	-34.15554	24.73816	119	7.664	rest	20	<0.1
Wilkie_S1	Spring	25-May-12	10:45	-34.12857	24.72561	71	0	rest	-	-
Wilkie_S2	Spring	25-May-12	10:48	-34.12925	24.72576	73	0	rest	-	-
Wilkie_S3	Spring	25-May-12	10:51	-34.12948	24.72665	69	0	rest	-	-
Wilkie_S4	Spring	25-May-12	10:54	-34.12958	24.72766	69	0	rest	-	-
Wilkie_S5	Spring	25-May-12	11:00	-34.12951	24.72796	70	0	rest	-	-
Wilkie_S6	Spring	25-May-12	11:04	-34.13025	24.72625	74	0	rest	-	-
Wilkie_S7	Spring	25-May-12	11:28	-34.13078	24.73055	68	0	rest	-	-
Wilkie_S8	Spring	25-May-12	11:38	-34.13200	24.7278	73	0	rest	-	-

Water samples were collected at 6 of the boreholes, namely Gerber_BH1, Gerber_BH2, Gerber_S2, Crouse_BH1, Quarry1_P and Quarry2_K. These sites are all located in or on the contact with the Peninsula Formation, the formation on which the proposed quarries are located. The water samples were submitted to Bemlab, Somerset West, for chemical analysis. The chemistry results are included in Appendix C.

Where possible field chemistry measurements were also taken. These are presented in Table 3 along with the water use and underlying lithology.

Table 3. On-site field chemistry measurements.

Site	pH	RP (mV)	T (°C)	EC (mS/m)	TDS (mg/l)	Borehole Use	Lithology
Crouse_BH1	5.67	16	19.4	44.2	212	domestic and stock watering	sandstone
Gerber_BH1	6.19	-10	16.9	51.3	247	Stock watering	Sandstone
Gerber_BH2	5.84	8	19.4	38.2	182.6	Irrigaiton	high Fe content
Gerber_S1	-	-	-	-	-	seeps into stock watering dam	below Sandstone outcrop
Gerber_S2	5.6	20	18.8	30	143	spring	quartzitic sands
Knott_BH1						irrigation	Sand
Knott_BH2	7.8	-94	19.2	67	325	abandoned	bedrock
PennySands						essentially dry	sandstone
Quarry1_P	5.3	35	19.6	15.55	73.3	Exploration BH	sandstone
Quarry1_V						Exploration BH	sandstone
Quarry1_W						Exploration BH	sandstone
Quarry2_C						Exploration BH	sandstone
Quarry2_F						Exploration BH	sandstone
Quarry2_H						Exploration BH	sandstone
Quarry2_I	6.18	-10	19.6	31.2	148.3	Exploration BH	sandstone
Quarry2_J						Exploration BH	sandstone
Quarry2_K	5.68	16	19.7	11	51.8	Exploration BH	sandstone
Wilkie_S1						Stock watering	sands below peat
Wilkie_S2						Stock watering	sands below peat
Wilkie_S3						Stock watering	sands below peat
Wilkie_S4						Stock watering	sands below peat
Wilkie_S5						Stock watering	sands below peat
Wilkie_S6						Stock watering	sands below peat
Wilkie_S7						Stock watering	sands below peat
Wilkie_S8	6.2	-11	15.2	72	350	Stock watering	sands below peat

The proposed quarries are located on elevated portions of the Peninsula Formation, and exploration drilling to 20 m at these sites did not intercept any significant water strikes. Water level measurements at these sites show the groundwater level to range between 17 and 5.87 mbgl. Boreholes drilled into the Peninsula Formation at the quarry sites and nearby are low yielding (≤ 0.1 ℓ/s) and the water in the exploration holes would have slowly seeped in following their drilling. Some of the boreholes were open at the top making them open to surface water inflow from rainfall, but all the exploration boreholes where field chemistry and samples were taken were covered. These therefore are considered to be representative of groundwater.

The general topography dips away from the quarry sites in a north easterly direction, and to the north east of the two quarry sites there is no Peninsula Formation outcrop as the unit dip at 40 degrees in a north easterly direction. A quartzitic sand predominates down gradient of the site overlying the Cedarberg and Goudini Formations of the Table Mountain Group. Groundwater within these sands is very prominent, supporting high yielding boreholes and numerous springs. Knott_BH1 is very high yielding (11 ℓ/s) drilled using mud rotary into the sands to a reported depth of about 50 m. A borehole in the same location drilled into the underlying bedrock (Goudini Formation) with the sands cased off is essentially dry. A 0.6 m thick, clay rich and loamy "peat" layer overlies the quartzitic sands. In places this peat layer has been forced up and water seeps out. The sand beneath the peat is quartzitic sand and acts almost like sinking sand. The farmers in the area have dug out the peat to open a few these springs for stock watering and apparently cattle have been lost in these sands.

5. RESULTS AND ANALYSES

5.1 Geohydrology of the sites

Based on the hydrogeological setting a geological cross-section was drawn through the area between the two quarry areas – perpendicular to the strike of the geological formations. The cross-section is representative of geological setting of both quarries, and the orientation of the cross-section is shown on the geological map (Map 4, Appendix A) extending from the south-west to the north-east. The geological cross section is shown in Figure 2.

The cross-section has a vertical exaggeration of 2, and the actual dips have been adjusted accordingly. Nearby boreholes and springs have been moved perpendicular to the cross-section line and superimposed on the cross-section. As the boreholes and springs are moved parallel to the strike of the formations the geological setting is considered relevant for the respective sites. Borehole yields are also indicated, along with an inferred water level where site measurements were obtained.

The two proposed quarry sites are located on the Peninsula Formation. In the area the Peninsula Formation has shown little faulting and fracturing and yields are very low ($\leq$ 0.1 ℓ/s). Measured yields at the Hydrocensus sites are presented in Map 8 (Appendix A) and the cross-section (Figure 2). All the exploration boreholes drilled didn't have water strikes (Site Plan Consulting, 2011). The water level within the quartzites of the Peninsula Formation, was found to range between 5.8 and 17 mbgl. The groundwater levels are presented in Map 9 (Appendix A). The exploration boreholes were dry when drilled (Site Plan Consulting, 2011) which once again suggests that groundwater flow is low.

The proposed quarry depth is 40 m, which would be below the water table. Groundwater flow into the pit is expected to be very low based on the unfractured nature and low yields observed in the Peninsula Formation.

