2.8 TOPOGRAPHY BASELINE

JMA Consulting (Pty) Ltd conducted a detailed topographical base line assessment for the Glencore Merafe Boshoek Mine and Smelter (GMBS) study area. The comprehensive Topography Specialist Baseline Report is attached as **APPENDIX 2.8 (A).**

2.8.1 Regional Topography

The study area is located in the north-eastern region of the North West Province as indicated in Figure 2.8.1(a). Figure 2.8.1(a) also illustrates the regional topography of the North West Province of the Republic of South Africa.

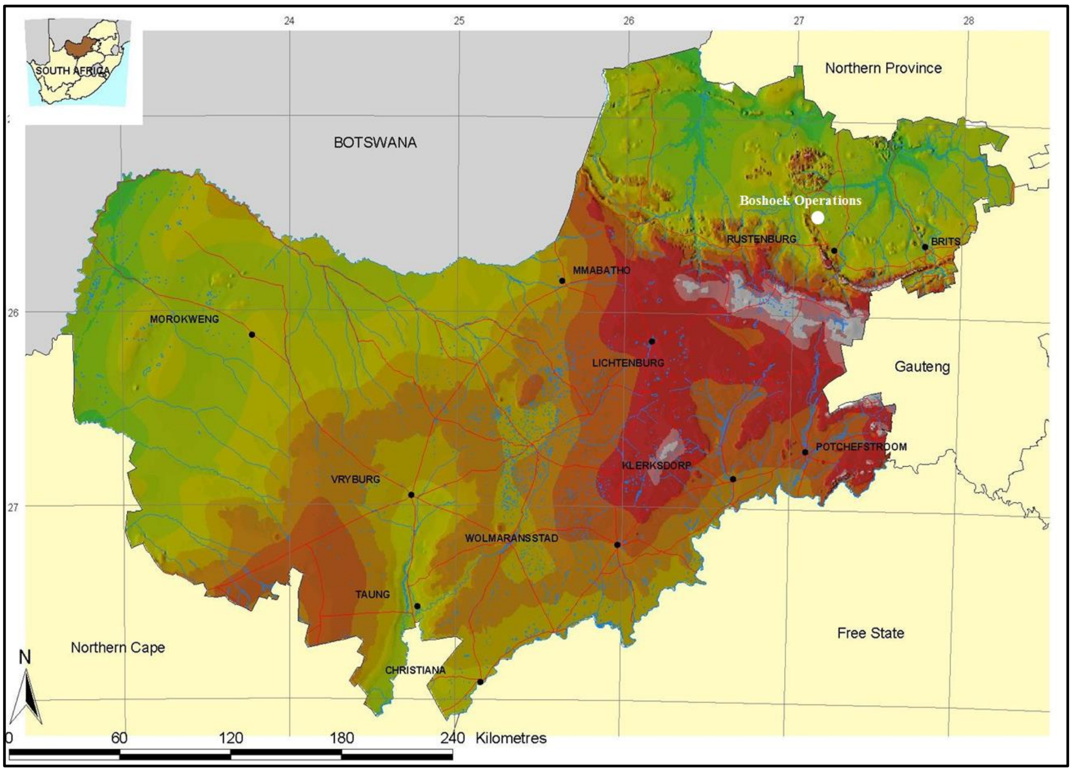

Figure 2.8.1(a): Surface Topography of the North West Province

Topographically, the North West Province is indicated to have one of the most uniform terrains of all the provinces within South Africa. The topography of the eastern region is more variable than that of the southern and western regions and ranges in altitude from 920 mamsl to 1782 mamsl across the province.

The eastern region gives rise to the Magaliesberg mountain range of the Transvaal Sequence as well as the Pilanesberg, another prominent feature in the east, remnants of an ancient volcano which consists of a formation of concentric hills or ring-dykes.

2.8.2 Local Topography

The topographical map of the study area is depicted as Figure 2.8.2(a) and incorporates clipped regions of the published 1:50 000 Topographical Maps of South Africa, Sheets 2527 AC Sun City (1982) and 2527 CA Rustenburg West (1980).

The study area is flanked by the Magaliesberg Mountain Range to the west and south-west and by the Pilanesberg to the north. The land use adjacent to the Boshoek Operations is dominated by agricultural and mining related activities as indicated on Figure 2.8.2(a).

The Magaliesberg Mountain Range extends across the south-western extent of the study area in south-easterly to north-westerly direction (Figure 2.8.2(b)). The Magaliesberg Mountain Range ranges significantly in elevation between 1200 mamsl and 1650 mamsl.

The Pilanesberg, located to the north of the Boshoek Operations, consists of a formation of concentric hills or ring-dykes and ranges in elevation between around 1050 mamsl and 1670 mamsl.

The north-western extent of the Magaliesberg Mountain Range and the southern extent of the Pilanesberg are evidently seen on the 3-D shaded relief map depicted as Figure 2.8.2(b). The delineated site (properties) is delineated in blue on Figure 2.8.2(b).

The highly irregular topography of the resistant Magaliesberg becomes gentler and flattens out towards the east and north-east. The surface topography at the Boshoek Operations is relatively flat and ranges in elevation between around 1150 mamsl and 1120 mamsl (Figure 2.8.2(b)).

This is evidently seen in the oblique Google™ earth images of the Plant Area (Figure 2.8.2(c)) as well as of the Mining Area and Plant Area (Figure 2.8.2(d)).

The 20 m surface elevation contours as well as the natural surface water drainage lines (depicted in yellow and blue respectively) are obtained from the published 1:50 000 Topographical Sheets of South Africa and were overlaid onto the Google™ earth image using the Topoglide Software.

The average surface gradient at the Boshoek Operations is 0.01 (1 m per 100 m) in a north-easterly direction. The surface topography continues to dip in a north-easterly direction, giving rise to the north-easterly surface water drainage within the study area.

The major surface water drainage body within the study area is the Matlapyane Stream, which flows in a north-easterly direction (Figure 2.8.2(c) and Figure 2.8.2(d)).

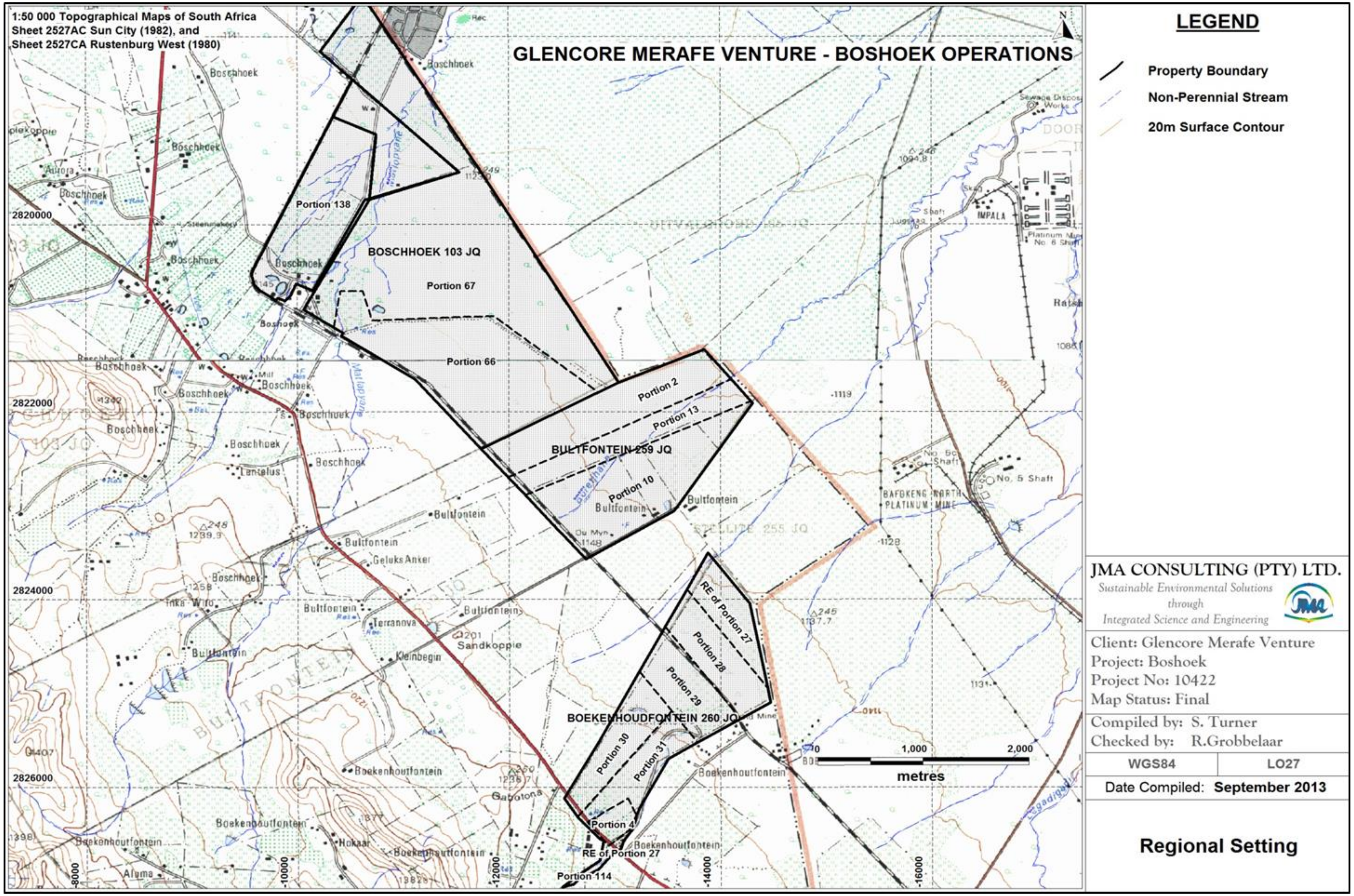

Figure 2.8.2(a): The GMBS Site Topography in Regional Context

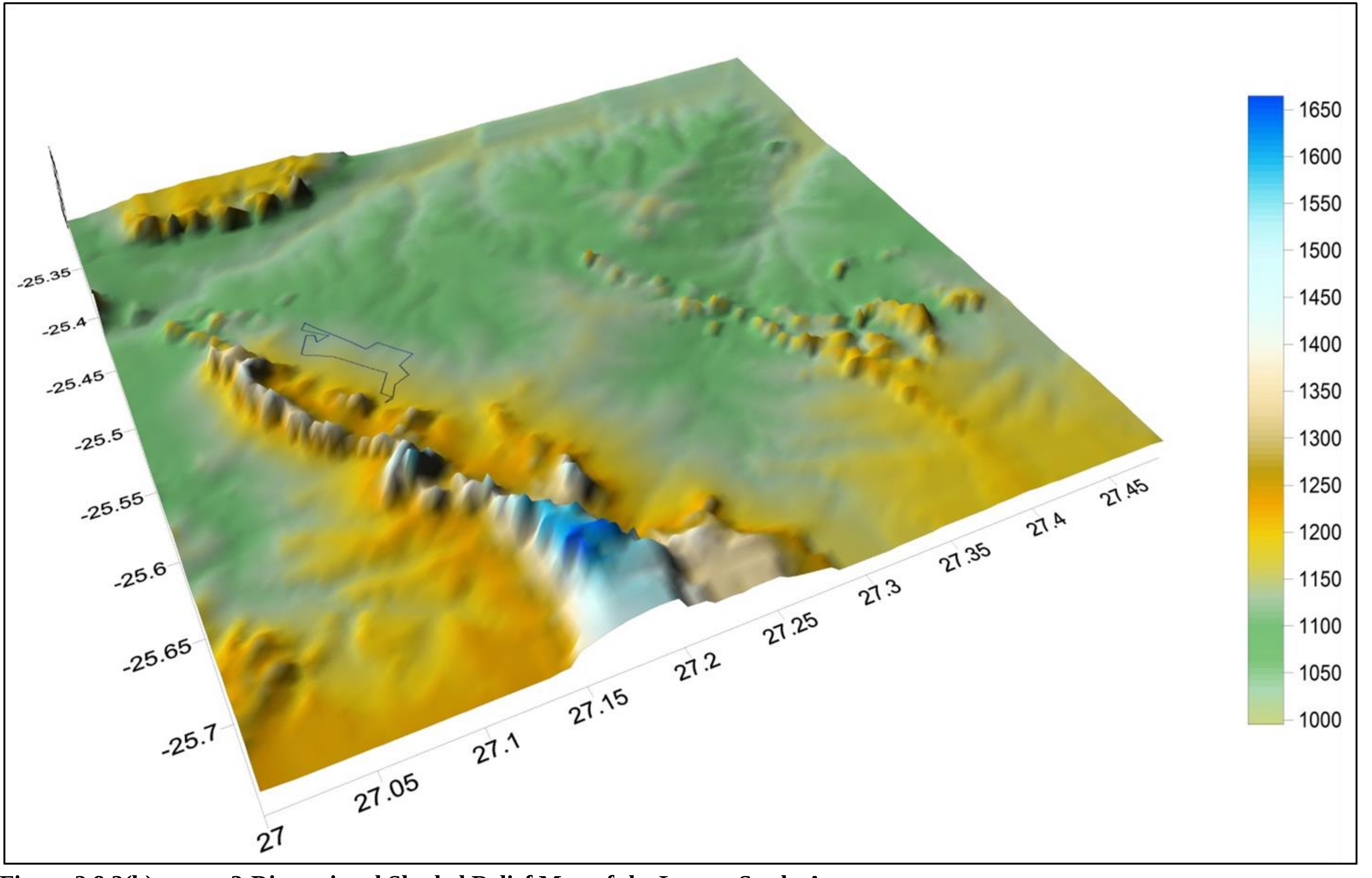

Figure 2.8.2(b): 3-Dimensional Shaded Relief Map of the Larger Study Area

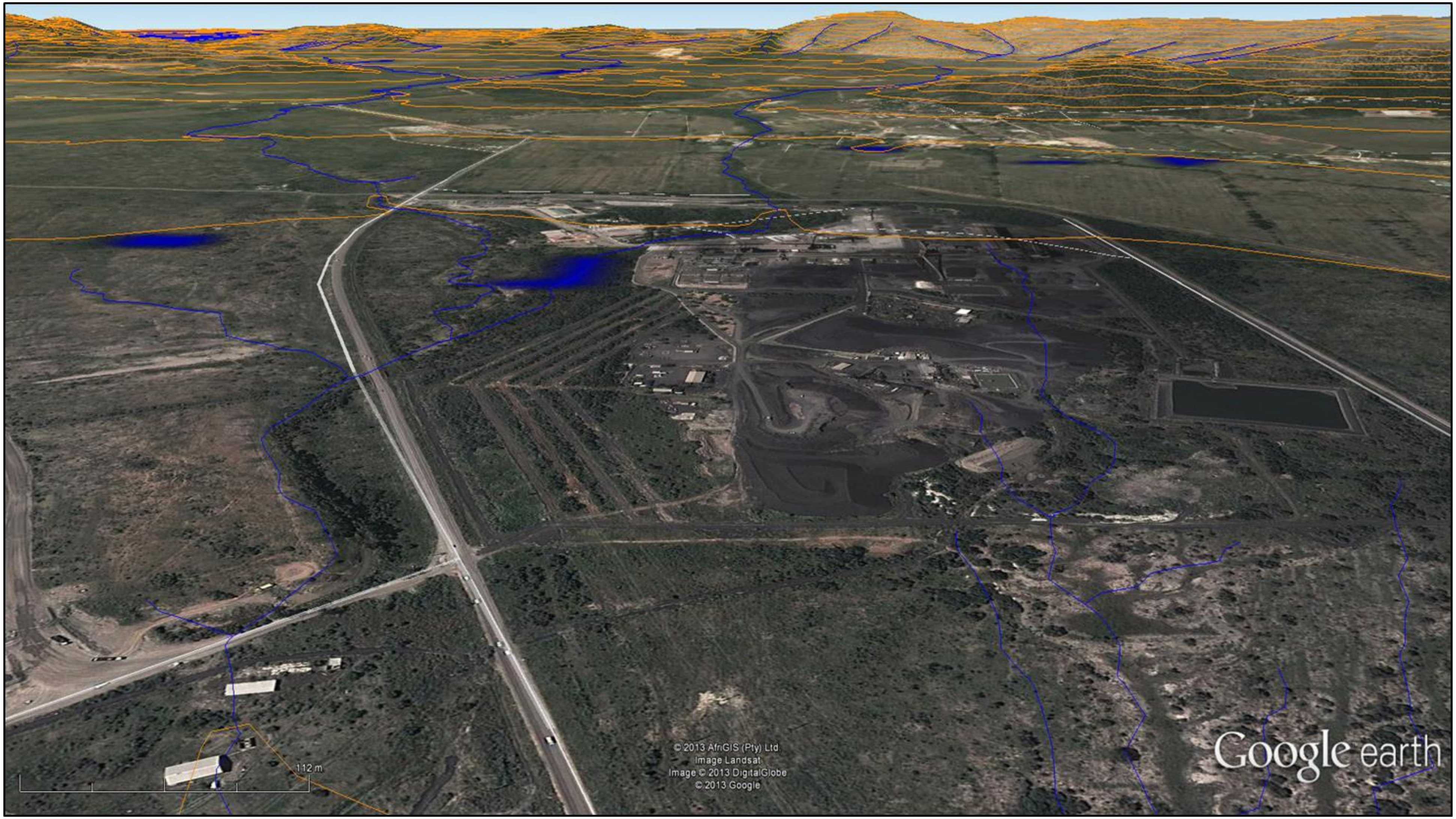

Figure 2.8.2(c): **Oblique View of Surface Topography (Plant Area) – Looking towards the South-West**
Reference: Google™ earth Image – Image Date 25/01/2013