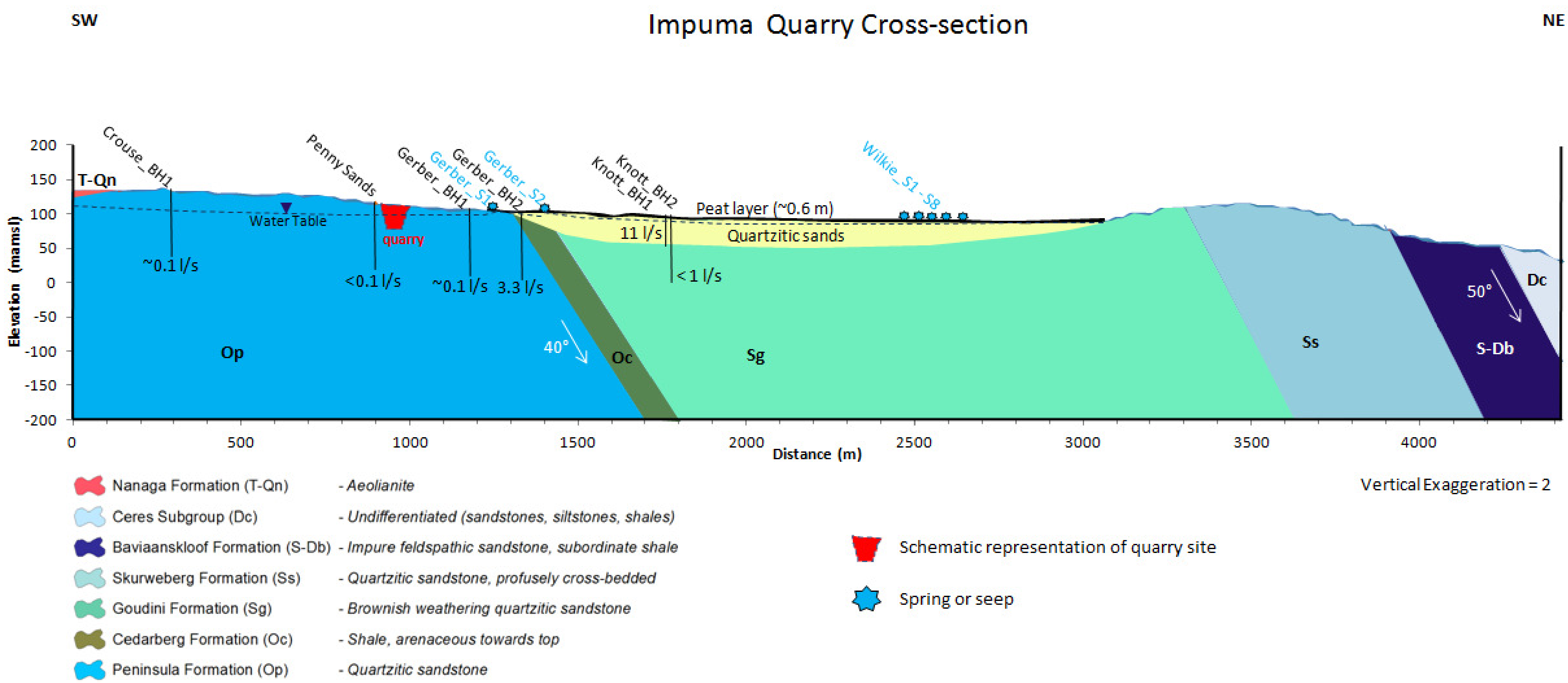

Figure 2. South-west/north-east geological cross-section

5.2 Groundwater chemistry

From the hydrochemical perspective, the six samples submitted for chemistry analysis were taken from flowing springs or from covered boreholes. They are therefore considered to be representative of groundwater. The analysis results are included in Appendix C.

Figure 3 shows the chemical signature of the water samples, plotted on a trilinear Piper diagram. The water shows a dominant Na cation and Cl anion, as would be expected for the area and for relatively pure quartzitic sandstone. Calcium and alkalinity concentration are elevated slightly for Quarry2_K, Gerber_BH1 and Gerber_BH2.

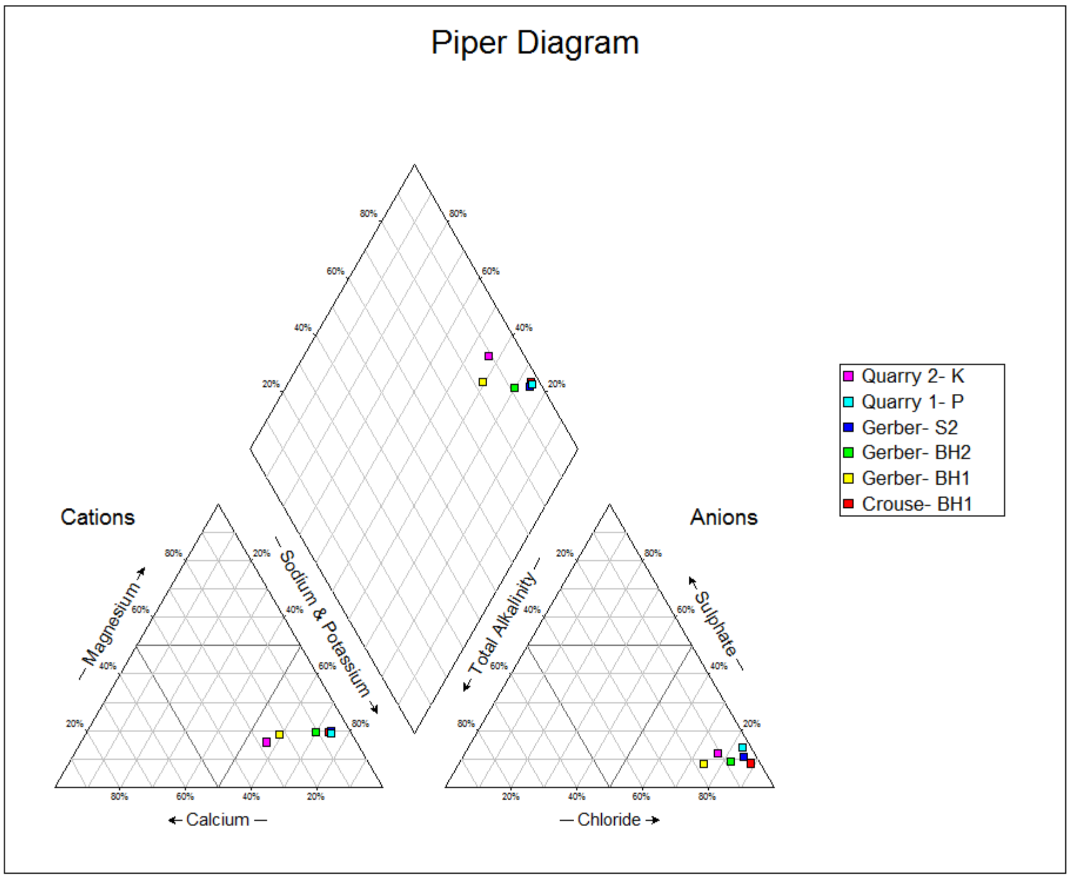

Figure 3. Water chemical signature (Piper diagram) for the sites samples

The Trilinear Piper diagram shown in Figure 3 shows the similar nature of the groundwater at the sites sampled. Comparison between the sites is best done using STIFF diagrams to compare the respective plots. Figure 4 shows the sites sampled, and also shows the similar bell shaped signature for all the sites. The sites where abstraction (Crouse_BH1, Gerber_BH1 and Gerber_BH2) and flow (in the case of Gerber_S2) is taking place have slightly elevated concentrations in comparison to the two quarry exploration boreholes that were sampled.