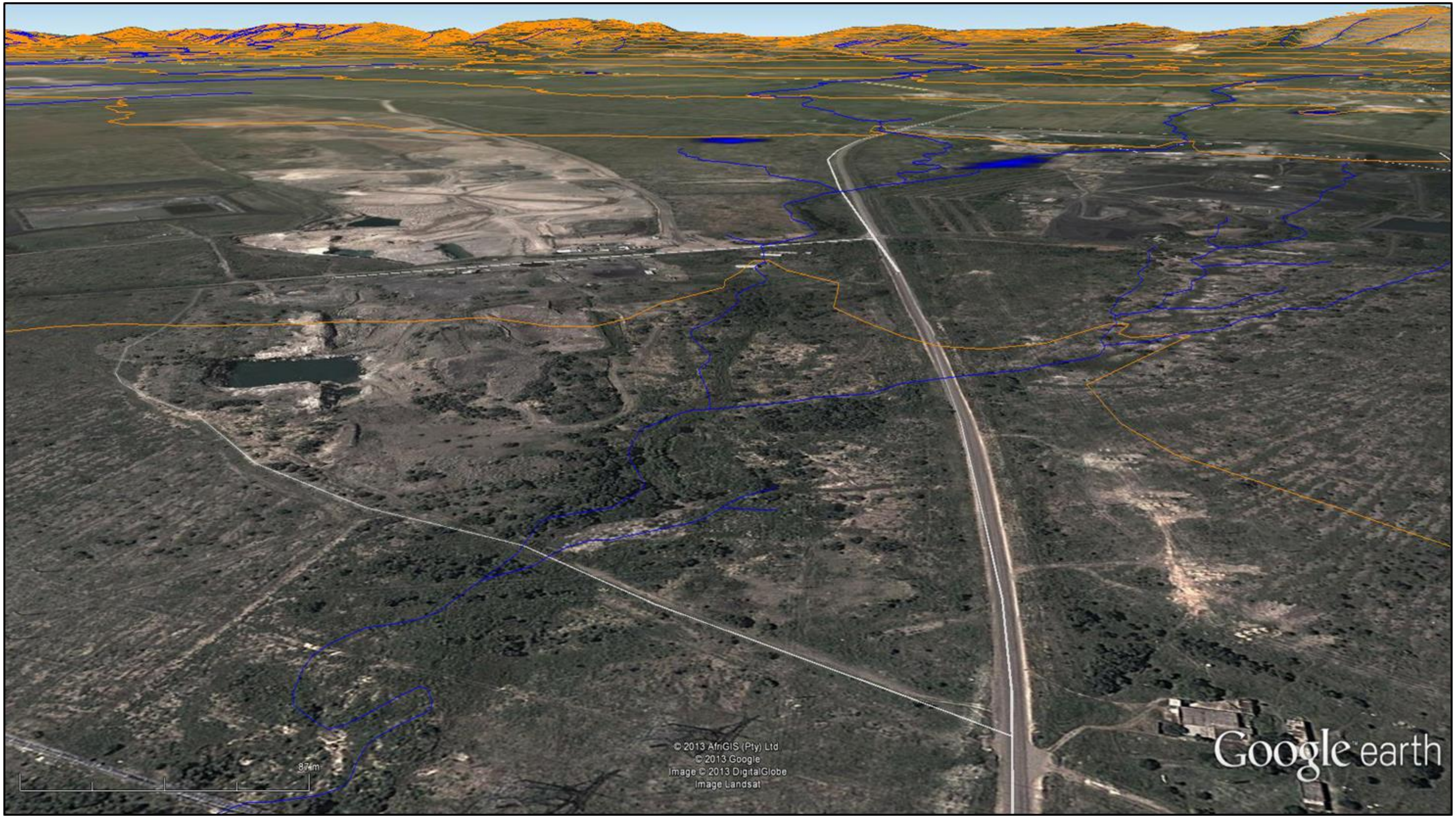

Figure 2.8.2(d): **Oblique View of Surface Topography (Mining and Plant Areas) – Looking towards the South**
Reference: Google™ earth Image – Image Date 25/01/2013

A view-shed analysis of the topography within the study area was generated and is depicted as Figure 2.8.2(e). The areas from which the the Boshoek Operations can be seen (based entirely on the 10 m contour elevations) are depicted in green on Figure 2.8.2(e). The areas indicated in pink have no view of the the Boshoek Operations. ***It should be noted that the view-shed analyses does not take vegetation or surface infrastructure into consideration during the analyses.***

The view-shed analysis indicates that due to the flat topography adjacent to the Boshoek Operations, the operations can potentially be seen from almost every locality within a 1 km radius from the site *(not taking vegetation and surface infrastructure into consideration*).

The Boshoek operations could potentially be seen from a significant area within a 5 km radius from the operations as well (Figure 2.8.2(e)). The Boshoek Operations are also indicated to be visible from the topographically higher lying areas including the Pilanesberg and Magaliesberg Mountains.

2.8.3 Aerial Photograph

A recent aerial photograph of the study area was taken on **11 March 2012** by **Azur Aerial Work cc**. An A0 copy of the aerial photograph is attached as APPENDIX II to the Topography Specialist Report. A smaller scale version of the aerial photograph is depicted on Figure 2.8.3(a) for reference purposes.

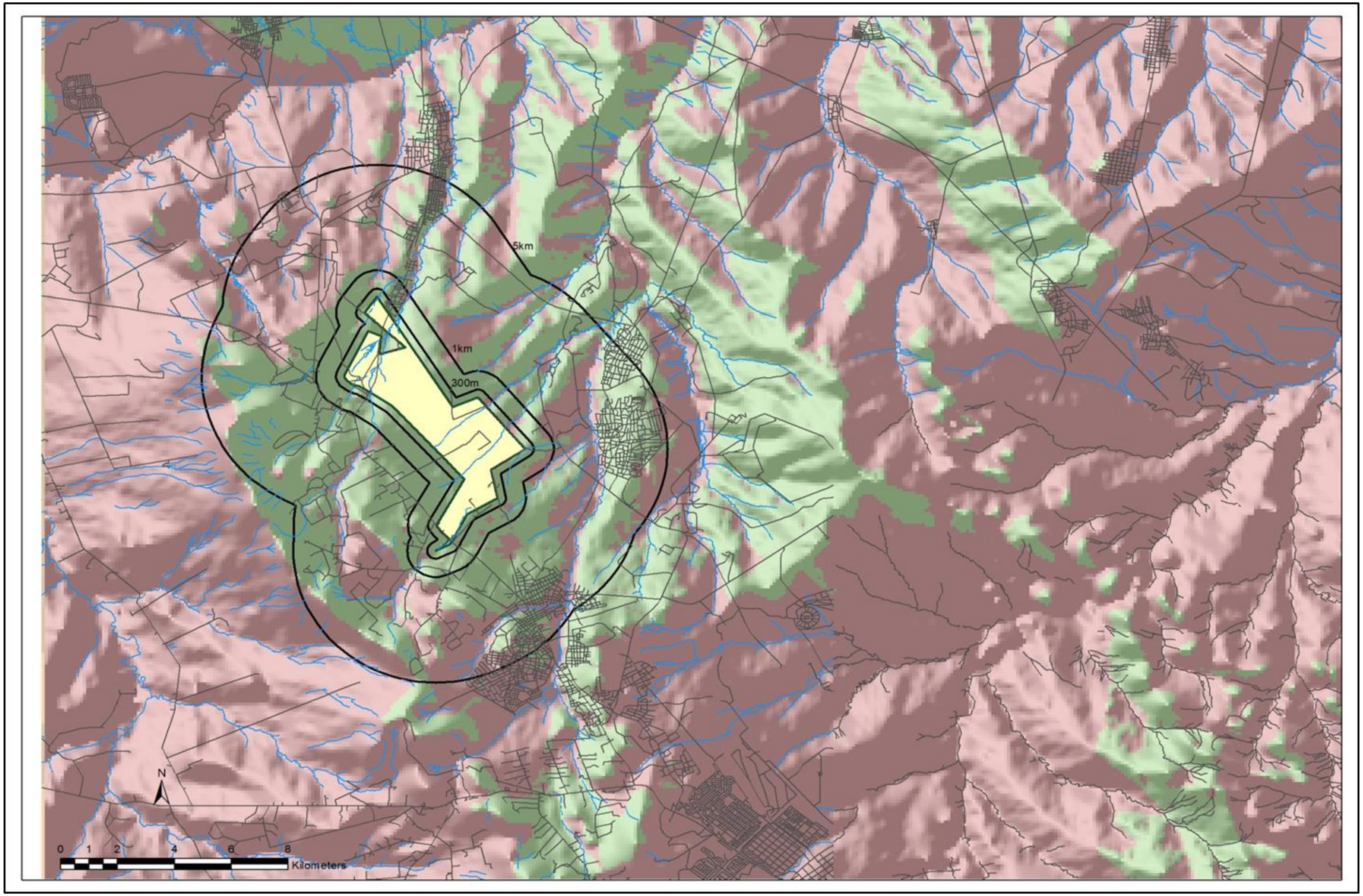

Figure 2.8.2(e): View Shed Analyses

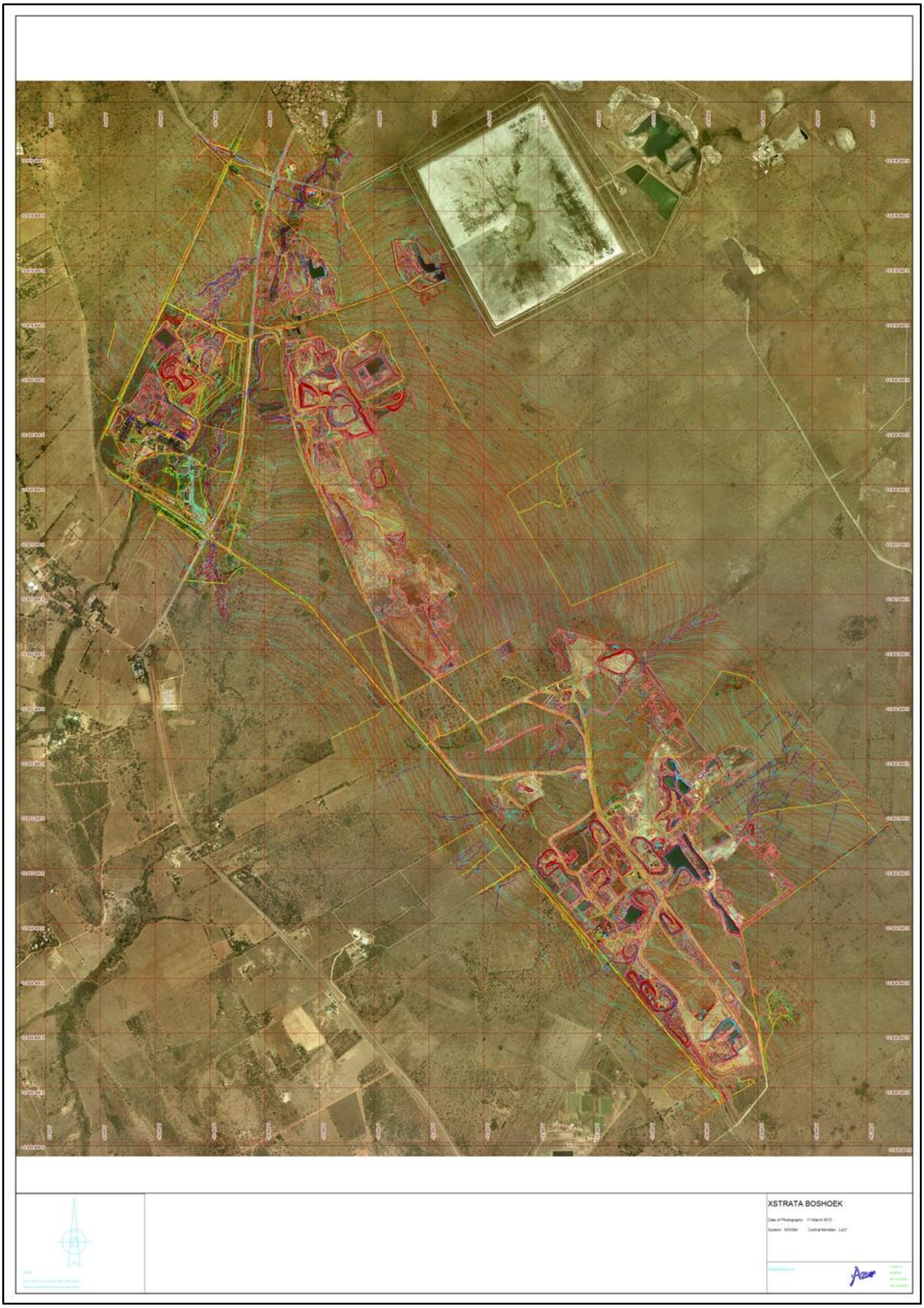

Figure 2.8.3(a): **Aerial Photograph of the Study Area**
Image taken by Azur Aerial Work cc on 11 March 2012

2.9 SOILS AND LAND CAPABILITY BASELINE

The Existing Status of the Soils, Land Capability and Land Use within the bounds of the Glencore Merafe Boshoek Mine and Smelter (GMBS) Project Area was assessed by Red Earth CC, specialist consultants in Soils, Land Capability and Land Use. A Specialist Soils, Land Capability and Land Use Study Report compiled by Red Earth, detailing a full base line description, is attached as **APPENDIX 2.4 (A)** to this report.

However, for the purposes of this Scoping Report, a synoptic summary in terms of the Soils and Land Capability was extracted from this Specialist Report and is presented below.

2.9.1 Soil Form

The different soil types identified were grouped together into soil-mapping units on the basis of soil form, effective soil depth (ESD), for mining (stripping depth) and cropping (effective rooting depth), surface features, parent material, colour, perched water table depth, location of saline/sodic soils (none observed), location of precipitated salts associated with pollution plumes (none observed, although moist soils/fragmites sp./cynodon sp. were indicators of a plume in the vicinity of the plant), and overburden type/depth where present. Each soil-mapping unit has a unique code, which describes these factors.

Table 2.9.1 (a) (Summary of Soil Form) summarises the information presented on Figure 2.9.1 (a) (Soil Mapping Units) in terms of soil form.

2.9.2 Soil Analytical Characteristics

Apart from the soils (including the streams and the donga) [781.82 ha, 71.58 % of survey area], a diverse range of industrial and mining related man-made features are present [310.45 ha, 28.42 %], the total surveyed area being 1092.27 ha.

Parent material (the material from which soil has developed, which in turn has weathered from the parent rock) types encountered during the course of the soil survey include (descending order of frequency): basic igneous rocks, chromite, colluvium, alluvium (rare), and dolerite (very rare). Bands of quartzite/quartz stones/gravel (deposited during an ancient flood event) [frequently], or carbonate (soft or hardpan) [frequently], or ferricrete [rarely] often directly overlie the underlying parent rock. These ‘parent material bands’ have made a significant contribution to soil formation/properties. Sand grade and textural ranges for the various broad soil groups, varies as follows, where:

Vertic	: topsoils Fi-Co	Cl(ClLm),	subsoils Fi-Co,	Cl;
Pedocutanic	: topsoils Co-Fi,	ClLm-SaLm,	subsoils Co-Fi,	Cl-ClLm;
Red apedal/structured	: topsoils Co-Fi,	SaClLm-LmSa,	subsoils Co-Fi,	SaClLm(ClLm-SaCl)
Yellow-brown apedal	: topsoils Me-Co,	SaClLm,	subsoils Me-Co,	SaClLm-SaCl;
Neocutanic	: topsoils Co-Fi,	SaClLm,	subsoils Co-Me,	SaClLm-SaCl;
Alluvial	: topsoils Fi-Co,	LmSa-SaLm,	subsoils Co,	LmSa;
Shallow	: topsoils Co,	Cl-SaClLm,	subsoils - ,	- ;
Hydromorphic	: topsoils Co(Fi),	Cl-ClLm-SaClLm,	subsoils Co,	Cl or SaClLm-ClLm;
Man-made (vertic)	: topsoils Fi-Co,	Cl,	subsoils - ,	- ; and
Man-made (red)	: topsoils Co-Fi,	SaClLm,	subsoils - ,	- .