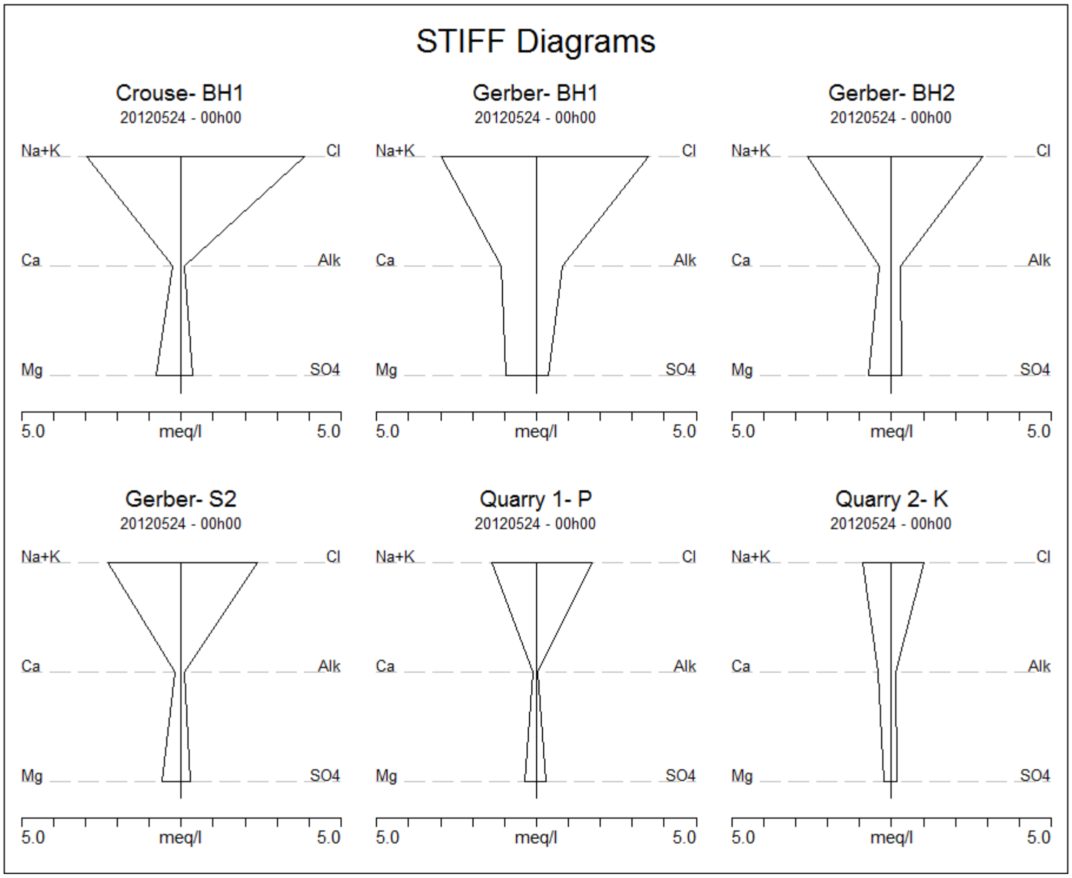

Figure 4. Water chemical signatures (Stiff diagram) of the boreholes and spring that were sampled.

The water EC and pH measurements also indicate that the water quality is of an excellent quality. The measured groundwater EC is plotted in Map 7 (Appendix A). The chemistry results are presented in Table 4 where major ion concentrations are colour coded according to the Department of Water Affairs (DWA) domestic water quality guidelines, as presented in Table 5. It is evident that the water quality is ideal for all the boreholes for the parameters consider with the exception of Fe at Gerber_BH2 and Cl at the three abstraction boreholes Gerber_BH1, Gerber_BH2 and Crouse_BH1. The Cl concentration is still good and suitable for use, but the Fe concentration at Gerber_BH2 is marginal to poor and can have affects on sensitive groups (young children and those sensitive to Fe). This borehole is drilled through the confining Cedarberg Formation into the Peninsula Formation, and the high iron is most likely related to the shales and argillaceous units of the Cedarberg Formation.

Table 4. Water quality results colour coded according to the DWA water quality guidelines for domestic supply (DWA, 1998).

Sample Marked :	Gerber- BH1	Gerber- BH2	Gerber- S2	Crouse- BH1	Quarry 1- P	Quarry 2- K
pH	6.5	6.2	6.1	6.1	5.5	6.1
Conductivity (mS/m)	62.1	48.3	40.5	54.6	26.1	19.18
Total Hardness (as $CaCO_3$)	102.288	56.254	39.415	51.458	23.478	34.064
Calcium (as Ca)	22.17	7.84	3.63	5.2	2.29	8.64
Magnesium (as Mg)	11.43	8.94	7.4	9.38	4.33	3.04
Sodium (as Na)	68.25	59.96	52.35	67.33	31.33	19.51
Potassium (as K)	1.15	1.26	1.33	1.61	1.95	1.72
Chloride (as Cl)	123.61	101.54	83.88	136.86	61.81	35.32
Sulphate (as SO4)	18.03	15.34	14	17.57	14.26	7.31
Total Dissolved Solids	316	246	206	277	131.9	97.1
Iron (as Fe)	0.008	3.931	0.051	0.054	0.109	0.459
Bicarbonate (HCO3)	84.21	38.28	30.62	38.28	30.62	29.09
Alkalinity	40.16	14.56	5.02	5.52	2.51	7.03

Table 5. Classification table taken from DWA (1998).

Blue	**(Class 0)**	**Ideal water quality** - suitable for lifetime use.
Green	**(Class I)**	**Good water quality** - suitable for use, rare instances of negative effects.
Yellow	**(Class II)**	**Marginal water quality** - conditionally acceptable. Negative effects may occur.
Red	**(Class III)**	**Poor water quality** - unsuitable for use without treatment. Chronic effects may occur.
Purple	**(ClassIV)**	**Dangerous water quality** - totally unsuitable for use. Acute effects may occur.

5.3 Evaporation

The low yielding nature of the formation means that it is unlikely that evaporation from the quarry would deplete the aquifer. Estimations of open water evaporation are typically modelled from measured A-pan evaporation or estimated using simple energy balance methods, such as the Penman equation, in which evaporation is estimated from meteorological and water temperature measurements. In energy balance methods, the meteorological parameters which are used to calculate evaporation will differ between the quarry site and at a weather station (due to altered landscape); and prior to the quarry being excavated the surface temperature of the water remains unknown. Accurate estimates of evaporation will therefore only be possible after the quarry is excavated and water temperatures and precise meteorological conditions are measured. An accurate prediction of evaporation from groundwater using the Penman method is therefore problematic at this stage.

A-pan evaporation exceeds open water evaporation due to the small size of the pan and therefore a higher water temperature in the pan than in an open water scenario. The A-pan estimate of evaporation will need to be reduced by an unknown factor to determine actual evaporation from the quarry. According to Schulze (1997), the mean annual A-pan for the site is 1655 mm, approximately twice the mean annual precipitation for the same site. However due to the shading of the surface water in the quarry, reduced windspeed due to quarry walls and lower water temperature, it is anticipated that actual evaporation will be significantly lower than this figure, potentially equivalent to rainfall.

6. DISCUSSION

Based on the groundwater characterisation it is possible to assess the potential impacts that the quarry sites may have. Both sites have been located on the Peninsula Formation which in the area does not constitute a significant aquifer. Abstraction from this formation is taking place but only at very low rates (0.1 ℓ/s).

It is expected that there will be seepage of groundwater into the quarry sites but based on observed borehole yields it is not expected to flow in significantly. Losses as a result of evaporation are therefore not considered to be significant and shouldn't impact the aquifer.

No boreholes have been identified down gradient and nearby the Section 2 Quarry area on Klein Rivier 713 Portion 32. The site is located on the contact zone between the Peninsula Formation and the Cedarberg Formation. This contact may represent a zone of preferential groundwater flow and this should be investigated further during further exploratory drilling.

Section 1 Quarry area on Buffelsbosch 742 Portion 14 has abstraction boreholes located down gradient of the site. Gerber_BH2 and Gerber_BH1 are abstraction boreholes used for domestic supply and stock watering. Gerber_BH1 is located some 450 m from the proposed quarry floor, and approximately only 250 m from the plant stockpiling area and plant and facility area. This borehole is drilled into the Peninsula Formation and shows the same characteristic chemistry and yield. Gerber_S1 is a seep located nearby as well which flows into a dam used for stock watering. Peninsula Formation outcrop at this site suggests this may be on the contact between the Peninsula Formation and the Cedarberg Formation. The closest borehole to the quarry is some 420 m to the north east, Gerber_BH1. It is not expected that the quarry will impact the abstraction at this site based on the low transmissivity and storativity.

Groundwater quality in the Peninsula Formation in the area is of a very good quality and near to the proposed quarry boreholes are used for domestic supply. It is therefore essential that the groundwater quality must not be compromised in any way. With the proposed quarry sites and associated activities related to the mining, stock piling and the processing plant facilities it will very important to ensure that no contamination takes place. Special attention must be give to hydrocarbon management and the prevention and containment of spillages from vehicles, machinery and storage facilities.

7. CONCLUSION

From the assessment of the hydrogeological setting of the proposed quarries it is concluded that the quarries are not expected to impact the borehole yields nearby. Evaporation losses are also not expected to be significant or to impact the water table in the surrounding area. Groundwater is currently of a very good quality, and it is important that no on site activities impact this. It will be essential that preventative measures are put in place to prevent contamination, and in particular hydrocarbon contamination.

8. ACKNOWLEDGEMENTS

The following people are gratefully thanked for their input and support into this project:

- Craig Donald of Site Plan Consulting for providing site information, contact details for neighbouring farmers and the exploration drill sites.
- The land owner Rudolf Gerber for providing site orientation and information.
- Neighbouring farmers who granted access to their farms and provided information on the groundwater.

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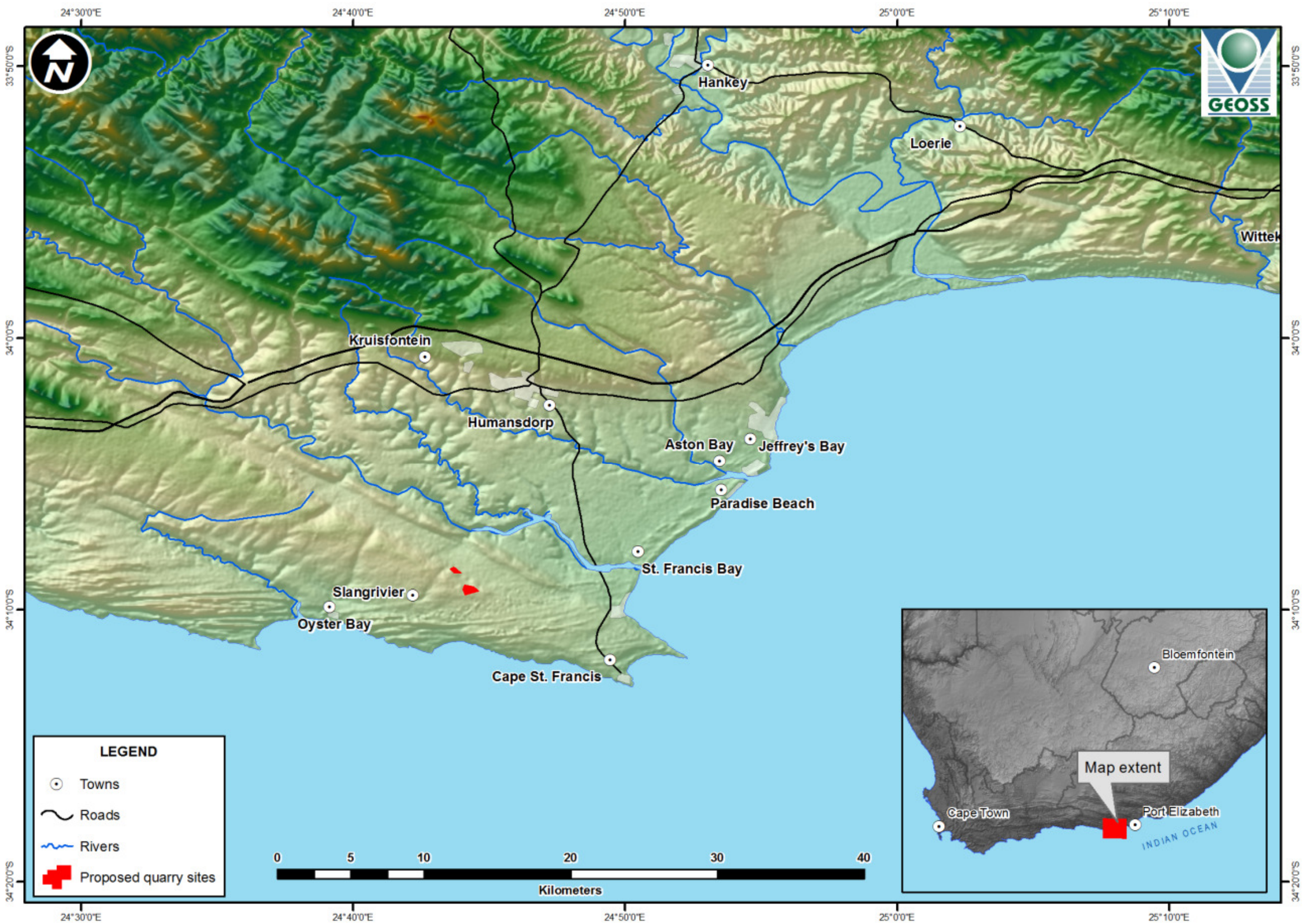
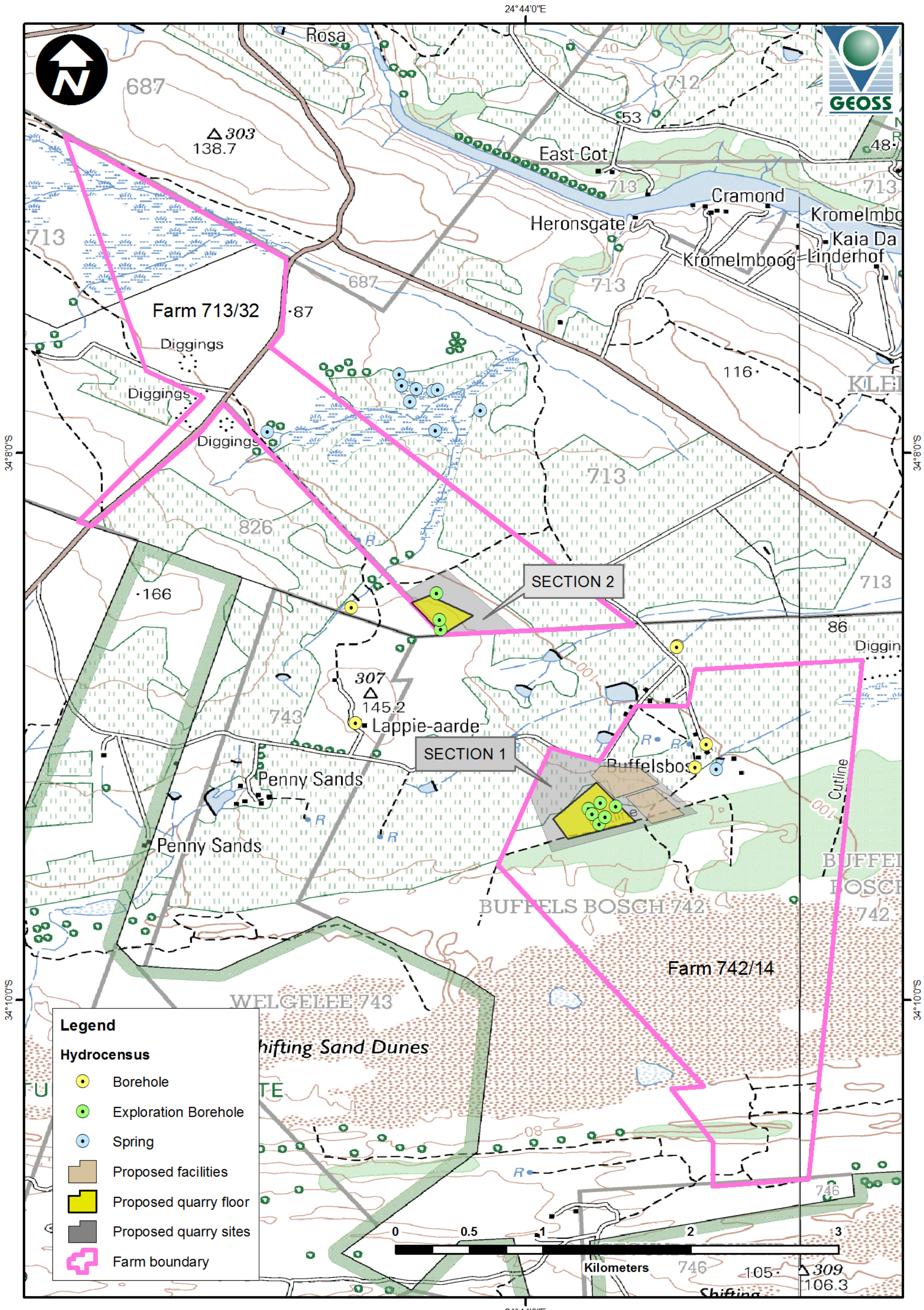
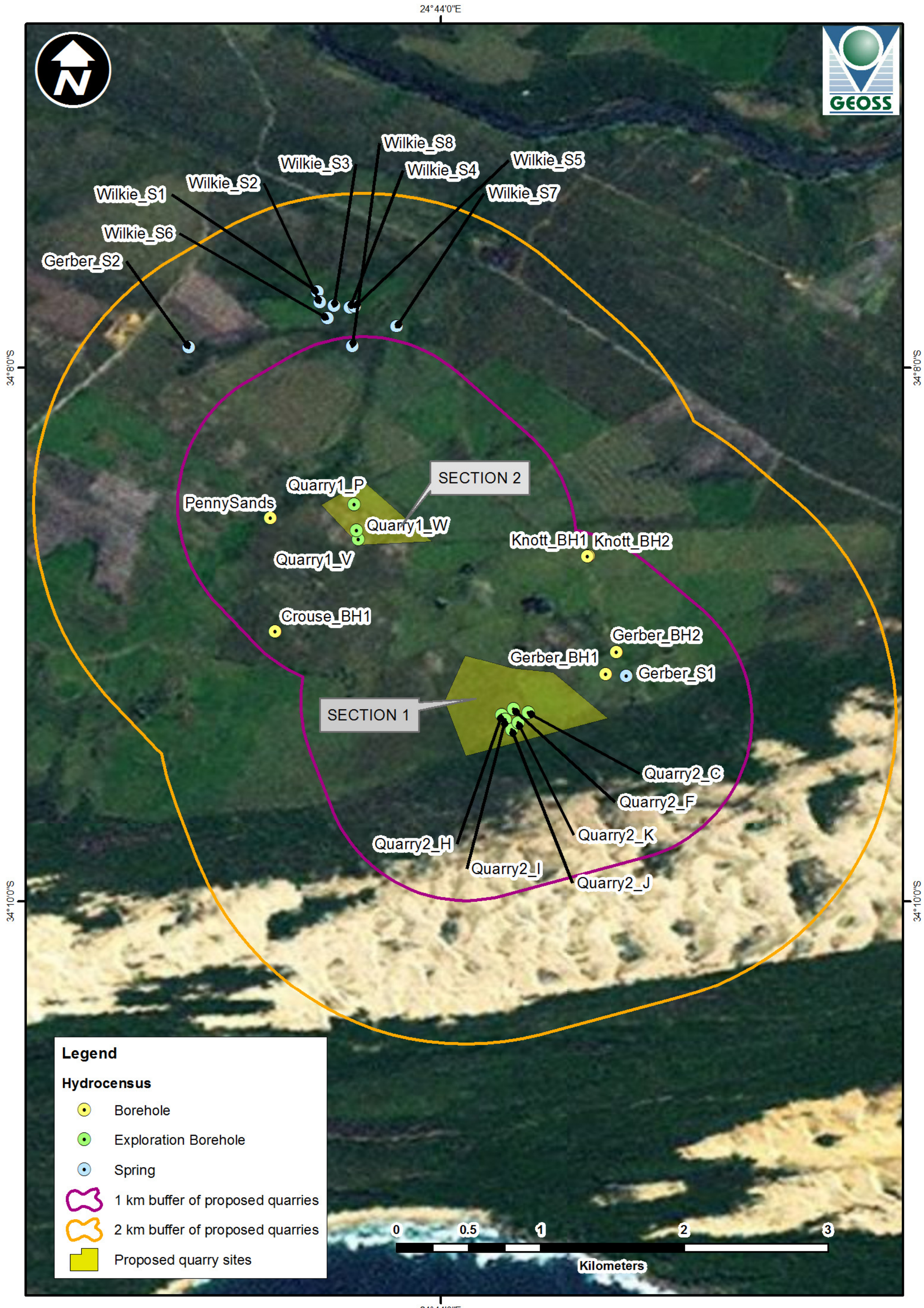
APPENDIX A: MAPS