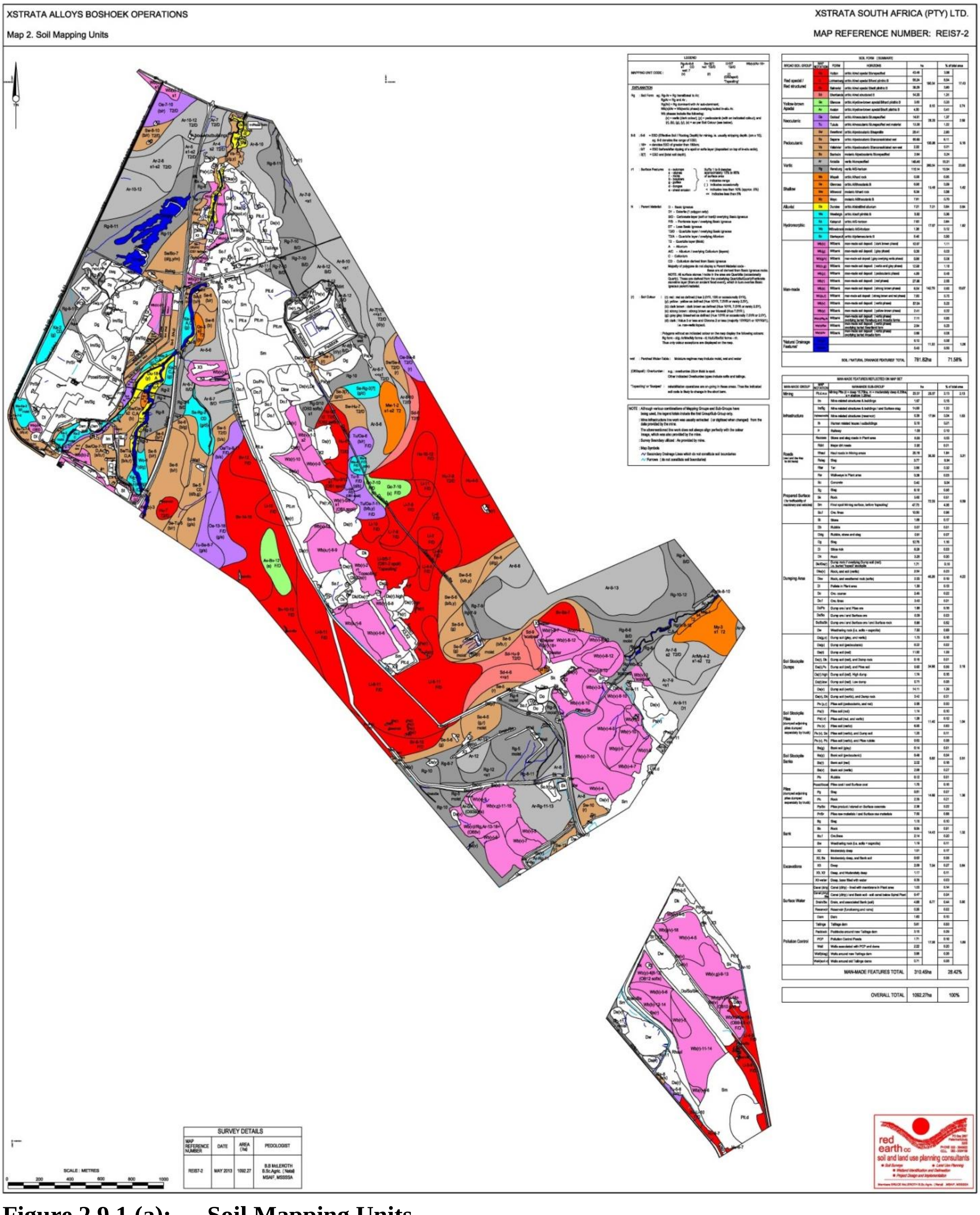

**Figure 2.9.1 (a):	Soil Mapping Units**

Table 2.9.1 (a): Summary of Soil Form

SOIL FORM (SUMMARY)							
BROAD SOIL GROUP	MAP NOTATION	FORM	HORIZONS	ha		% of total area	
Red apedal / Red structured	Hu	Hutton	orthic A/red apedal B/unspecified	43.48	190.34	3.98	17.43
	Li	Lichtenburg	orthic A/red apedal B/hard plinthic B	93.24		8.54	
	Bv	Bainsvlei	orthic A/red apedal B/soft plinthic B	39.29		3.60	
	Sd	Shortlands	orthic A/red structured B	14.33		1.31	
Yellow-brown Apedal	Gc	Glencoe	orthic A/yellow-brown apedal B/hard plinthic B	3.60	8.10	0.33	0.74
	Av	Avalon	orthic A/yellow-brown apedal B/soft plinthic B	4.50		0.41	
Neocutanic	Oa	Oakleaf	orthic A/neocutanic B/unspecified	14.91	28.29	1.37	2.59
	Tu	Tukulu	orthic A/neocutanic B/unspecified wet material	13.38		1.22	
Pedocutanic	Sw	Swartland	orthic A/pedocutanic B/saprolite	28.41	100.06	2.60	9.16
	Se	Sepane	orthic A/pedocutanic B/unconsolidated wet	66.69		6.11	
	Va	Valsrivier	orthic A/pedocutanic B/unconsolidated non-wet	2.32		0.21	
	Bo	Bonheim	melanic A/pedocutanic B/unspecified	2.64		0.24	
Vertic	Ar	Arcadia	vertic A/unspecified	145.40	260.54	13.31	23.85
	Rg	Rensburg	vertic A/G-horizon	115.14		10.54	
Shallow	Ms	Mispah	orthic A/hard rock	0.58	15.49	0.05	1.42
	Gs	Glenrosa	orthic A/lithocutanic B	0.96		0.09	
	Mw	Milkwood	melanic A/hard rock	6.34		0.58	
	My	Mayo	melanic A/lithocutanic B	7.61		0.70	
Alluvial	Du	Dundee	orthic A/stratified alluvium	7.01	7.01	0.64	0.64
Hydromorphic	We	Westleigh	orthic A/soft plinthic B	3.92	17.67	0.36	1.62
	Ka	Katspruit	orthic A/G-horizon	7.03		0.64	
	Wo	Willowbrook	melanic A/G-horizon	1.26		0.12	
	Ss	Sterkspruit	orthic A/prismacutanic B	5.46		0.50	
Man-made	Wb(b)	Witbank	man-made soil deposit (dark brown phase)	12.07	142.79	1.11	13.07
	Wb(g)	Witbank	man-made soil deposit (gley phase)	0.38		0.03	
	Wb(g/v)	Witbank	man-made soil deposit (gley overlying vertic phase)	0.66		0.06	
	Wb(v,g)	Witbank	man-made soil deposit (vertic and gley phase)	12.88		1.18	
	Wb(p)	Witbank	man-made soil deposit (pedocutanic phase)	4.99		0.46	
	Wb(r)	Witbank	man-made soil deposit (red phase)	27.88		2.55	
	Wb(s)	Witbank	man-made soil deposit (strong brown phase)	6.54		0.60	
	Wb(s,r)	Witbank	man-made soil deposit (strong brown and red phase)	7.60		0.70	
	Wb(v)	Witbank	man-made soil deposit (vertic phase)	57.04		5.22	
	Wb(y)	Witbank	man-made soil deposit (yellow-brown phase)	2.41		0.22	
	Wb(v)//Rg,Ar	Witbank	man-made soil deposit (vertic phase) overlying buried Rensburg and Arcadia forms	7.11		0.65	
	Wb(v)//Sw	Witbank	man-made soil deposit (vertic phase) overlying buried Swartland form	2.54		0.23	
	Wb(v)//Ar	Witbank	man-made soil deposit (vertic phase) overlying buried Arcadia form	0.69		0.06	
'Natural Drainage Features'	Donga			6.10	11.53	0.56	1.06
	Stream			5.43		0.50	
SOIL / 'NATURAL DRAINAGE FEATURES' TOTAL				781.82ha		71.58%	

Textures are generally clay to clay-loam for the vertic, man-made (vertic phase), shallow (with melanic topsoils), pedocutanic, and hydromorphic soils. Exceptions are the red apedal, man-made (red apedal phase), red structured, yellow-brown apedal, neocutanic, and shallow (with orthic topsoils) soils that generally have a sandy-clay-loam texture in the topsoil, and a sandy-clay-loam to sandy-clay texture in the subsoil; and the alluvial soils that generally have a loamy-sand to sandy-loam texture in both the topsoil and the subsoil.

Soil structure varies as follows: vertic, man-made (vertic phase), and shallow (with melanic topsoils) soils [strong blocky]; pedocutanic soils [weak or moderate blocky topsoil overlying moderate or strong blocky subsoil]; red structured soils [weak blocky topsoil overlying moderate blocky subsoil]; shallow soils (with orthic topsoils) [weak blocky]; red apedal, yellow-brown apedal, and neocutanic soils [apedal or occasionally weak blocky topsoil overlying weak blocky or occasionally apedal subsoil]; and alluvial soils [apedal or single grain in both horizons].

The vertic, man-made (vertic phase), shallow (with melanic topsoils), pedocutanic, and hydromorphic soils have a very high base status = very poorly leached = eutrophic (vertic soils: S-value 60.7 – 93.6 cmol (+) kg^{-1} clay; cation exchange capacity CEC 60.7 – 93.3 cmol (+) kg^{-1} clay; and one third of vertic topsoils, melanic topsoils, and pedocutanic subsoils are slightly calcareous). These soils are derived from the most-base-rich, to base-rich parent material types or phases (very basic to basic igneous rocks).

The red structured, red apedal, man-made (red apedal phase) /, neocutanic, yellow-brown apedal, shallow (with orthic topsoils), and alluvial soils have a high base status = very poorly leached = eutrophic (red apedal and neocutanic soils: S-value 16.0 – 30.4 cmol (+) kg^{-1} clay; cation exchange capacity CEC 27.5 – 51.3 cmol (+) kg^{-1} clay; and non-calcareous). These soils are derived from parent material types or phases (least basic of the basic rocks, ferricrete /, quartzite, and alluvium) with a moderate / to low base reserve respectively.

The soils in the area are very poorly to poorly leached, given both the high base reserve of the majority of parent materials, as well as the low effective rainfall (interaction of the low mean annual precipitation, the high mean annual evaporation, and the moderate mean annual temperature) in the area, whereby the leaching potential is insufficient to remove base cations (calcium and/or calcium-magnesium carbonates) from the soil profile.

The soils in the survey area may be divided into two distinct groups based on pH. For the purposes of this discussion, the pH of the ‘less desirable’ to ‘undesirable pH group’ will vary from 7.4 (mildly alkaline) to 9.24 (very strongly alkaline), which are marginally high, too much too high. This pH group caters for soils that are derived from the most base rich to base rich parent material types/phases (very basic to basic igneous rocks). On this basis the vertic, man-made (vertic phase), shallow (with melanic topsoils), pedocutanic, and hydromorphic broad soil groups are included.

The Chamber of Mines arable definition requires a soil pH value of between 4.0 and 8.4. Thus according to this definition, a limited number of the vertic soils are borderline non-arable/arable in terms of their pH.

The pH of the 'desirable pH group' will vary from 6.1 (slightly acid) to 7.3 (neutral), which are both ideal. This pH group caters for soils that are derived parent material types or phases (least basic of the basic rocks, ferricrete /, quartzite, and alluvium) with a moderate / to low base reserve respectively. On this basis, the red structured, red apedal, man-made (red apedal phase) /, neocutanic, yellow-brown apedal, shallow (with orthic topsoils), and alluvial broad soil groups are included.

The vast majority of the soils in the survey area are non-saline (as per The Chamber of Mines definition) since they will have an EC (not analysed in current survey area) of less than 400mS/m. The analysed samples from another survey in the region have low to moderate EC values that range from approximately 16 (red apedal soils) to 41 – 44 (vertic soils). Given that the analysed samples were collected from non-calcareous (did not effervesce visibly when treated with cold 10 % hydrochloric acid) sites, the EC in one third of the vertic areas (slightly calcareous) will be higher (probably high : >75) than those presented here.

The author considers the limited highly calcareous variants (limited area of possible anorthosite derived vertic topsoils, that lie to the south-east of the main soil survey block) of the vertic broad soil group that exist to be highly saline (not analysed) and moderately sodic (ESP 8.40 %). Thus these variants are marginally arable/non-arable (actually of the wetland and grazing capability classes) and must not be cultivated or irrigated.

The analysed soils in the survey area (Table 2.9.2 (a)) are non-sodic (as per the Chamber of Mines definition), since they have a very low ESP that ranges from 0.19 to 1.50 (with one outlier at 8.40). Topsoil organic carbon percentage was not analysed, but appears to vary from approximately 0.6 to 1.4 % (moderate to moderate-high) for the majority of the broad soil groups, and from 1.0 to 2.0 % (high) for the hydromorphic broad soil group.

In terms of fertility for maize, the optimal levels of nutrients (exchangeable cations) are: K (120 ppm optimal – 100 ppm acceptable), Mg (60 ppm) and P (34 ppm). Levels of K in the vertic soils are adequate to more than adequate (102 – 430 ppm) for seven samples, and deficient (74 - 90 ppm) for three samples. Levels of K in the red apedal and neocutanic soils are deficient (27 - 63 ppm) for nine samples, and adequate (102 ppm) for one sample.

Levels of Mg in the vertic soils are more than adequate (1368 - 3051 ppm) for all samples (ten). Levels of Mg in the red apedal and neocutanic soils are also more than adequate (215 - 871 ppm) for all samples (ten). Levels of P are seriously deficient (3.25-9.88 ppm) for all samples (twenty).

Levels of Ca should be in the range of 300 to 400 ppm. The vast majority (sixteen) of the topsoils and subsoils displayed more than adequate (359 - 5578 ppm) levels, while a limited number (four) were deficient (259 - 297 ppm).

In the case of the subsoils, nutrient deficiencies are of no consequence unless the material is to be utilized for rehabilitation purposes, at which stage the deficiencies should be ameliorated.

Table 2.9.2 (a): Soil Analytical Data for Boshoek

'Broad Soil Group'	Soil Form	Sample Reference	Soil Horizon and (Depth cm)	Clay (%)	Exchangeable Cations (ppm)				S-value cmol(+)kg-1clay	CEC cmol(+)kg-1clay	ESP (%)	P (ppm)	pH water
					Ca	Mg	K	Na					
Vertic	previously Arcadia (now a pit)	E166	vertic A (0-30cm)	33.6	1080	1931	152	18	64.7	87.8	0.27	5.73	6.62
		E167	vertic A (60-80cm)	45.1	1317	2735	102	48	65.5	65.5	0.71	3.82	7.36
	Arcadia	E160	vertic A (0-20cm)	47.4	1489	2723	270	18	64.6	88.1	0.19	7.28	7.08
		E161	vertic A (50-70cm)	49.2	1431	3001	133	30	65.7	93.3	0.28	6.13	7.54
	Rensburg	E174	vertic A (0-25cm)	30.5	1385	1368	106	18	60.7	60.7	0.43	3.41	7.39
		E175	vertic A (25-55cm) (clay occurs at 110cm)	40.5	3411	2033	43	21	83.8	83.8	0.27	4.52	8.26
	Arcadia	E176	vertic A (0-30cm)	46.7	3944	2680	188	120	91.5	74.2	1.50	7.86	8.60
		E177	vertic A (30-100cm)	51.1	2982	3232	82	883	89.1	89.5	8.40	4.44	9.24
	previously Arcadia (now an ore dump)	E168	vertic A (0-100cm)	55.8	3405	3051	74	126	76.8	72.9	1.35	7.98	8.57
		E169	vertic A (0-90cm)	51.8	5575	2460	90	44	93.6	77.7	0.47	8.17	8.54
Red apedal	Hutton	E164	orthic A (0-30cm)	22.4	359	525	47	9	28.0	49.2	0.36	6.21	6.67
		E165	red apedal B (50-70cm)	33.9	439	773	43	12	25.7	33.5	0.44	8.69	6.94
	Hutton	E162	orthic A (0-30cm)	21.8	281	253	39	9	16.6	27.6	0.66	7.00	6.54
		E163	red apedal B (50-70cm)	31.7	297	441	31	12	16.5	28.9	0.54	5.06	6.49
	Lichtenburg	E172	orthic A (0-25cm)	18.6	259	215	63	12	17.6	35.7	0.75	5.83	6.23
		E173	red apedal B (25-80cm)	28.8	259	388	27	12	16.0	27.5	0.63	9.55	6.44
	Lichtenburg/Hutton (now a pit)	E158	orthic A (0-30cm)	26.2	569	390	102	14	24.3	42.4	0.54	6.58	6.12
		E159	red apedal B (50-70cm)	30.1	481	433	43	9	20.3	35.5	0.38	3.25	6.57
Neocutanic	Tukulu (strong-brown colour) [now a 'topsoil' stockpile]	E170	orthic A (0-20cm)	23.9	519	541	59	16	30.4	50.8	0.58	9.88	6.05
		E171	neocutanic B (20-50cm)	34.1	711	871	47	18	32.0	51.3	0.46	4.23	6.44

2.9.3 Erosion Hazard and Slope

Slope in the survey area varies as follows:

Natural Areas:
very gently (>1 - 2 degrees) sloping (vast majority) [92 % of natural areas]; and
gently (>2 - <5 degrees) sloping (very rarely – north-eastern boundary area, and close to streams) [8 %].

Rehabilitated Areas: (Witbank soil form)
very gently (>1 - 2 degrees) sloping (frequently) [approximately 34 % of rehabilitated areas]; and
gently (>2 - <5 degrees) sloping (dominant) [approximately 55 %];
moderately (>5 - <10 degrees) sloping (very rarely) [1.95 % / 2.79 ha]; and
moderately steeply to steeply (>10 - <25 degrees) sloping (occasionally) [9.33 % / 13.32 ha).

The maximum critical slope at which unacceptable levels of soil erosion will begin to occur (bare soils without vegetative cover) for the in-situ (undisturbed natural areas), and rehabilitated areas (two scenarios) is as follows:

i) In-situ soils

Unacceptable levels of soil erosion are likely to occur on bare soils with slopes of greater than:
10.0 % (5.7 degrees) [vertic, man-made vertic phase, hydromorphic, shallow, and possibly pedocutanic soils]; to
13.2 % (7.5 degrees) [red apedal, red structured, man-made red apedal phase, yellow-brown apedal, and neocutanic soils].

Slope was not a limiting factor in the survey area with regard to the determination of the arable capability class since the soils which were deep enough to qualify as arable (≥75cm) occurred in areas where the slope was less than 10.0% (5.7 degrees) or 13.2 % (7.5 degrees) [two critical erosion slopes selected to represent the range of broad soil groups which occur]. Other very limited steeper sections display soils of intermediate (<75cm) to shallow (<25cm) depth, and thus already classify as grazing or wilderness areas.

ii) Rehabilitated ‘topsoiled’ areas overlying building rubble and spoil [not compacted]
[i.e. rehabilitated ‘topsoiled’ areas overlying all man-made features not included in point iii); as well as those of the overburden rock/spoil/ ‘softs’ dumps that remain in perpetuity due to the bulking factor associated with replacing overburden rock in the pit]

Vertic (also applied to the man-made vertic phase, and possibly pedocutanic) soils: A-horizons preferred: 10.0 % (5.7 degrees) [non-vegetated, but slightly steeper (undetermined) after re-vegetation].

Although these slopes are also applicable to the shallow and hydromorphic soils, these soils are not suitable for rehabilitation 'topsoiling' purposes, as a surface placement.

Red apedal/red structured (also applied to the man-made red apedal phase, yellow-brown apedal, and neocutanic) soils: A-horizons preferred: 15.7 % (8.9 degrees) [non-vegetated, but slightly steeper (undetermined) after re-vegetation].

iii) Rehabilitated 'topsoiled' areas overlying a compacted 're-moulded' 'seal' layer
[i.e. the 'seal' layer must overly rehabilitated slag dumps (to be determined), tailings/slimes dams, and pollution control/return water dams (i.e. ponds), at the time that these features become redundant]

In terms of the overlying non-compacted 'topsoil' layer (and thus the slope of the feature), the following slopes should not be exceeded when utilizing:

Red apedal or red structured soils (first choice), A-horizons only: 9.9 % (5.6 degrees) [non-vegetated, but slightly steeper (undetermined) after re-vegetation], or

Vertic or pedocutanic soils
A-horizons only: .2 % (5.2 degrees) [non-vegetated, but slightly steeper (undetermined) after re-vegetation].

Only vertic soils should be utilized for the underlying compacted 're-moulded' 'seal' layer in the area.

Given the method which the mine utilizes for the 'topsoil' [suitable topsoil (A-horizon) and subsoil (B-horizon)] stripping and stockpiling operations, A-horizon and B-horizon mixing is likely, despite the fact that it would be desirable to strip and 'topsoil' these reserves separately (A-horizons replaced at the surface).

2.9.4 Dryland/Irrigated Production Potential

Dryland crops are not recommended in the area due to the low mean annual precipitation (approximately 641mm in Rustenburg) and thus the high associated risk (occasional droughts).

Dryland yields are rainfall dependant; and vary as follows: sunflowers (0.8 – 3.0 tons/ha, average years 1.5 – 2.0 tons/ha); soya beans (1.5 – 1.8 tons/ha); wheat (2.8 – 3.8 tons/ha); and maize (average 3.0 tons/ha). Sorghum is also occasionally planted.

However, irrigated yields (with high levels of management) are high, the following yields having been obtained by farmers in the area: maize (12.0 – 14.8 tons/ha), wheat (6.5 – 7.5 tons/ha), sunflowers (3.8 – 4.0 tons/ha); soya beans (3.0 – 3.5 tons/ha); beetroot (26.2 tons/ha); carrots (30.8 tons/ha); spinach (7.3 tons/ha); cabbage (135.0 tons/ha); and onions (85.0 – 95.0 tons/ha).