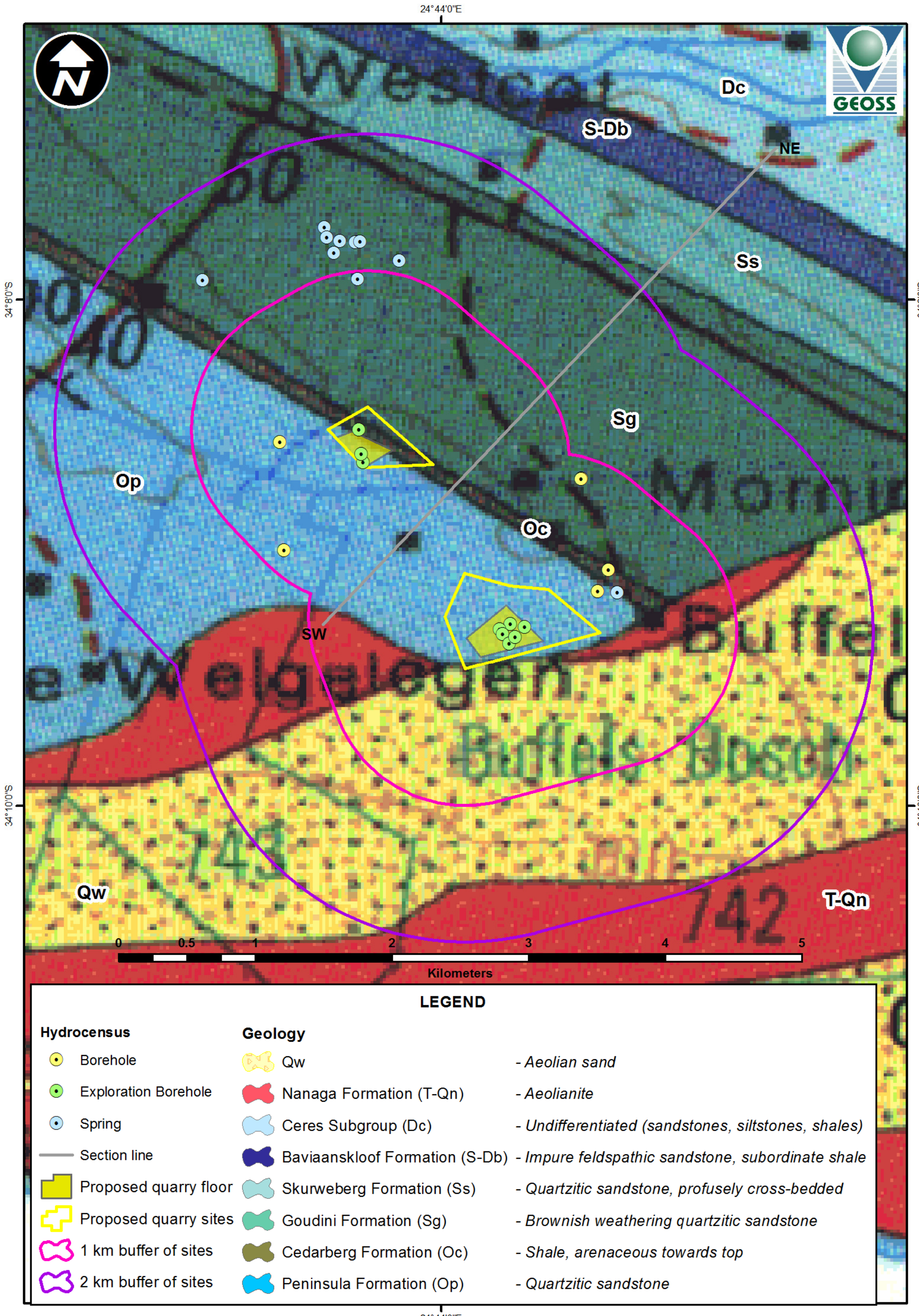
Map 1. Location of the study area within a regional setting



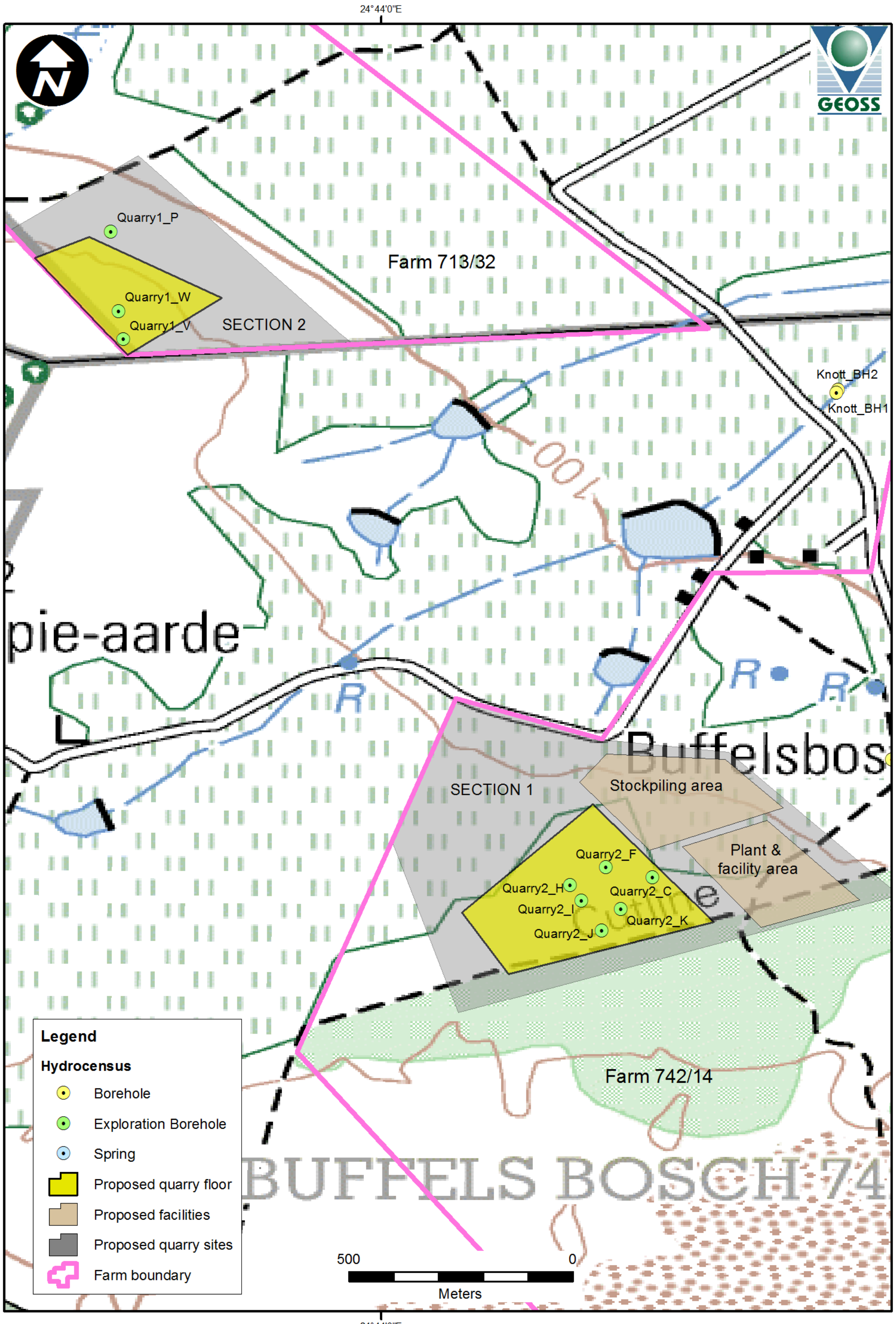
Map 2. The study site and surrounding area



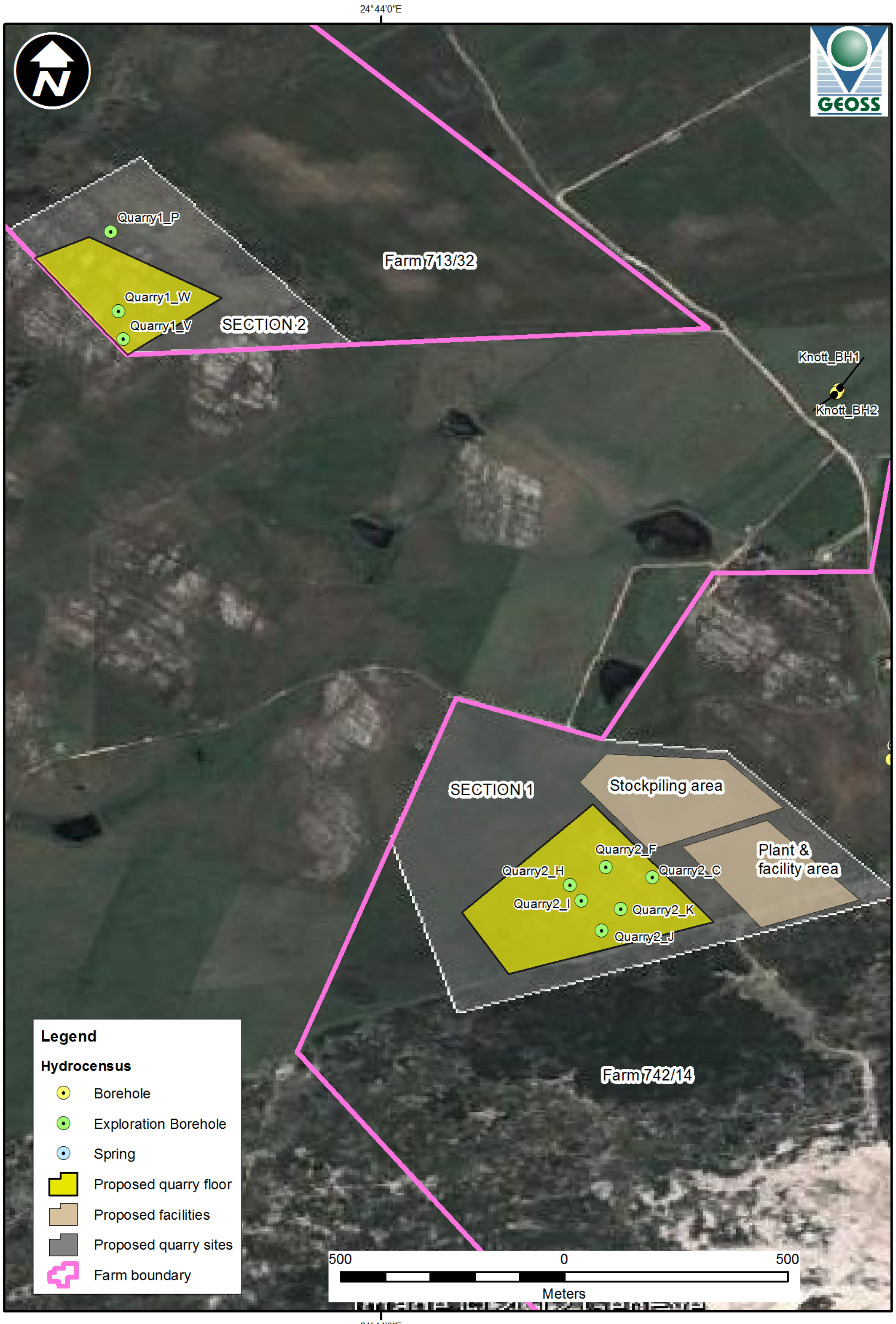
Map 3. Aerial photo of the proposed quarry areas showing hydrocensus sites visited.