Irrigation potential is based on the characteristics of the soils that occur, and generally varies as follows:

very high - high (red apedal, red structured, and yellow-brown apedal soils);
high (non-hard-setting pedocutanic soils with a 'red' colour, and neocutanic soils);
moderate (non-hard-setting pedocutanic soils with a 'dark-brown' or 'brown' colour);
low (vertic [although high yields can be achieved with high levels of management], man-made, and luvic or hard-setting pedocutanic soils with a 'grey' colour); or
unsuitable (shallow, hydromorphic, and alluvial [due to proximity to stream] soils);
effective rooting depth and texture being the major determining factors in the area.

2.9.5 Land Capability

The survey area is comprised of the following capability classes:

- Wetland (permanent) streams and donga [i.e. natural drainage features] (11.53 ha 1.06 %);
- wetland (permanent) vertic soils in concave/lower-midslope/valley-bottom/footslope positions (117.64 ha, 10.77 %);
- wetland (permanent) man-made vertic soils in midslope positions (1.42 ha, 0.13 %);
- wetland (permanent) hydromorphic soils in valley-bottom and footslope positions (8.29 ha, 0.76 %);
- wetland (seasonal) hydromorphic soils in concave/footslope/valley-bottom positions (3.92 ha, 0.36 %);
- wetland (temporary) pedocutanic/neocutanic soils in concave/lower-midslope positions (27.43 ha, 2.51 %);
  Note: Total Wetland Soils excluding stream/donga (158.70 ha, 14.53 %);
- riparian alluvial soils on stream banks (8.21 ha, 0.75 %);
- arable soils with an orthic topsoil (185.21 ha, 16.96 %);
- arable soils with a vertic (occasionally melanic) topsoil (108.32 ha, 9.92 %);
  Note: Total Arable Soils (293.53 ha, 26.87 %);
- grazing soils with an orthic topsoil (97.17 ha, 8.90 %);
- grazing soils with a vertic (occasionally melanic) topsoil (46.79 ha, 4.28 %);
  Note: Total Grazing Soils (143.96 ha, 13.18 %);
- wilderness soils with an orthic topsoil (3.88 ha, 0.36 %);
- wilderness soils with a melanic topsoil (6.34 ha, 0.58 %);
  Note: Total Wilderness Soils (10.22 ha, 0.94 %);
- rehabilitated arable (78.70 ha, 7.21 %);
- rehabilitated grazing (45.79 ha, 4.19 %);
- rehabilitated wilderness (16.76 ha, 1.53 %);
- rehabilitated wilderness, overlying buried in-situ soils (14.42 ha, 1.32 %);
  Note: Total Rehabilitated Areas (155.67 ha, 14.25 %); and
  Note: Total Soils, and Natural Drainage Features (781.82 ha, 71.58 %).
- the balance of the survey area (310.45 ha, 28.42 %) is comprised of existing man-made features (man-made wilderness capability class). Total survey area 1092.27 ha.

2.10 GEOLOGY/ GEOCHEMISTRY/PALAENTOLOGY BASELINE

JMA Consulting (Pty) Ltd conducted a detailed geological base line assessment for the Glencore Merafe Boshoek Mine and Smelter (GMBS) study area. The comprehensive Geology/Geochemistry/Palaeontology Specialist Baseline Report is attached as **APPENDIX 2.10 (A).**

2.10.1 Introduction

The geology of the study area forms the basis for the topography, soils, vegetation, groundwater and surface water components of the biophysical environment. The opencast mining operations at GMBS as well as the extensive opencast and underground mining operations adjacent to GMBS are dependent on the nature of the underlying geology as well. The geology and nature thereof therefore represent a crucially important component of the overall environment.

A fundamental understanding of the regional geology, as well as a site specific quantitative description of the geology at and adjacent to GMBS is thus a prerequisite on which to base impact assessments for the geophysical as well biophysical environments and from which to design and implement effective environmental management measures related to these environmental components.

The geology baseline description is compiled with reference to available information pertaining to the site as well as with regards to the quantitative site specific geological information generated during the field investigations. The geology baseline description provides an indication of the regional geological setting of the study area, the site-specific geology as well as information regarding the current and historical mining activities at and adjacent to the study area. The geology baseline description is further documented in such a manner to support the information required for the respective applications in terms of the MPRDA, the NEMA, the NEMWA as well as the NWA.

2.10.2 Regional Setting

The GMBS operations are located approximately 30 km to the north-west of Rustenburg in the North West Province of South Africa. The site falls within the Rustenburg Local Municipality within the Bojanala Platinum District Municipality (DC37).

The GMBS study area is flanked by the Magaliesberg Mountain Range to the west and south-west and by the Pilanesberg to the north. The land use adjacent to GMBS is dominated by agricultural and mining related activities. The study area is located within the western limb of the Bushveld Igneous Complex (BIC). The BIC is subdivided into a felsic suite namely the Rooiberg Group and three mafic suites, namely the Lebowa Granite Suite, the Rashoop Granophyre Suite and the Rustenburg Layered Suite. The mining operations take the form of opencast and underground operations that exploit the Rustenburg Layered Suite (RLS) of the BIC for its chrome, platinum and platinum group element (PGE) content. The LG-6 chromitite layer, UG-2 chromitite layer and the Merensky Reef are the main reefs that are currently being at and to the east of GMBS.

2.10.3 Regional Geology

The regional geology of the study area is discussed with reference to data obtained in the field as well as the map extract from the 1:250 000 Geological Map Series of the Republic of South Africa - Sheet 2526 Rustenburg, (1981), depicted as Figure 2.10.3(a).

The study area is located within the western limb of the BIC and is underlain by RLS lithologies which dip at an angle of between 10^o and 12^o to the north-east. These lithologies range from norites and anorthosites through to gabbros, harzburgites, magnetites and pyroxenites. The western limb of the BIC has been and is still currently being extensively mined for chromium and platinum group elements by both opencast and underground mining methods.

The surface geology to the far west and south-west of the study area consists predominantly of lithologies of the Magaliesberg Formation (Vm) and Silverton Formation (Vsi) of the Pretoria Group. The Magaliesberg Formation sandstones and quartzites are highly resistant and give rise to the Magaliesberg Mountain Range. The Magaliesberg Formation gradationally overlies the Silverton Formation which consists predominantly of high-alumina shales (Eriksson, P.G et al (2006)).

The surface geology to the east of the Magaliesberg Formation and west and south-west of GMBS consists of Kolobeng Norites (Vn) of the BIC which intruded into and above the Magaliesberg Formation quartzites and argillaceous Silverton Formation lithologies of the Pretoria Group. The Silverton Formation has further been intruded by diabase (di) dykes to the south-west of the study area as well.

The Kolobeng Norites are overlain by Ruighoek Pyroxenites (Vcr) to the east and north-east. The Ruighoek Pyroxenites outcrop across the entire extent of the current GMBS. The Ruighoek Pyroxenites are further overlain by the Mathlagame Norites and Anorthosites (Vcm) and Pyramid Gabbro-Norites (Vg) which make up the majority of the surface geology to the east and north-east of GMBS. Quaternary sedimentary deposits (Q) occur within the topographically lower lying areas to the east and north-east of the study area as well as well as adjacent to the major surface water drainage bodies.

The Kolobeng Norites, Ruighoek Pyroxenites, Mathlagame Norites, and Pyramid Gabbro-Norites all form part of the Rustenburg Layered Suite of the Bushveld Igneous Complex. The Rustenburg Layered Suite consists of five distinct zones, namely the; Upper Zone, Main Zone, Critical Zone, Lower Zone and Marginal Zone. The Mathlagame Norites and Anorthosites and Pyramid Gabbro-Norites within the study area are confined to the economically important Upper Critical and Main zones of the Rustenburg Layered Suite.

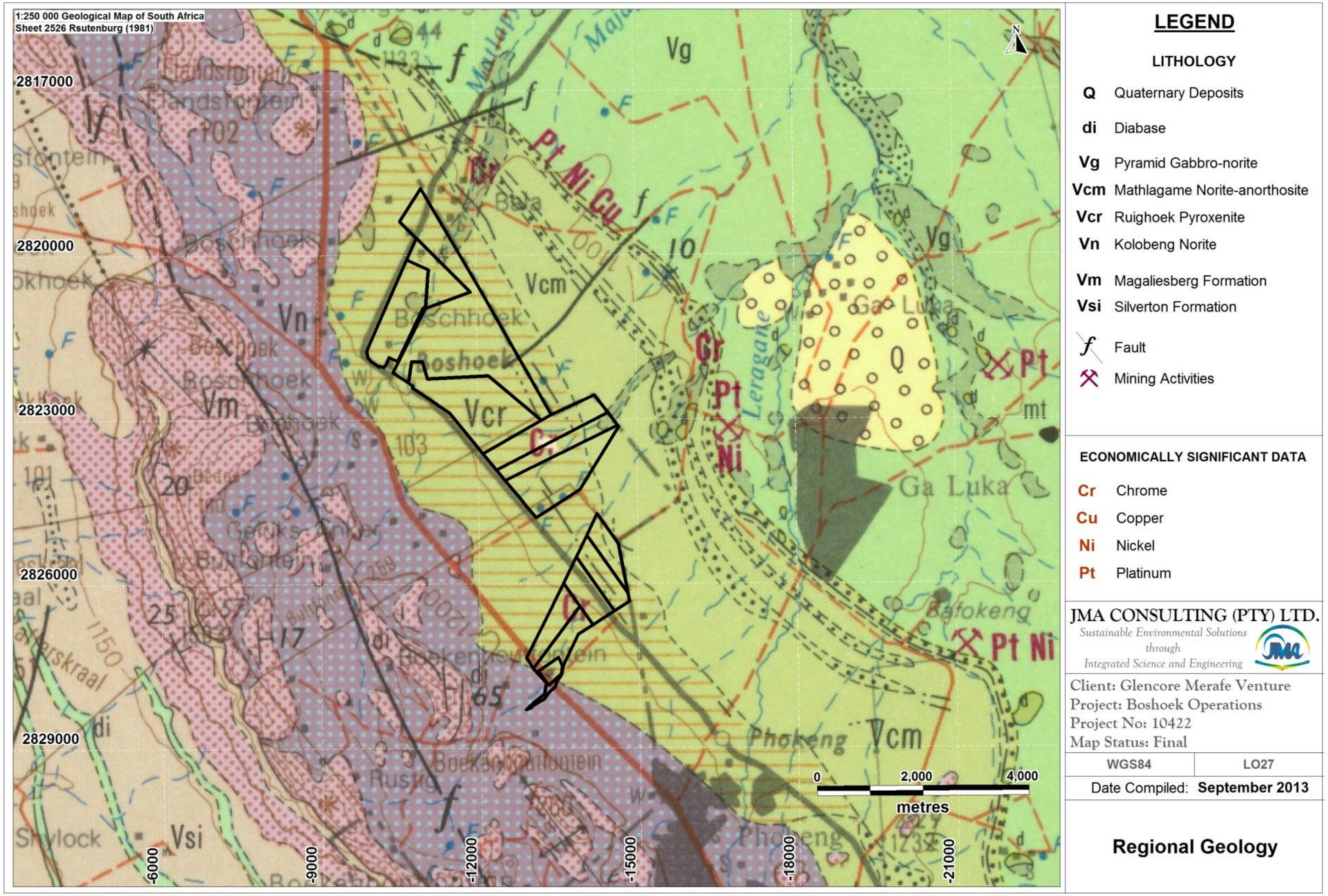

Figure 2.10.3(a): Regional Surface Geology of the Study Area

Some of the more important and economically exploitable horizons within the BIC include the LG-6, UG-2, UG-1 and MG-1 chromitite layers as well as the Merensky Reef. The Lower Group (LG) and Middle Group (MG) chromitite layers of the Rustenburg Layered Suite sub-outcrop within the study area. These chromitite layers have a north-west to south-east strike and are currently being exploited for their chromium content. The chromitite layers which are of primary economic interest at GMBS are the LG-6 and MG-1 chromitite layers.
It is inferred that Platinum (Pt), Chrome (Cr), Copper (Cu) and Nickel (Ni) have historically and are currently being mined from within the Upper Critical and Main zones of the Rustenburg Layered Suite within the study area.

Large scale faulting is observed within the study area as well, the most predominant being the sinistral fault that trends in a north-easterly direction directly to the north-east of GMBS, the dextral fault that trends in a north-easterly direction to the north of GMBS as well as the north-west trending fault to the west of the study area.

2.10.4 Site Geology

2.10.4.1 Lithology

The geology underlying the study area was verified and assessed during the drilling of 15 geological / geohydrological investigative boreholes in addition to the geological information obtained from the geological exploration boreholes and information contained within GMBS's Amended Mining Work Programme (March 2012). The localities of the geological investigative boreholes (BGW-) and exploration (BH & BFN) boreholes are depicted on Figure 2.10.4(a) and Figure 2.10.4(b) respectively.

The geological / geohydrological investigative boreholes were drilled to a depth that fully intersected the shallow weathered zone aquifers and were drilled to an average depth of 30.44 meters below ground level (mbgl). The lithology that was penetrated, its weathering and fracturing status as well as its water yielding capacity was recorded for each borehole during the drilling operations. Borehole logs and site information reports were generated for each of the fifteen boreholes and are attached as APPENDIX III to geology baseline report.

The host rock matrix at GMBS (down to an average depth of 30.44 mbgl) comprises predominantly of weathered, fractured and fresh norites, anorthosites (Mathlagame Norite-anorthosite) and pyroxenites (Ruighoek Pyroxenites), extensively covered by soil and / or overburden material at the surface.

The soil comprises of a dark brown to greyish brown structured fine grained and clayey "turf" soil derived from the predominantly noritic parent material. The thickness of the soil penetrated during the drilling of the 15 investigative boreholes varied between 0.0 m and 3.0 m, with an average thickness of 1.7 m. Large areas of soil have either been covered by overburden material or have been removed, due to the current opencast mining operations as well as during the construction of the beneficiation plant and associated surface activities.

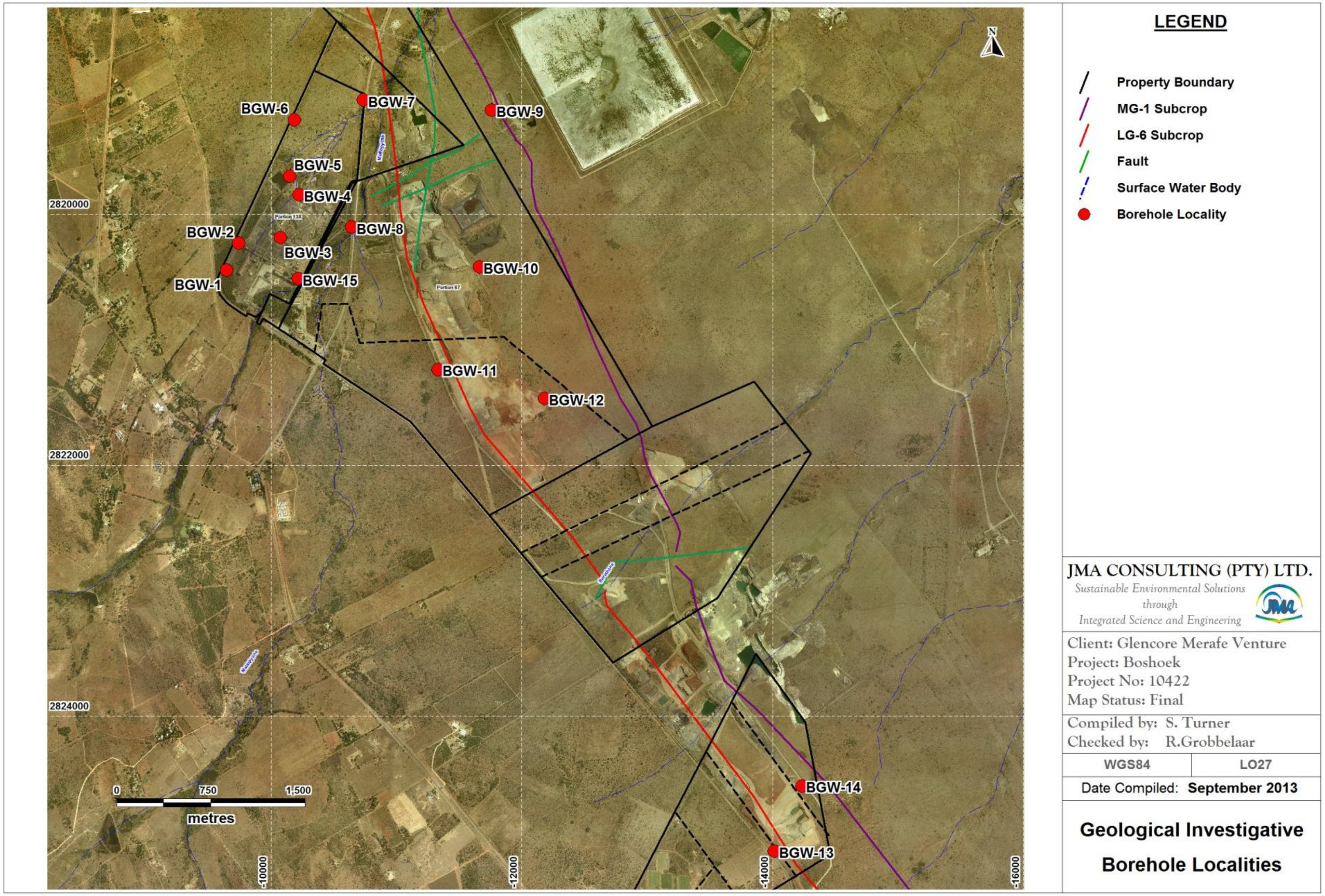

Figure 2.10.4(a): Geological Investigative Borehole Localities

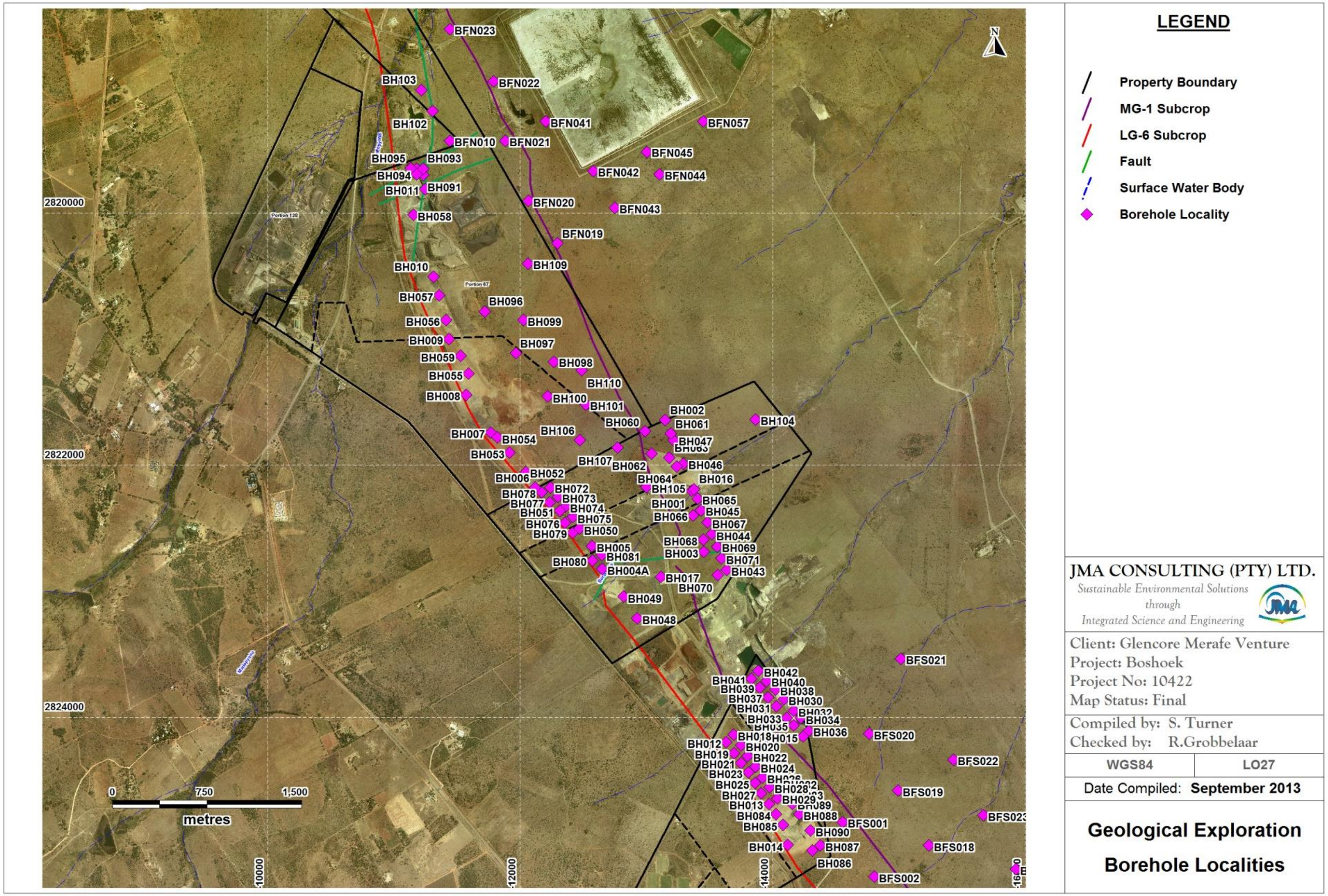

Figure 2.10.4(b): Geological Exploration Borehole Localities

The norite penetrated is predominantly grey to dark grey in colour and is medium grained in texture. The norite comprises predominantly of pyroxenes and plagioclase feldspars, with biotite, hornblende and mica's observed in several of the samples. Gabbro-norite was observed in one of the boreholes as well. The anorthosite penetrated is predominantly light grey in colour and is medium to course grained in texture. The anorthosite comprises mainly of plagioclase feldspars and is also basic in composition. The norite is less resistant to weathering than the anorthosite and weathers into a soft gritty material. The pyroxenite penetrated is predominantly dark grey in colour and is medium grained in texture. The pyroxenite comprises predominantly of pyroxenes, with minor amounts of biotite observed and is ultrabasic in composition.

Although not penetrated in any of the boreholes (due to the restricted depth of drilling as well as the extent of the current mining operations), several chromitite layers are present within the study area. The LG-6 and MG-1 chromitite layers are of economic importance in the study area and currently being mined by opencast mining operations within the eastern extent of the study area. The information obtained from the exploration boreholes indicates that the LG-6 chromitite layer has an average thickness of 0.97 m whilst the MG-1 chromitite layer has an average thickness of 0.78 m.

The MG-2, MG-3 and LG-6A chromitite layers within the study area are of poor quality and are thus, often treated as part of the overlying overburden material. Transgressive dykes, rolls, potholes and fault structures are indicated to often influence and negatively impact continuity of the chromitite layers exploited.

2.10.4.2 Weathering / Fracture Profile

The depth of weathering and weathering related fracturing is relatively deep and varies between 19.0 m and 30.0 m, with an average depth of 25.5 m. The norite weathers down to a soft gritty matrix, whilst the anorthosite appears to weather slightly to a course consolidated gravel matrix. The weathering fracture profile depth is combination of the primary weathering profile and the transitional fracturing zone which occurs immediately above the fresh bedrock interface.

The depth of weathering and weathering related fracturing, is an important attribute from a geohydrological perspective. This zone essentially represents the bulk of what is commonly referred to as the weathered zone aquifer. Within the GMBS geological setting, weathered zone aquifers will constitute the major ground water zones, both from a recharge and storage perspective.

2.10.4.3 Geochemistry

The mineralogical composition of the geology samples collected was determined by means of X-Ray Diffraction (XRD) analyses. The elemental analyses of the material samples were determined by means of X-Ray Fluorescence (XRF) analyses. The elements that could potentially leach from the lithologies sampled as well as their potential concentrations were determined by means of Distilled Water Static Leaching tests. The XRD, XRF and Distilled Water Static Leaching test results are attached as APPENDIX IV, APPENDIX V and APPENDIX VI to the Geology Specialist Report respectively.

The lithologies penetrated during the drilling operations comprise entirely of oxides and silicates. No sulphide and sulphate mineral phases were identified in the geology samples analysed. The soil sample is an in-situ soil formed from the weathering of the underlying mafic to ultramafic host rocks.

The topsoil sampled (BGC-1) is deemed representative of the topsoil within the study area and originates from the in-situ weathering of the mafic to ultramafic rocks host rocks, with almost no relics of the original host rock remaining in the topsoil. Quartz (39.1%), smectite (swelling clay) (35.6%) and palygorskite (fibrous clay) (22.3%) are the dominant mineral phases present in the topsoil and are typical weathering products of minerals from the mafic to ultra-mafic host rocks. In general, clay is the major weathering product of mafic to ultramafic rocks. The topsoil in very similar in composition to the anorthosite (BGC-3) which is a highly weathered anorthosite sample and is almost characterised as a clayey soil.

The norite sampled (BGC-2) consists predominantly of enstatite (ortho-pyroxene) (60.7%) as well as plagioclase feldspar (25.1%) as major mineral phases. Norite is typically characterised with having ortho-pyroxene and plagioclase as major minerals. The anorthosite sampled (BGC-3) consists predominantly of quartz (51.7%), palygorskite (21.6%) and smectite (17.5%) as the major minerals. Anorthosite is typically characterised with having more than 90% plagioclase feldspar and the sample is therefore indicative of a highly weathered sampled.

The pyroxenite sampled (BGC-4) comprises predominantly of enstatite (40.1%), smectite (18.8%), hornblende (13.7%) and talc (9.5%). The smectite present in the sample is a product of and indicates the weathering of mafic minerals. The gabbro-norite sampled (BGC-5) is similar in composition to the norite sample collected and together indicate the two least weathered sampled. The pyroxenite comprises mostly of enstatite (77.0%) and plagioclase feldspar (19.7%) as the major mineral phases.

In order to provide an indication of geochemical makeup of the samples collected their major oxide and trace element concentrations are assessed with regards to the geochemistry of the average upper crust (AUC) lithologies, taken from Rudnick and Gao (2003). The average upper crust values serve as a standard reference used to determine whether the analysed components within the material are expected to be elevated or depleted in certain elements.

The following has reference with regards to the geochemical assessment of the 5 samples collected and the AUC concentrations stipulated by Rudnick and Gao (2003):

- The geochemical analyses of the topsoil and geology samples collected indicate that in each sample collected the major oxides of the dominant/major minerals in the samples collected were elevated above the stipulated AUC values.
- Only Al_2O_3, Na_2O, K_2O and SO_3 had concentrations below the stipulated AUC concentrations in each of the samples collected.

- The SiO_2 composition ranges between 51.0% and 81.6% and is slightly elevated in the topsoil (72.8%) and anorthosite (81.6%) samples which are both similar in composition.
- The TiO_2 composition ranges between 0.2% and 1.0% and is slightly elevated in the topsoil (0.7%) and pyroxenite (1.0%) samples.
- The Fe_2O_3 composition ranges between 4.4% and 15.2% and is elevated in the norite (12.9%), pyroxenite (15.2%) and gabbro-norite (14.2%) samples.
- The MnO composition ranges between 0.06% and 0.3% and is elevated in the topsoil (0.2%), norite (0.2%), pyroxenite (0.3%) and gabbro-norite (0.2%) samples.
- The MgO composition ranges between 2.1% and 20.8% and is slightly elevated in the topsoil (3.6%) sample. The MgO is however significantly elevated in the norite (15.9%), pyroxenite (19.1%) and the gabbro-norite (20.8%) samples.
- The CaO composition ranges between 0.4% and 5.6% and is slightly elevated in the norite (5.6%) and gabbro-norite (3.8%) samples.
- The P_2O_5 composition ranges between <0.01% and 0.9% and is elevated in the norite (0.9%), pyroxenite (0.4%) and gabbro-norite (0.5%) samples.
- The Cr_2O_3 composition ranges between 0.3% and 1.8% and is substantially elevated in each of the 5 samples collected. The Cr_2O_3 concentration is the most elevated in the gabbro-norite sample (1.8%), followed by the pyroxenite (0.6%), norite (0.4%), anorthosite (0.3%) and topsoil (0.3%) samples.
- The trace elements that exceeded the AUC concentrations in each of the 5 samples collected include: chlorine (Cl), hafnium (Hf), molybdenum (Mo), neodymium (Nd), nickel (Ni), lead (Pb), vanadium (V), tungsten (W) and zinc (Zn).
- The following trace elements exceeded the AUC concentrations in at least 1 of the 5 samples collected: cobalt (Co), copper (Cu), lanthanum (La), niobium (Nb), antimony (Sb), scandium (Sc), samarium (Sm), tin (Sn), tantalum (Ta), thorium (Th), yttrium (Y), ytterbium (Yb) and zircon (Zr).
- The AUC concentrations stipulated by Rudnick and Gao (2003) are stringent and only 17 of the 39 trace elements analysed are lower than the AUC concentrations in 5 samples collected.

Distilled Water Leaching tests were further conducted on each of the 5 samples collected in order to identify and quantify the elements that could potentially leach out topsoil and underlying geology at GMBS.

During the distilled water leachate analyses, the material samples were crushed to <9.5 mm and the appropriate mass of the material (50 ml) is reacted with 1 litre of distilled water solution for 18 hours. The 1:20 solution was agitated on an orbital shaker and was filtered through a 0.45 μm sieve and preserved with 10% nitric acid (HNO_3) before being analysed by means of a quantified Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) analyses method.

The elemental concentrations in the leachate were assessed with regards to the South African National Standard (SANS) 241 – Drinking Water (2011) Edition 1 (SANS 241:2011 Drinking Water Standard), published by the South African

Bureau of Standards (SABS) Standards Division in June 2011 for mere academic reference and assessment purposes.

Water qualities that comply with concentrations stipulated within Part 1 of SANS 241:2011 is deemed to present an acceptable health risk for a lifetime consumption (this implies an average consumption of 2 l of water per day for 70 years by a person that weighs 60 kg).

The following observations are made with regards to the distilled water leaching test results:

- The distilled water leaching tests do not directly reflect the site-specific conditions as well as the exact concentration of these elements in actual seepage as a different water/rock ratio and contact time will be present in the field.
- The distilled water leaching tests were performed to 1) identify the elements that will leach out of samples and 2) give an indication of the concentration and elevation of these elements with regards to a certain standard.
- The pH of the leachates remains neutral between 6.8 and 7.6.
- The TDS of the leachate is low and ranges between <10 mg/l and 64 mg/l. The TDS is the highest in the leachate from the topsoil sample and may be influenced by certain surface conditions.
- NO_3 was only detected (0.4 mg/l) in the leachate in one of the samples (Anorthosite).
- F was only detected in two of the leachates at concentrations of 0.4 mg/l and 0.2 mg/l for the topsoil and anorthosite samples respectively.
- The Al concentrations in the leachates were elevated and ranged in concentration between 1.45 mg/l and 12.00 mg/l. The Al concentration is the highest in the leachate obtained from the topsoil sample.
- The calcium concentrations in the leachates are low and range between 1.0 mg/l and 4.0 mg/l.
- The Cr concentration in the leachates ranged between 0.005 mg/l and 0.057 mg/l and was the highest in the leachate obtained from the topsoil sample.
- The Fe concentration in the leachates were elevated and ranged between 1.90 mg/l and 12.19 mg/l and was the highest in the leachate obtained from the topsoil sample.
- The K concentration in the leachates ranged between 0.32 mg/l and 0.98 mg/l whilst the Mg concentration in the leachates ranged between 4.0 mg/l and 9.0 mg/l, with an average concentration of 6.6 mg/l for the 5 samples.
- The Na concentration in the leachates ranged significantly between 0.03 mg/l and 18.00 mg/l.

Piper and Durov Diagrams of the leachates were created using the macro chemistry variables pH, EC, Ca, Mg, Na, K, Total Alkalinity, Cl and SO_4 and are depicted as Figure 2.10.4.3(a).

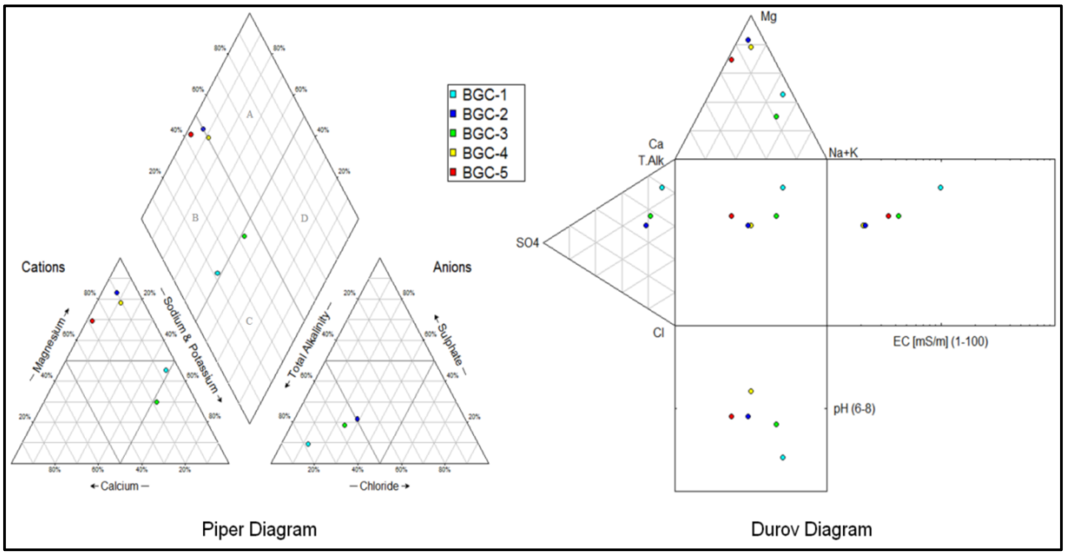

Figure 2.10.4.3(a): Piper and Durov Diagrams of the Distilled Water Leachates

The Piper and Durov Diagrams indicate that the leachates obtained from the norite (BGC-2), pyroxenite (BGC-4) and gabbro-norite (BGC-5) samples are similar in composition, with Mg^{2+} as the major cation. The leachates obtained from the topsoil (BGC-1) and anorthosite (BGC-3) samples are similar in composition, with an increase in the Na^{+} and K^{+} milliequivalent (meq) concentrations.

The leachate obtained from the norite, pyroxenite and gabbro-norite samples is characterised as having a Type-A to Type-B hydrochemical image, with dominant cations Mg^{2+} and dominant anion HCO_3^{-}. The leachates obtained from the topsoil and anorthosite samples is characterised as having a Type-B to Type-C hydrochemical image, with a mixture of dominant cations between Mg^{2+}, Na^{+} and K^{+} and dominant anions HCO_3^{-}.

2.10.5 Faults and Dykes

A geophysical assessment was not performed to delineate faults and dykes within the study area for the purpose of this geology specialist study. The faults that are indicated in GMBS Amended Mining Works Programme are delineated on Figure 2.10.4.4(a).

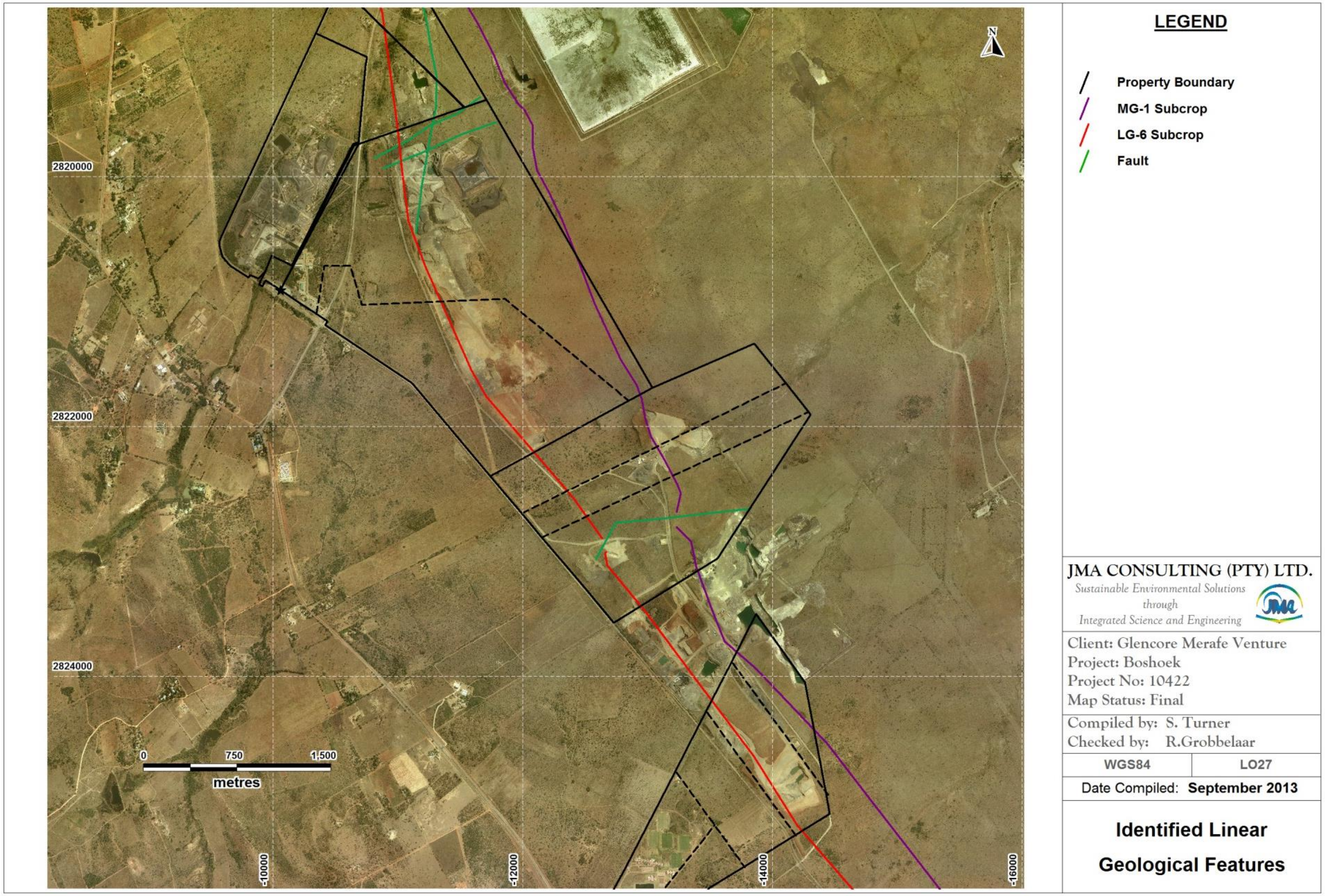

Figure 2.10.4.4(a): Delineated Economically Significant Chromitite Layers and Faults

Several large scale faults have been identified and delineated within the study area. The most predominant faults are the sinistral fault that trends in a north-easterly direction directly to the north-east of GMBS, the dextral fault that trends in a north-easterly direction to the north of GMBS as well as the north-west trending fault to the west of GMBS. The east-west trending faults identified have displaced the host rock lithologies including the LG-6 and MG-1 chromitite layers within portion 67 of Boshoek 103 JQ and Portions 10 of Bultfontein 259 JQ.