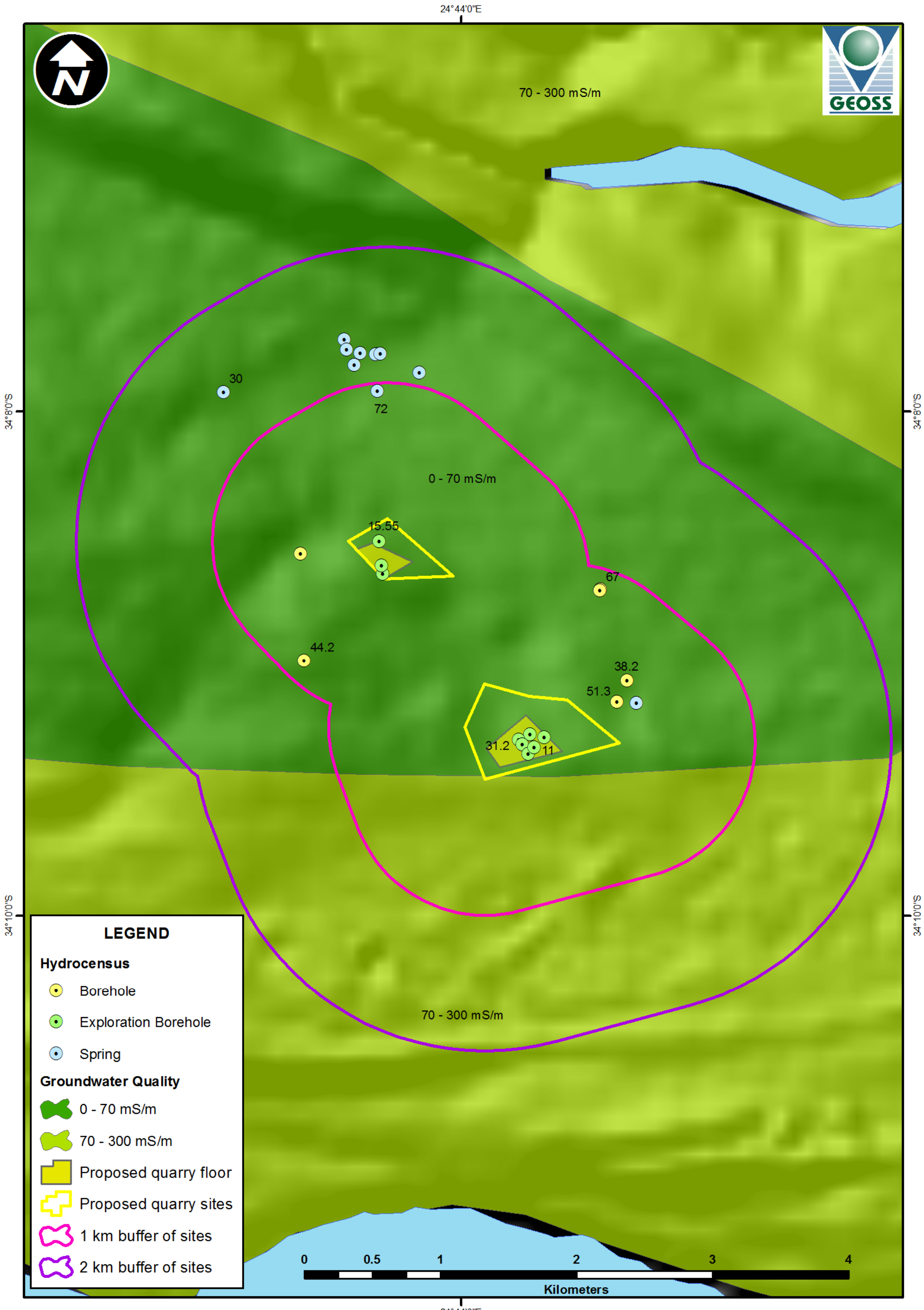
Map 4. Geological setting of the study area (1:250 000 Cape Town 3318).



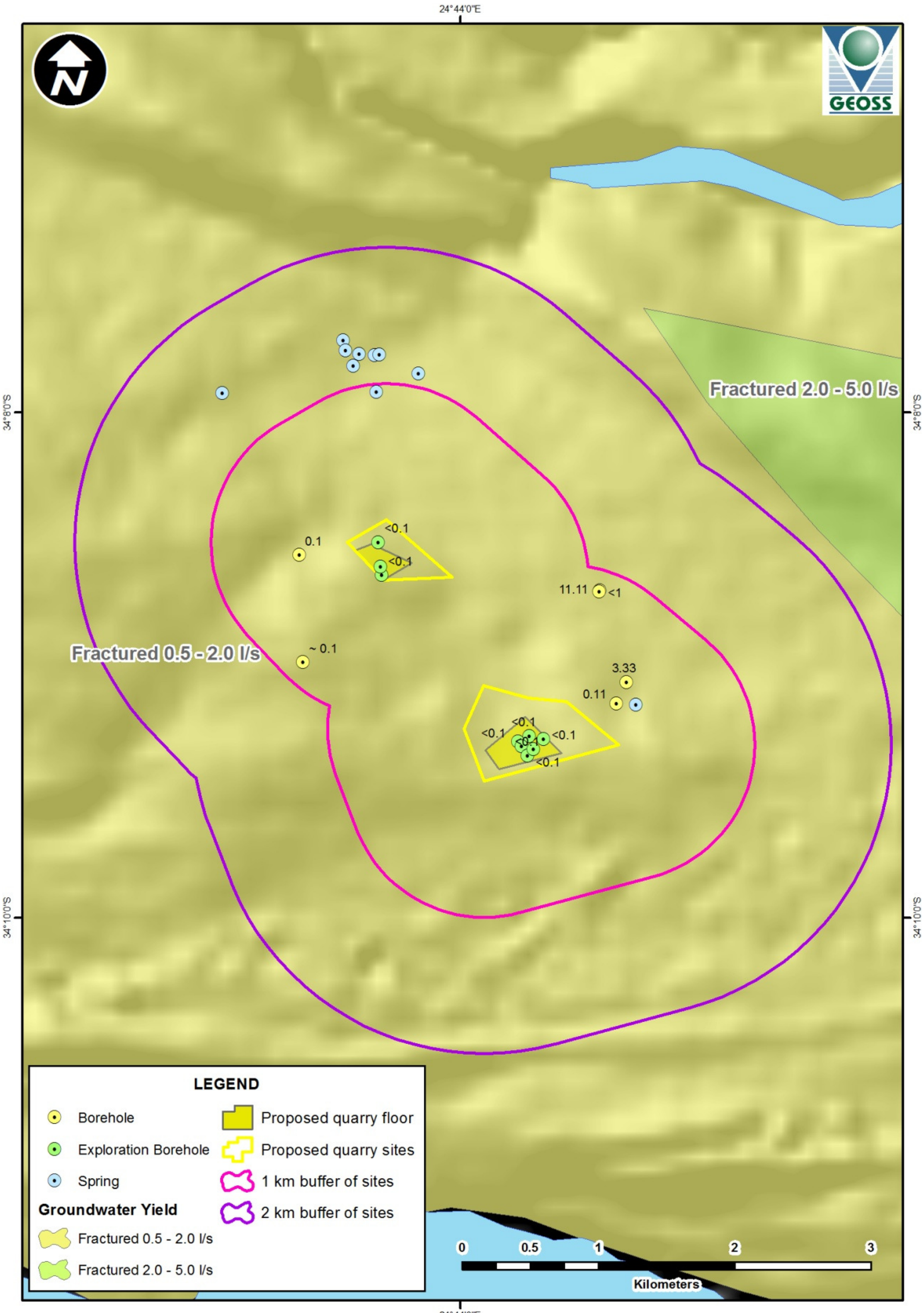
Map 5. Topomap of the proposed quarry sites and boreholes visited in the area.