2.10.6 Mining Operations

There are currently two separate opencast mining operations at GMBS, located on Portions 66 and 67 of the Farm Boschoek 103 JQ and Portions 28, 29 and the Remaining Extent of Portion 27 of the Farm Boekenhoutfontein 260 JQ. GMBS currently sub-contracts the operation of their opencast mining activities to Benhaus Mining (Pty) Ltd and Andru Mining (Pty) Ltd. The northern opencast mining operations are being operated by Benhaus Mining and the southern opencast mining operations are being operated by Andru Mining. The extent of northern (Benhaus) and southern (Andru) opencast mining areas are delineated on Figure 2.10.5(a).

The opencast mining operations have historically and currently predominantly extract chromitite ore from the LG-6 and MG-1 chromitite layers of the Rustenburg Layered Suite, which forms part of the Bushveld Igneous Complex. Both mining operations are currently associated with the mining of the LG-6 chromitite layer. The MG-1 opencast resources have been exhausted and no mining operations are currently exploiting the MG-1 chromitite layer.

There are no opencast mining operations that are currently taking place in the southern mining area as Andru Mining (Pty) Ltd has completed rehabilitation and has vacated the site. Rehabilitation was completed in September 2013. Mining Operations within the northern opencast mining area operated by Benhaus has ceased in February 2013 and the rehabilitation of the pit was completed in January 2014 excluding the workshop area which is anticipated to be completed by end March 2014.03.07

There are certain infrastructure that will remain on both Andru and Benhaus mining areas for possible future mining purposes (security available to look after the infrastructure). This infrastructure includes:

- Roads
- Concrete slabs in workshops
- Fences
- Guard Houses
- Chrome stockpiles (to be collected)

All the ore mined at Glencore Merafe Boshoek is sold to outside consumers and is not used at the GMBS Ferrochrome beneficiation plant.

The minerals currently exploited at GMBS (as obtained from the Amended Mining Work Programme (March 2012)) are listed in Table 2.10.5(a), with chromite being the primary mineral exploited.

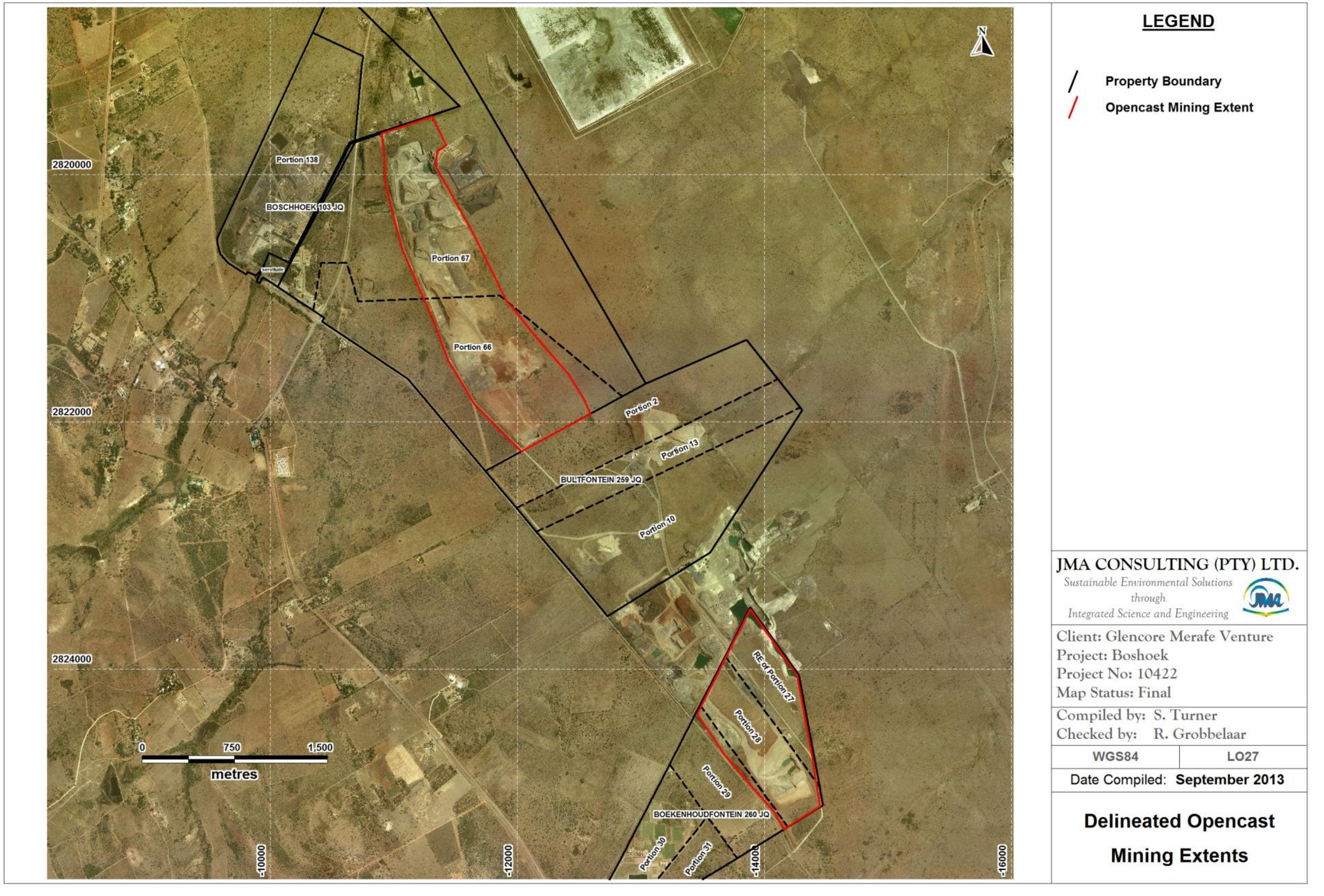

Figure 2.10.5(a): Delineated Opencast Mining Extents

Table 2.10.5(a): Minerals Currently Exploited at Glencore Merafe Boshoek's Mining Operations

Mineral	Primary / Associated	Definition as per MPRDA			
		Code	Commodity	Type Code	Type Description
Chromite	Primary	Cr	Chrome Ore	B	Ferrous and base metals
Platinum Group Minerals	Associated	PGM	Platinum Group Metals	PGM	Platinum Group Minerals
Copper Ore Minerals	Associated	Cu	Copper Ore	B	Ferrous and base metals
Gold Ore Minerals	Associated	Au	Gold Ore	GS	Gemstones (except diamonds)
Nickel Ore Minerals	Associated	Ni	Nickel Ore	B	*Ferrous and base metals*
Lead Ore Minerals	Associated	Pb	Lead	B	*Ferrous and base metals*

The mineral content of the various chromitite layers identified at GMBS are indicated by the Cr_2O_3 grade, which is expressed as the Cr_2O_3 mass percentage (%). The average Cr_2O_3 grade (%) of the various chromitite layers identified at GMBS are listed in Table 2.10.5(b).

Table 2.10.5(b): Average Cr_2O_3 grade (%) of the Chromitite Layers at GMBS

Chromitite Layer	MG4C	MG4B	MG4A	MG3	MG2	MG-1	LG-6A	LG-6	LG5
Cr_2O_3 (5%)	30.66	32.91	33.30	33.87	37.82	**39.15**	33.33	**40.08**	37.53

The Mineral Resources and Mineral Reserves are obtained from the Amended Mining Work Programme (March 2012) and are reported using the Joint Ore Reserves Committee (JORC) Code as a guideline. The Mineral Resources and Mineral Reserves quantification and categories are based on the exploration drilling that has been done at GMBS. The drilling is planned according to a regular 200 m x 200 m grid, although this is not permitted in certain areas due to various infrastructure and facilities at the surface. The Mineral Resources at GMBS are categorised and listed in Table 2.10.5(c) below for the area as at 30 June 2010.

Table 2.10.5(c): GMBS Mineral Resource Categories

Mineral Resource Category	Inferred	Indicated	Measured
Tonnage (Mt)	-	15.93	1.41
Grade (% Cr_2O_3)	-	40.20	40.28

2.10.7 Site Palaeontology

As described in the preceeding sections, the project area is situated entirely on norites and anorthosites through to gabbros, harzburgites, magnetites and pyroxenites of Rustenburg Layered Suite of the Precambrian Bushveld Igneous Complex.

As the rocks of the Bushveld Complex are of igneous origin there is no possibility of fossils being present. If there are Tertiary-Quaternary alluvial deposits in the low-lying areas there is a slight, but very unlikely, possibility that fossils could be present. However the geological map does not indicate the presence of alluvial deposits.

It is therefore concluded that the GMBS operations will not negatively affect paleontological heritage.

2.11 GROUND WATER BASELINE

JMA Consulting (Pty) Ltd conducted a detailed ground water base line assessment for the Glencore Merafe Boshoek Mine and Smelter (GMBS) study area. The Geohydrological Specialist Report compiled by them is attached as **APPENDIX 2.11 (A).** The information in this section represents a summary extract from the specialist report and was compiled for Scoping purposes.

2.11.1 Introduction

The groundwater baseline description is compiled with reference to available information pertaining to the site as well as to the quantitative site specific hydrogeological information generated during the field investigations. The groundwater baseline description is documented in such a manner to support the information required for the respective applications in terms of the MPRDA, the NEMA, the NEMWA as well as the NWA.

2.11.2 Regional Setting

The GMBS operations are located approximately 30 km to the north-west of Rustenburg in the North West Province of South Africa. The site falls within the Rustenburg Local Municipality within the Bojanala Platinum District Municipality (DC37).

The GMBS study area is flanked by the Magaliesberg Mountain Range to the west and south-west and by the Pilanesberg to the north. The land use adjacent to GMBS is dominated by agricultural and mining related activities. The Magaliesberg Mountain Range extends across the south-western extent of the study area in south-easterly to north-westerly direction and ranges in elevation between 1500 meters above mean sea level (mamsl) and 1200 mamsl. The surface at GMBS is relatively flat and ranges in elevation between around 1150 mamsl and 1120 mamsl. The average surface gradient at GMBS is 0.01 (1m per 100 m) in a north-easterly direction.

The agricultural activities are dominated by local grazing veld for cattle and small livestock. The mining operations take the form of both opencast and extensive underground operations that exploit the Rustenburg Layered Suite (RLS) of the Bushveld Igneous Complex (BIC) for its chrome, platinum and platinum group element (PGE) content. The LG-6 chromitite layer, UG-2 chromitite layer and the Merensky Reef are the main reefs that are currently being exploited at and to the east of GMBS.

2.11.2.1 Regional Meteorology

The project area falls within the Highveld Climatic Zone, as defined by Schulze (1974), characterized by hot summer months between November and February (average temperature: 23^{o}C) and cold winters from June through to August (average temperature: 13^{o}C). Frost characteristically occurs in the winter months. The rainfall is also seasonal with the majority of the rainfall (84 %) between October and March, generally in the form of thunderstorms.

The mean annual precipitation/rainfall (MAP) for the study area is expected to range between 600 mm/annum and 700 mm/annum (WR2005) with a MAP of 663 mm/annum assigned to the study area.

The mean annual A-Pan evaporation is expected to range between 2200 mm/annum and 2600 mm/annum (WR2005) with an average of 2057 mm/annum assigned to the study area. The mean annual S-Pan evaporation (MAE) is expected to range between 1600 mm/annum and 1700 mm/annum (WR2005) with an MAE of 1612 mm/annum assigned to the study area. This indicates that that study area is characterized by a negative climatic water balance (Climatic Water Balance = MAP - MAE).

2.11.2.2 Regional Surface Drainage

GMBS is located in the south-western regions of the A22F quaternary catchment within the Limpopo River Primary Catchment Area and within the Crocodile (West) and Marico Water Management Area (Figure 2.11.2.2(a). The surface water at GMBS drains in a northerly and north-easterly direction and has been affected by the various surface activities (predominantly mining related) within the area.

The two major surface water drainage bodies of significance are namely the Matlapyane and Borethane drainage bodies. The Matlapyane stream, a non-perennial stream has its source within the Magaliesberg Mountain Range to the south-west of the GMBS and drains in a northerly direction through the Ferrochrome Beneficiation Management Area. The Borethane stream is a non-perennial stream which has its natural source within the Mining Management area at GMBS and drains in a north-easterly direction into the Lerangane River to the north-east of GMBS. Both the Matlapyane and the Borethane streams eventually drain into the Elands River to the north and north-east of GMBS.

The A22F quaternary catchment has a mean annual run-off of between 10 mm/annum and 20 mm/annum (WR2005), which accumulates to a total of between 15 Million m^3/annum and 30 Million m^3/annum.

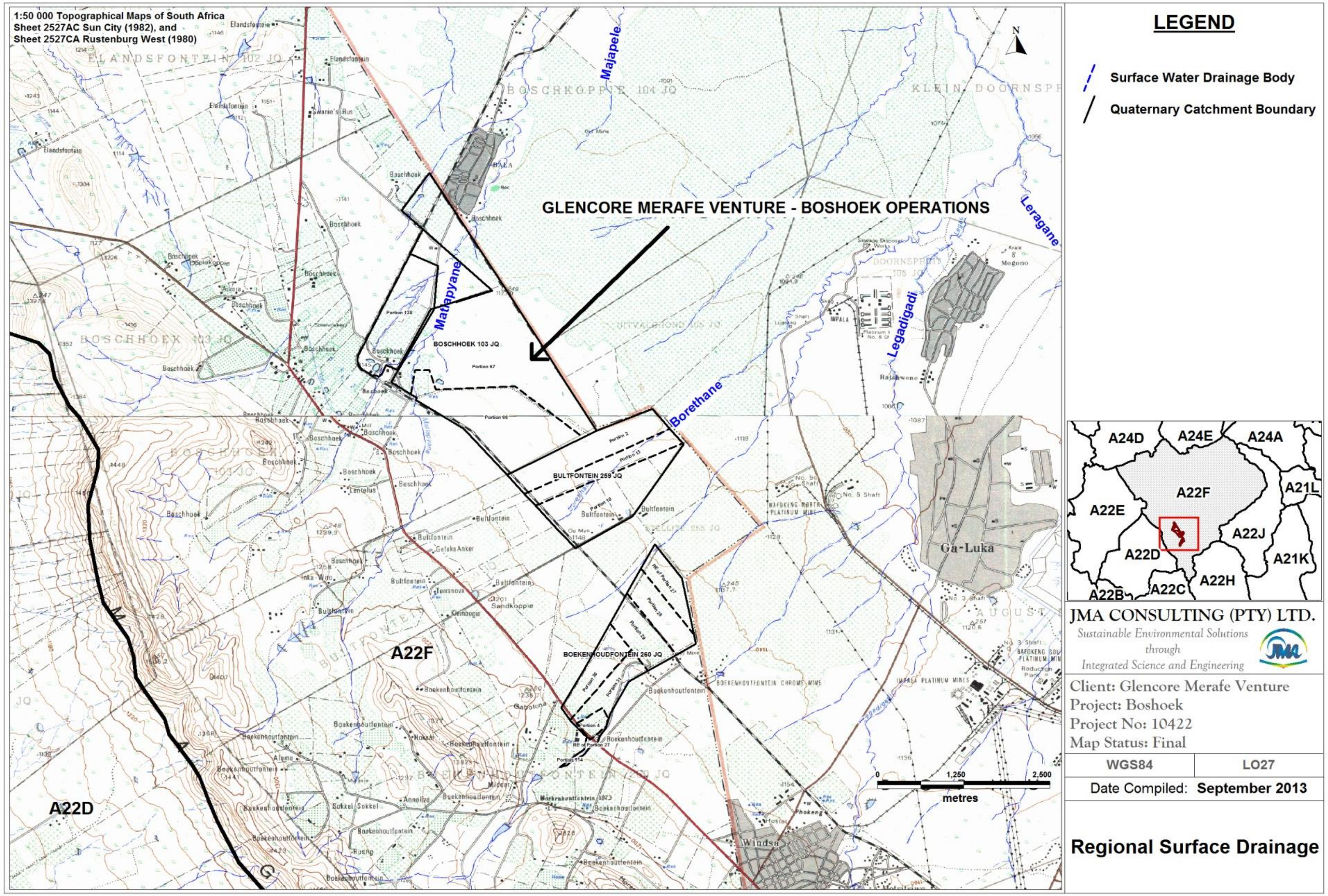

Figure 2.11.2.2(a): Regional Surface Drainage

2.11.2.3 Regional Geology

The study area is located within the western limb of the BIC and is underlain by the Rustenburg Layered Suite lithologies of the BIC which dip at an angle of between 10^o and 12^o to the north-east. These lithologies range in composition from norites and anorthosites through to gabbros, harzburgites, magnetites and pyroxenites. The western limb of the BIC has been and is still currently being extensively mined for chromium and platinum group elements by both opencast and underground mining methods.

The surface geology to the far west and south-west of the study area consists predominantly of lithologies of the Magaliesberg Formation and Silverton of the Pretoria Group. The Magaliesberg Formation sandstones and quartzites are highly resistant and give rise to the Magaliesberg Mountain Range. The Magaliesberg Formation gradationally overlies the Silverton Formation which consists predominantly of high-alumina shales (Eriksson, P.G et al (2006)).

The surface geology to the east of the Magaliesberg Formation and west and south-west of GMBS consists of Kolobeng Norites of the BIC which intruded into and above the Magaliesberg Formation quartzites and argillaceous Silverton Formation lithologies of the Pretoria Group. The Silverton Formation has further been intruded by diabase dykes to the south-west of the study area as well.

Ruighoek Pyroxenites outcrop across the entire surface extent of the current GMBS activities. The Ruighoek Pyroxenites are further overlain by the Mathlagame Norites and Anorthosites and Pyramid Gabbro-Norites which make up the majority of the surface geology to the east and north-east of GMBS. Quaternary sedimentary deposits occur within the topographically lower lying areas to the east and north-east of the study area as well as well as adjacent to the major surface water drainage bodies.

The Kolobeng Norites, Ruighoek Pyroxenites, Mathlagame Norites, and Pyramid Gabbro-Norites all form part of the Rustenburg Layered Suite of the Bushveld Igneous Complex. The Mathlagame Norites and Anorthosites and Pyramid Gabbro-Norites within the study area are confined to the economically important Upper Critical and Main zones of the Rustenburg Layered Suite.

Some of the more important and economically exploitable horizons within the BIC include the LG-6, UG-2, UG-1 and MG-1 chromitite layers as well as the Merensky Reef. The Lower Group (LG) and Middle Group (MG) chromitite layers of the Rustenburg Layered Suite sub-outcrop within the study area. These chromitite layers have a north-west to south-east strike and are currently being exploited for their chromium content. The chromitite layers which are of primary economic interest at GMBS are the LG-6 and MG-1 chromitite layers. It is inferred that Platinum (Pt), Chrome (Cr), Copper (Cu) and Nickel (Ni) have historically and are currently being mined from within the Upper Critical and Main zones of the Rustenburg Layered Suite within the study area.

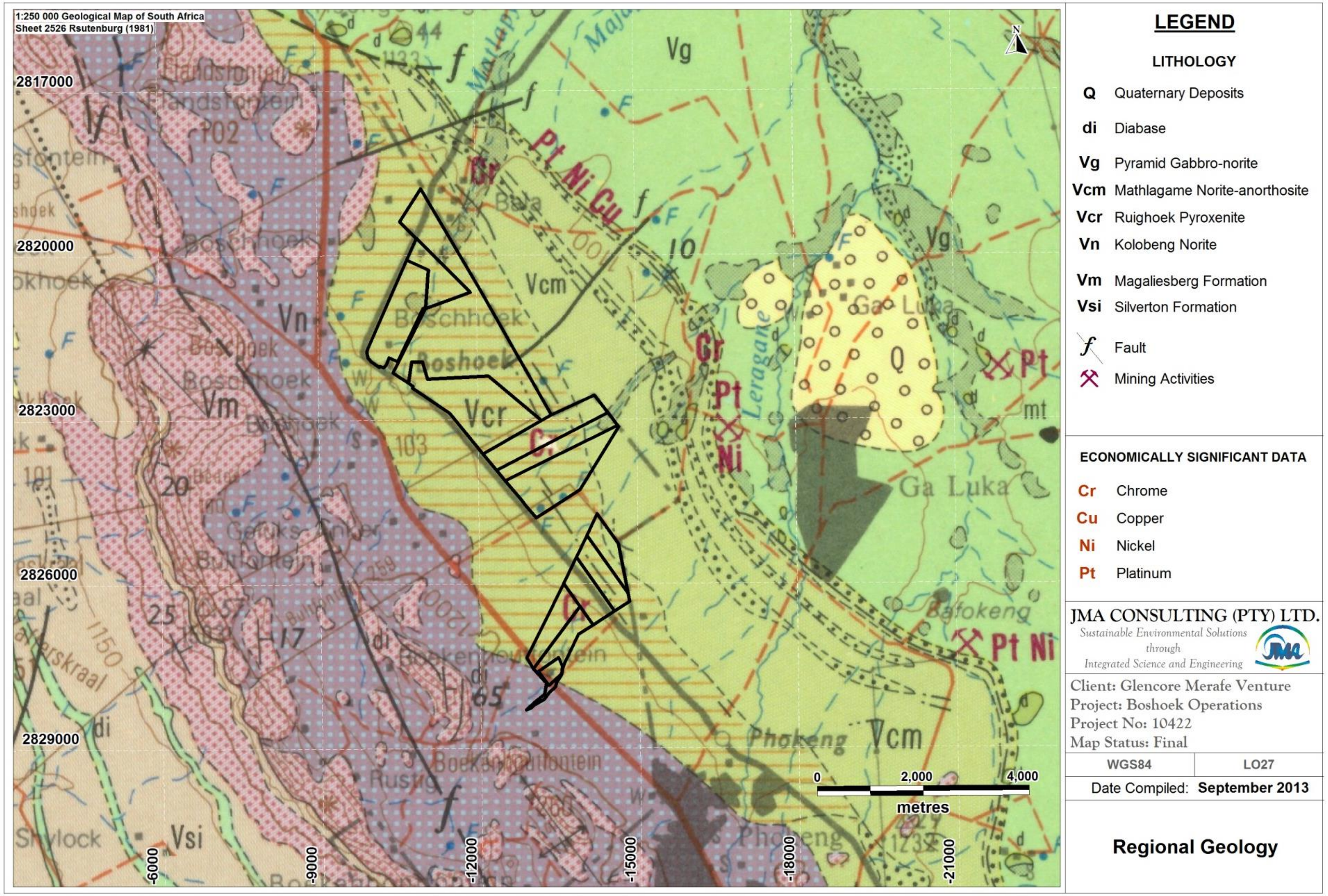

Figure 2.11.2.3(a): Regional Surface Geology

Large scale faulting is observed within the study area as well, the most predominant being the sinistral fault that trends in a north-easterly direction directly to the north-east of GMBS, the dextral fault that trends in a north-easterly direction to the north of GMBS as well as the north-west trending fault to the west of the study area

2.11.2.4 Regional Hydrogeology

The regional hydrogeological conditions are naturally influenced by the associated geological formations and properties thereof. The natural hydrogeological conditions to the east of GMBS have been altered as a result of the underground mining operations. The regional geohydrology adjacent to GMBS is discussed with reference to the available information relevant to the clipped region of the published 1:500 000 Hydrogeological Map Series of the Republic of South Africa – Sheet 2526 Johannesburg, 1999, depicted as Figure 2.11.2.4(a).

There are two distinctly separate stratigraphic sequences within the study area, each with their own geohydrological manifestations.

<u>Geohydrological Zone 1: Pretoria Group Meta-Sediments</u>

The area to the west of GMBS is underlain by predominantly meta-argillaceous and meta-arenaceous rocks of the Pretoria Group - denoted by Vp on the map.

Within this zone the groundwater primarily occurs within the joints and fractures of the competent argillaceous (mudstones, siltstones, shales) and arenaceous rocks (sandstones and quartzites), related to tensional or compressional stresses and offloading.

The borehole yielding potential within this geohydrological zone is indicated to vary between 0.5 l/s and 2.0 l/s. No large scale groundwater abstraction is indicated to occur from these fractured aquifers within the bounds of the study area. A large number of adjacent land users do however abstract groundwater from within these aquifers for domestic and small scale agricultural activities.

<u>Geohydrological Zone 2: Rustenburg Layered Suite</u>

The majority of the study area is underlain by ultramafic/mafic intrusive rocks of the Rustenburg Layered Suite - denoted by Vr on the map. The entire operations at GMBS are underlain by this geohydrological zone.

Within this zone, the primary groundwater occurrences are in the joints and fractures occurring within the contact zones related to the heating and cooling of the country rocks as well as in fractures in the transitional zones between the weathered and un-weathered rocks. Numerous faults are recorded within the Rustenburg Layered Suite within the study area and potentially act as additional preferential groundwater flow zones.

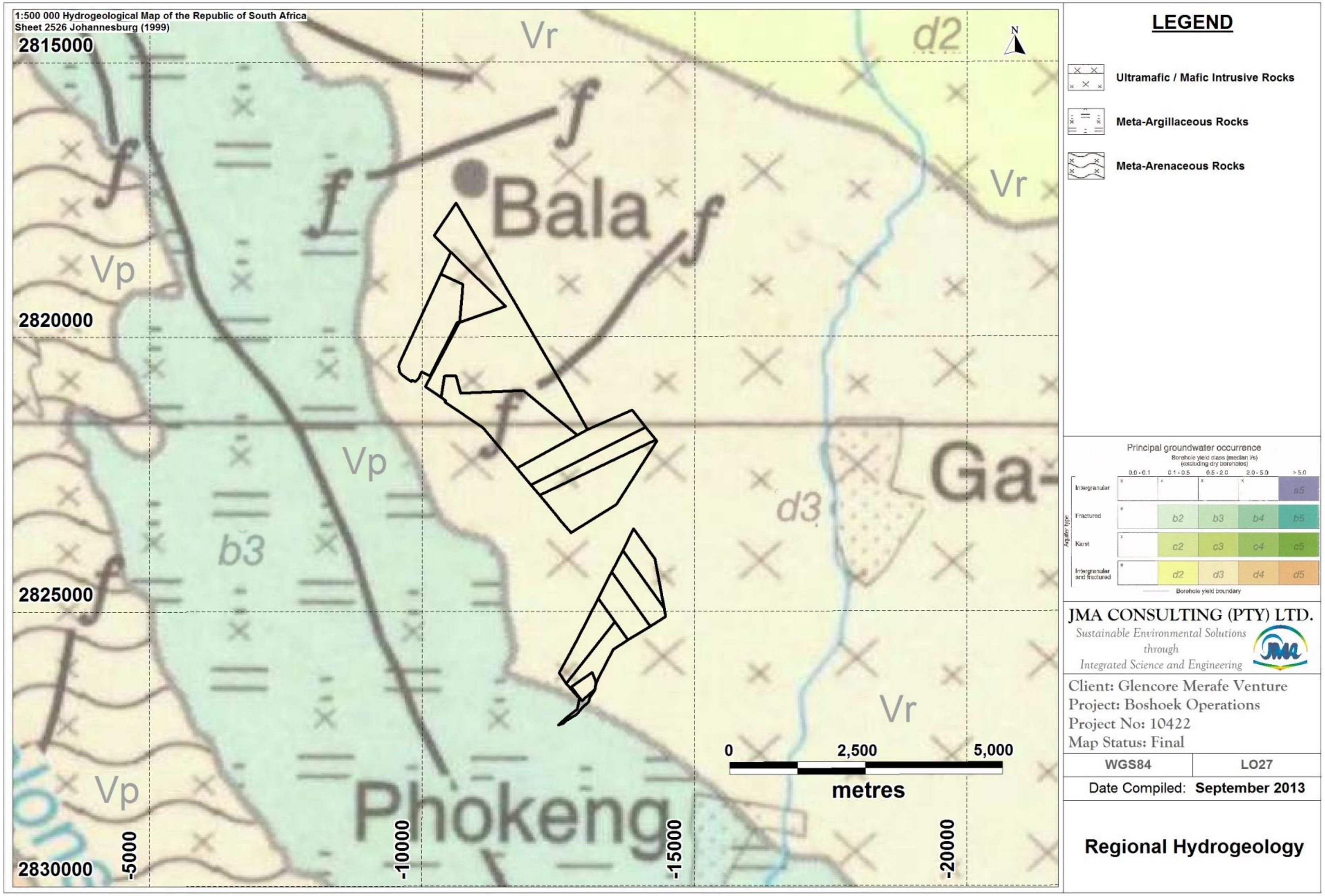

Figure 2.11.2.4(a): Regional Hydrogeology

The borehole yielding potential within this geohydrological zone within the study area is indicated to vary between 0.5 l/s and 2.0 l/s. A large number of adjacent land users do abstract groundwater from within these intergranular and fractured aquifers for domestic and small scale agricultural activities.

2.11.2.5 Regional Historical Mining

The area to the north-east, east and south-east of GMBS has historically been mined for both platinum and the associated platinum group elements (PGE's) as well for chromium, by both opencast and underground mining methods. The 2 layers of significant economic importance (from a platinum and PGE perspective) that occur within the study area are the Merensky Reef and UG-2 chromitite layer. Impala Platinum and Bafokeng Rasimone Platinum Mine (BRPM) have extensively mined platinum and PGE's from both the UG-2 and LG-6 chromite layers. Both the Merensky Reef and UG-2 Chromitite layers have been mined out down dip and along strike. A map depicting the current extent of the mining operations is depicted as Figure 2.11.2.5 (a).

The MG-1 and LG-6 Chromitite have been and are currently being mined by opencast mining operations within the study area for their chromium content. The mining activities at and adjacent to GMBS potentially impact the regional groundwater flow characteristics within the groundwater management area, as well as the chemistry thereof. Several of the opencast mining operations are currently being rehabilitated.

2.11.3 Physical Aquifer Description

The physical delineation and description of the aquifers within the study area is discussed with reference to the geological information generated during the quantitative site specific field investigation programmes. The geology underlying the study area was verified and assessed during the drilling of 15 geological / geohydrological investigative boreholes in addition to the geological information obtained from the geological exploration boreholes and information contained within GMBS's Amended Mining Work Programme (March 2012).

The geohydrological investigative boreholes were drilled to a depth that fully intersected the shallow weathered zone aquifers and were drilled to an average depth of 30.44 meters below ground level (mbgl). The lithology that was penetrated, its weathering and fracturing status as well as its water yielding capacity was recorded for each borehole during the drilling operations. The localities of the 15 additional investigative boreholes (BGW-) as well as the exploration (BH & BFN) boreholes used are depicted on Figures 2.11.3(a) and 2.11.3(b) respectively.

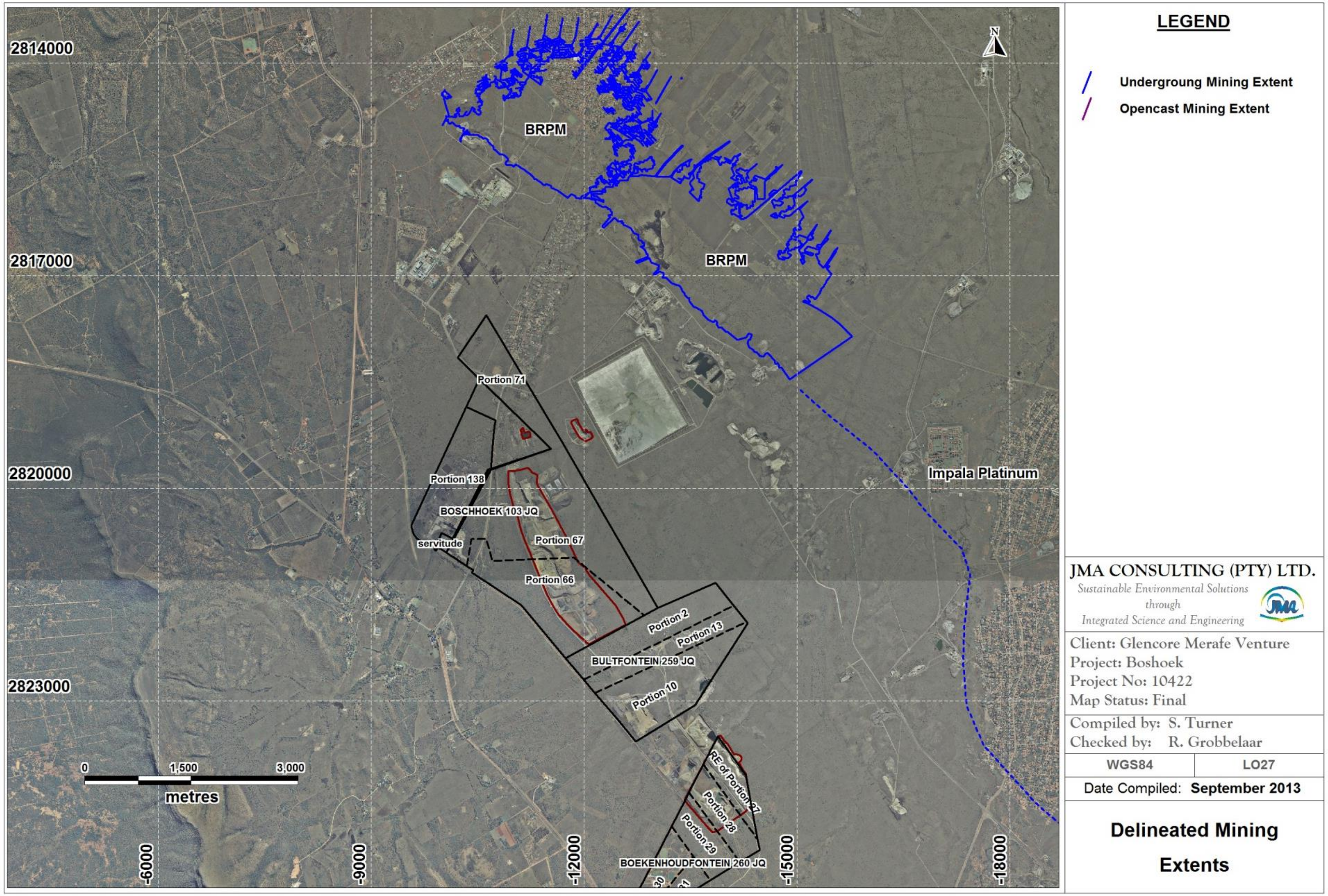

Figure 2.11.2.5(a): Delineated Extent of Mining Operations.