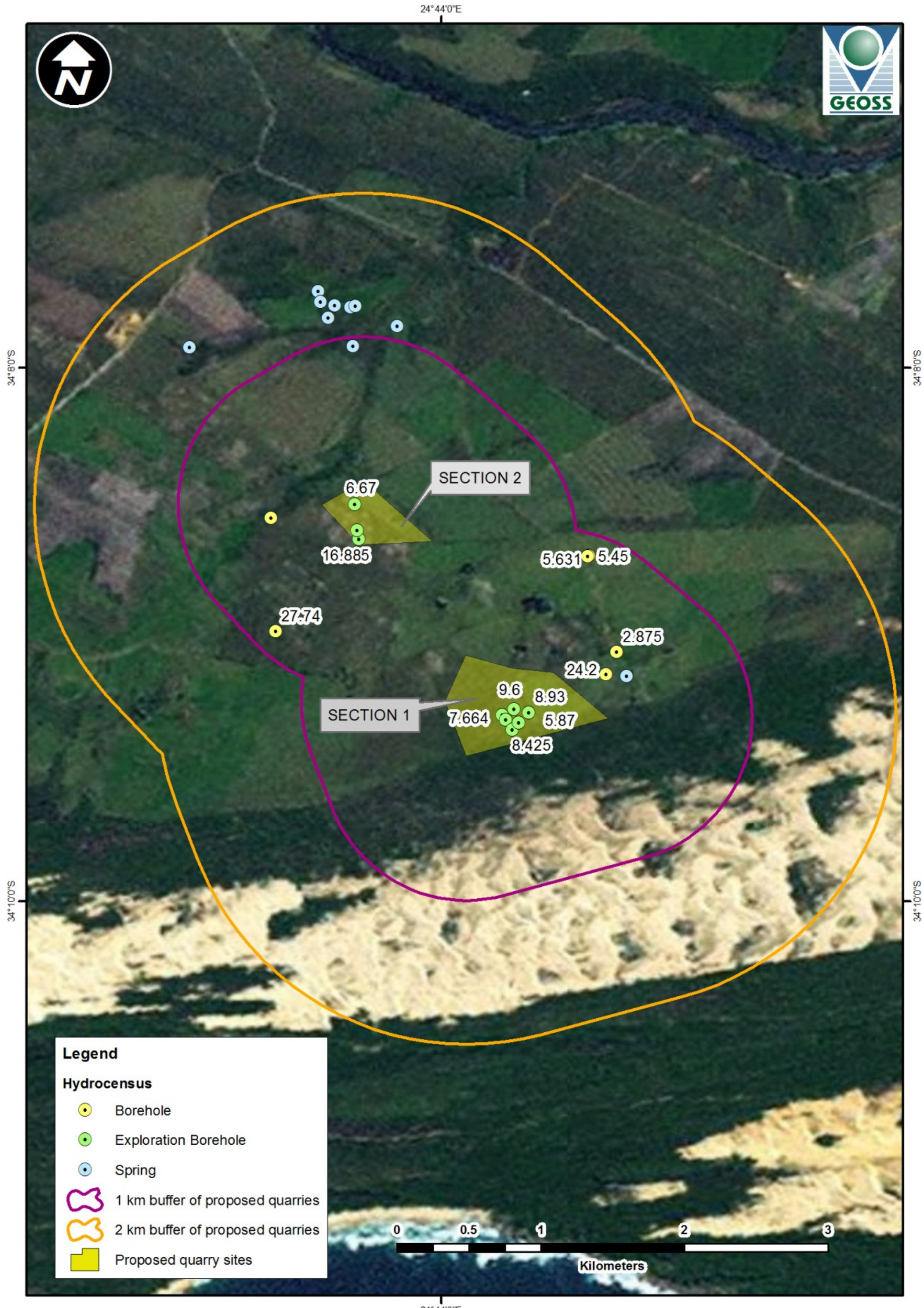
Map 6. Aerial photo of the proposed quarry sites and boreholes visited in the area.



Map 7. Groundwater quality map based on EC.



Map 8. Aquifer type and yield map.



Map 9. Groundwater level (mbgl) map.

APPENDIX B: PHOTO GALLERY

Photo 1 Crouse_BH1

Photo 2 Gerber_BH1

Photo 3 Gerber_BH2

Photo 4 Gerber_S1

Photo 5 Gerber_S2

Photo 6 Knott_BH1

Photo 7 Knott_BH2

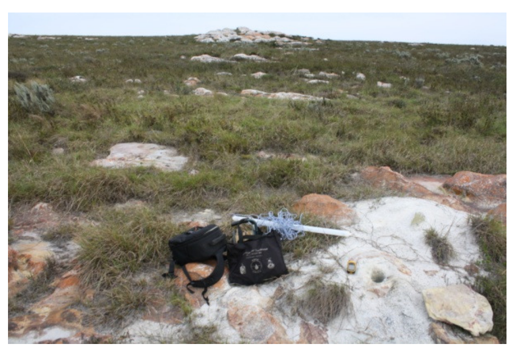


Photo 8 Quarry1_P

Photo 9 Quarry1_V

Photo 10 Quarry1_W

Photo 11 Quarry2_C

Photo 12 Quarry2_F

Photo 13 Quarry2_H

Photo 14 Quarry2_I

Photo 15 Quarry2_J

Photo 16 Quarry2_K

Photo 17 Wilkie_S1

Photo 18 Wilkie_S2

Photo 19 Wilkie_S3

Photo 20 Wilkie_S4

Photo 21 Wilkie_S5

Photo 22 Wilkie_S6

Photo 23 Wilkie_S7

Photo 24 Wilkie_S8

APPENDIX C: CHEMICAL RESULTS

bemlab
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Report No.: **WT7052**

Julian Conrad
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Unit 19, Technostell Building
9 Quantum Street, Technopark
Stellenbosch
7600

Water Analyses Report

Date received: 29/05/2012
Date tested: 31/05/2012

This test was done by Nemconsult and is not part of BemLab's scope of accreditation.

Reference No.	Lab. No.	Alkalinity mg/l	HCO_3 mg/l	Ca mg/l	Cl mg/l	EC mS/m	Fe mg/l	Mg mg/l	pH	K mg/l	Na mg/l	SO_4 mg/l	TDS mg/l
Gerber- BH1	7052	40.160	84.21	22.17	123.61	62.10	0.008	11.43	6.50	1.15	68.25	18.03	316.00
Gerber- BH2	7053	14.560	38.28	7.84	101.54	48.30	3.931	8.94	6.20	1.26	59.96	15.34	246.00
Gerber- S2	7054	5.020	30.62	3.63	83.88	40.50	0.051	7.40	6.10	1.33	52.35	14.00	206.00
Crouse- BH1	7055	5.520	38.28	5.20	136.86	54.60	0.054	9.38	6.10	1.61	67.33	17.57	277.00
Quarry 1- P	7056	2.510	30.62	2.29	61.81	26.10	0.109	4.33	5.50	1.95	31.33	14.26	131.90
Quarry 2- K	7057	7.030	29.09	8.64	35.32	19.18	0.459	3.04	6.10	1.72	19.51	7.31	97.10
Method#			3137	3126	3138	3135	3126	3126	3136	3126	3126		

#Refer to BemLab work instructions - Accredited methods identified by reference number. Methods with no reference number are not included in the SANAS schedule of accreditation

Geoss 892

Sample conditions

Samples received in good condition.

Statement

The reported results may be applied only to samples received. Any recommendations included with this report are based on the assumption that the samples were representative of the bulk from which they were taken. Opinions and recommendations are not accredited.

Dr. Pieter Raath
....
for BemLab

01-06-2012
....
Date Reported

Technical Signatory: Arrie van Deventer (Chemical Analyses)
Annerina Esterhuyse (Microbiology)

(last page)