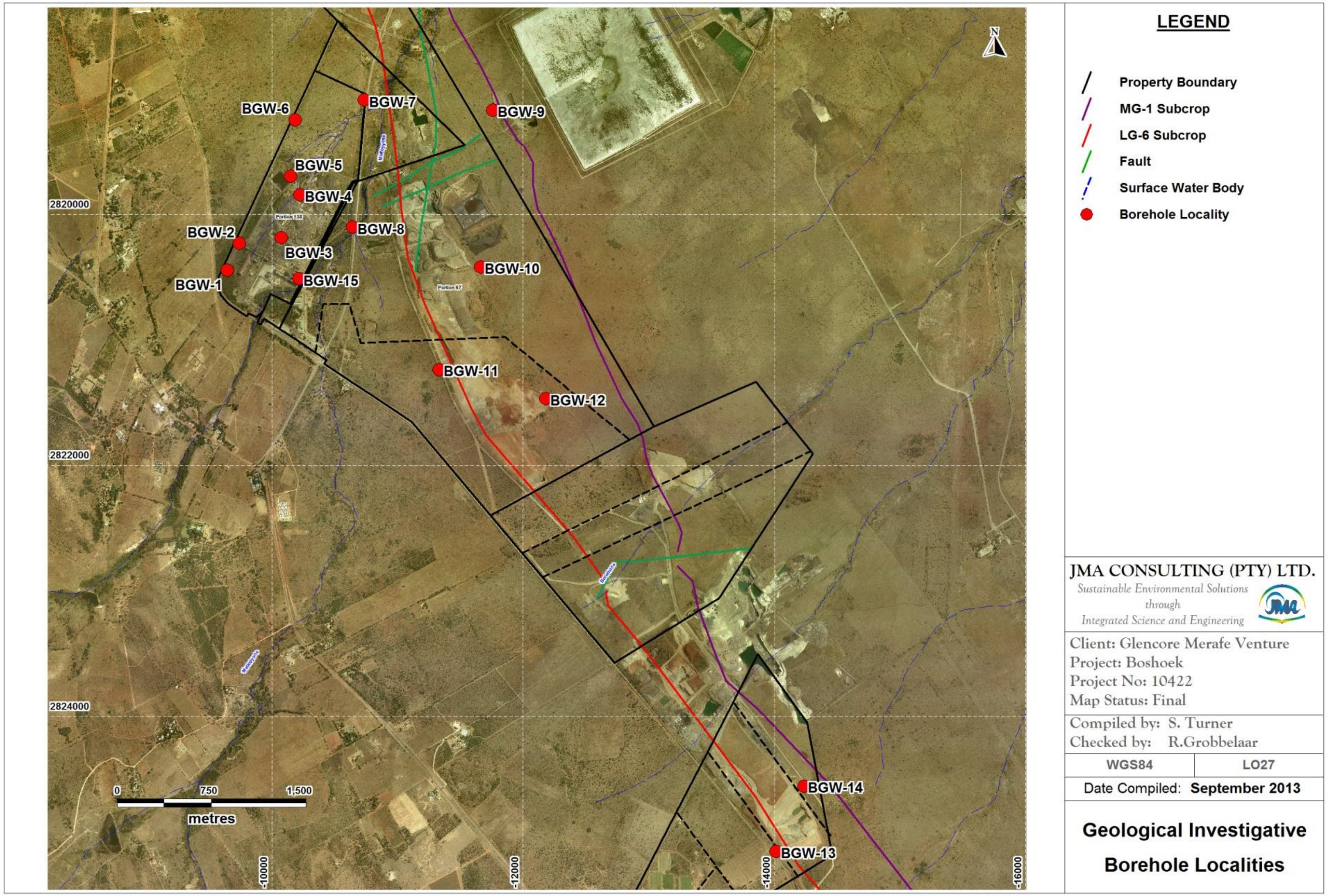

Figure 2.11.3(a): Geological Investigative Borehole Localities.

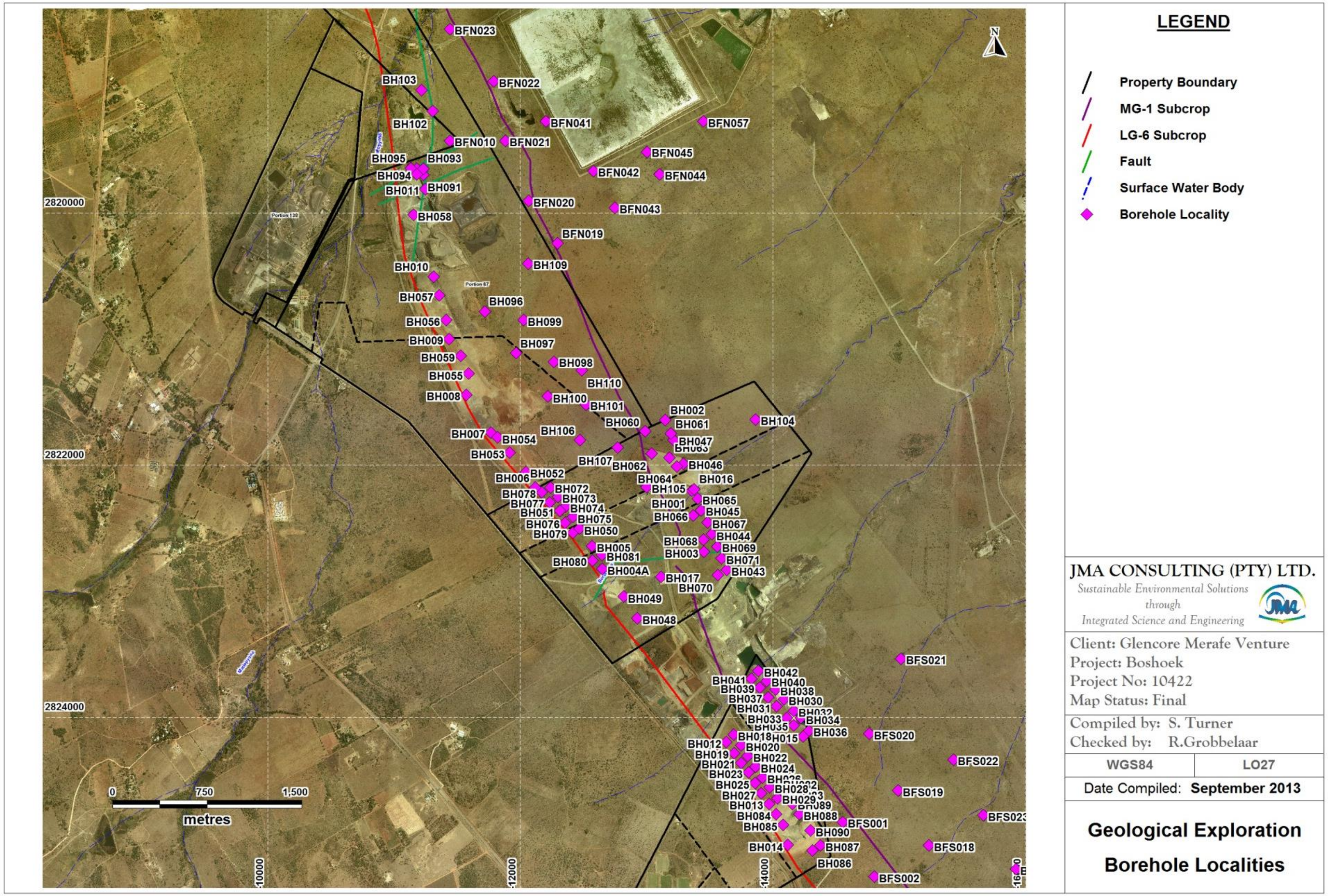

Figure 2.11.3(b): Geological Exploration Borehole Localities

2.11.3.1 Aquifer Matrix (Soil and Geological Matrix)

The host rock matrix at GMBS comprises predominantly of weathered, fractured and fresh norites, anorthosites (Mathlagame Norite-anorthosite) and pyroxenites (Ruighoek Pyroxenites), extensively covered by soil and / or overburden material at the surface.

The soil comprises of a dark brown to greyish brown structured fine grained and clay-rich “turf” soil derived from the predominantly noritic parent material. The thickness of the soil penetrated during the drilling of the 15 investigative boreholes varied between 0.0 m and 3.0 m, with an average thickness of 1.7 m. Large areas of soil has either been covered with overburden material or has been removed, due to the current opencast mining operations as well as during the construction of the beneficiation plant and associated surface activities.

The norite penetrated is predominantly grey to dark grey in colour and is medium grained in texture. The norite comprises predominantly of pyroxenes and plagioclase feldspars, with biotite, hornblende and mica’s observed in several of the samples. Gabbro-norite was observed in one of the boreholes as well. The anorthosite penetrated is predominantly light grey in colour and is medium to course grained in texture. The anorthosite comprises mainly of plagioclase feldspars and is also basic in composition. The norite is less resistant to weathering than the anorthosite and weathers into a soft gritty material. The pyroxenite penetrated is predominantly dark grey in colour and is medium grained in texture. The pyroxenite comprises predominantly of pyroxenes, with minor amounts of biotite observed and is ultrabasic in composition.

Although not penetrated in any of the boreholes (due to the restricted depth of drilling as well as the extent of the current mining operations), several chromitite layers are present within the study area. The LG-6 and MG-1 chromitite layers are of economic importance at GMBS and currently being mined by opencast mining operations within the eastern extent of the study area.

The information obtained from the exploration boreholes indicates that the LG-6 chromitite layer has an average thickness of 0.97 m whilst the MG-1 chromitite layer has an average thickness of 0.78 m. The MG-2, MG-3 and LG-6A chromitite layers within the study area are of poor quality and are thus, often treated as part of the overlying overburden material. The information obtained from the exploration boreholes further indicates that the lithologies of the Rustenburg Layered Suite within the study area (norite, anorthosite and pyroxenites) dip at an average angle of around 11° to the north-east within the mining area.

Transgressive dykes, rolls, potholes and fault structures are indicated to often influence and negatively impact continuity of the chromitite layers exploited. No dykes were however intersected in any of the geological / geohydrological investigative boreholes drilled during this groundwater specialist study assessment.

Several large scale faults have been identified and delineated within the study area as indicated in the 2012 Mining Works Programme.

The most predominant faults are the sinistral fault that trends in a north-easterly direction directly to the north-east of GMBS, the dextral fault that trends in a north-easterly direction to the north of GMBS as well as the north-west trending fault to the west of the study area.

The depth of weathering and weathering related fracturing is relatively deep and varies between 19.0 m and 30.0 m, with an average depth of 25.5 m within the study area. The norite weathers down to a soft gritty matrix, whilst the anorthosite appears to weather slightly to a course consolidated gravel matrix. The weathering fracture profile depth is combination of the primary weathering profile and the transitional fracturing zone which occurs immediately above the fresh bedrock interface.

2.11.3.2 Aquifer Types (Primary, Weathered, Fractured, Karst)

The predominant aquifer type present within the study area is a laterally extensive shallow weathered zone aquifer which occurs in the weathered and weathering related fractured zone, within the predominantly pyroxenite and norite host rock matrix. This aquifer extends across the entire study area with an average vertical thickness of 25.5 m (weathering / fracturing depth). This aquifer zone will store and transport the bulk of the groundwater in the study area and will display unconfined to semi-unconfined piezometric conditions. This shallow weathered zone aquifer will therefore as a result, be highly susceptible to surface induced anthropogenic influences on site.

The localized fractured aquifers present within the study area are restricted to the contact zones between the intrusive dolerite bodies and the host rocks as well as along the major fault zones. Although these aquifers may potentially have high yields, high transmissivity values and represent preferential flow paths, they have a limited storage capacity as well as restricted recharge characteristics. The bulk of the water supplied by the fractured aquifers will be drained laterally from storage within the shallow weathered zone aquifers neighbouring onto them.

2.11.3.3 Aquifer Zones (Unsaturated, Saturated)

Previous hydrogeological investigations as well as the information obtained during the drilling operations indicate that there are no extensive perched aquifer systems within the study area. This simplifies the geohydrology and indicates that the conceptual geohydrological model can be comprehensively described in terms of unconfined to semi-unconfined unsaturated and saturated zones within the weathered zone.

The recorded thickness of the unsaturated zone at GMBS was calculated using the groundwater level data recorded between November 2012 and March 2013 and varies between 3.37 m and 32.99 m with an average thickness of 14.08 m. The natural thickness of the unsaturated zone has been affected by the opencast mining operations and local groundwater abstraction at and adjacent to GMBS. The average thickness of the natural unsaturated zone at GMBS is recorded to range between 3.37 m and 18.76 m with an average thickness of 10.66 m. This excludes the areas that have been affected by aquifer dewatering associated with abstraction of the groundwater for domestic, agricultural and mining related uses and operations.

The recorded saturated thickness of the saturated zone at GMBS varies between 4.34 m and 21.91 m with an average thickness 12.62 m. The average thickness of the natural saturated zone at GMBS is recorded to range between 6.24 m and 21.91 m with an average thickness of 15.09 m. This excludes the areas that have been affected by aquifer dewatering associated with abstraction of the groundwater for domestic, agricultural and mining related uses and operations.

2.11.3.4 Lateral Aquifer Boundaries (Physical, Hydraulic, Arbitrary)

The delineated lateral aquifer boundaries for the GMBS study area define the extent of the groundwater zone that could potentially be affected by surface activities within the study area. The groundwater zone of influence may be defined and delineated by three principle types of aquifer boundaries, namely physical, hydraulic and arbitrary boundaries.

It is important to note that the GMBS operations are situated to the west and south-west (up-gradient) of well-developed mining areas, and artificial aquifer boundaries and voids therefore exist as well. These artificial voids and boundaries are related to both opencast or underground mining operations which produce groundwater sinks as a result of dewatering, which affect the availability of groundwater as well as the natural characteristics and flow thereof. Although the underground mining operations to the east of GMBS will inevitably form artificial groundwater boundaries, they have been excluded from the delineation of the (natural) lateral aquifer boundaries assigned to the study area.

The lateral aquifer boundaries have been delineated as follows (Figure 2.11.3.4(a)):

- The south-western aquifer boundary (up-gradient) is defined as a constant head hydraulic boundary and has been selected along the 1160 mamsl surface elevation contour.
- The north-western aquifer boundary is defined as a no flow hydraulic boundary and is initially delineated along the groundwater divide. The northern segment of the north-western aquifer boundary is further defined as a groundwater discharge hydraulic aquifer boundary and has been selected along two tributary drainage lines of the non-perennial Matlapyane Stream which drains in a north-easterly direction.
- The north-eastern aquifer boundary (down-gradient) is defined as a constant head hydraulic boundary and has been selected along the 1100 mamsl surface elevation contour. The area below and to the east and north-east of this hydraulic aquifer boundary has been and is currently being mined by both opencast and underground mining operations.
- The south-eastern aquifer boundary is defined as a groundwater discharge hydraulic aquifer boundary and has been selected along a tributary drainage line of the non-perennial Legadigadi Stream that drains in a northerly to north-easterly direction.

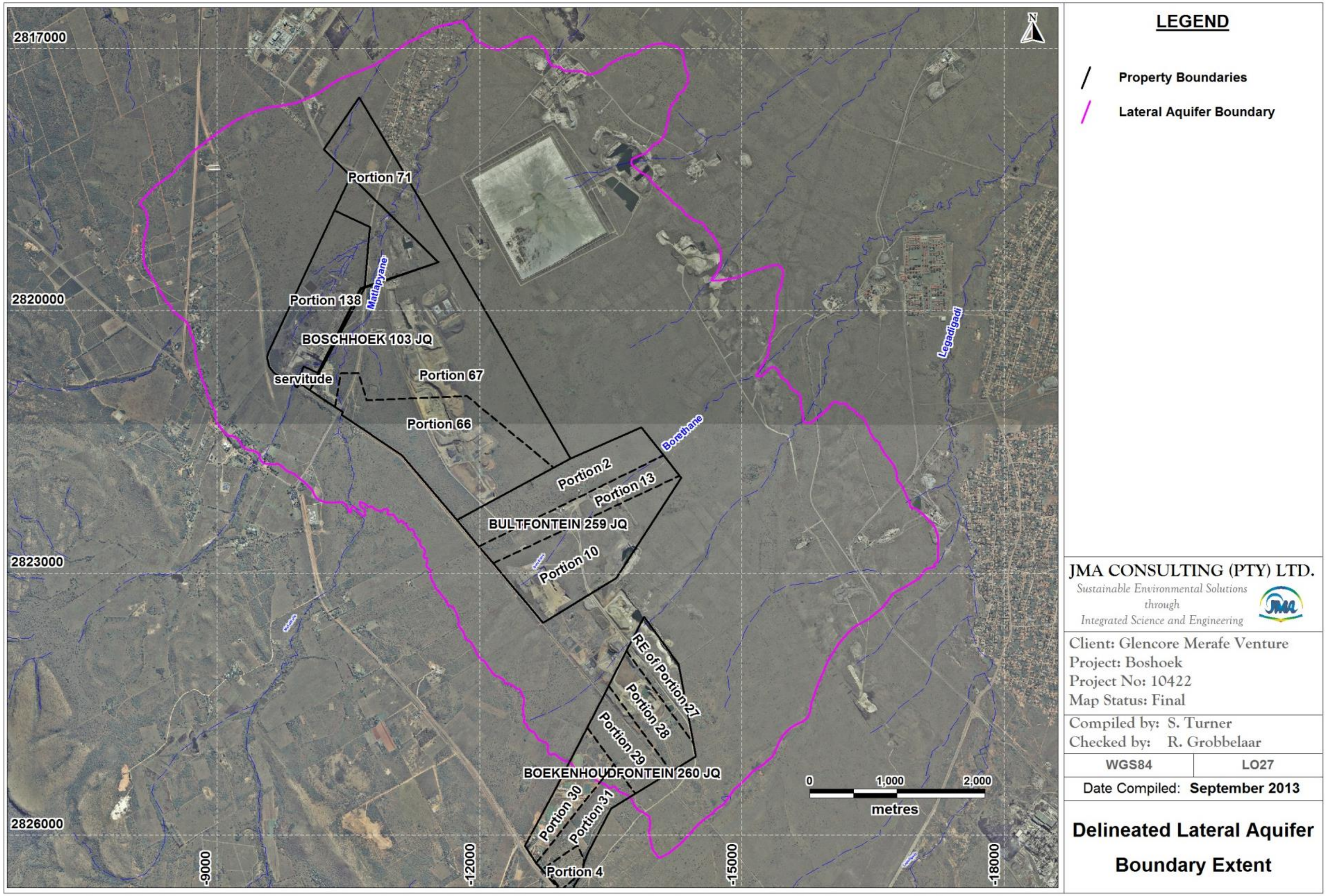

Figure 2.11.3.4(a): Lateral Aquifer Boundary Delineation at GMBS

2.11.3.5 Preferential Groundwater Flow Zones

Preferential groundwater flow zones are generally associated with the highly fractured zones along faults as well as within contact zones associated with intrusive igneous bodies. The zones adjacent to the contact zones between dykes and the norite host rock are generally highly fractured due to their intrusive nature and are often associated with fault zones.

No faults and dykes were intersected in any of the geological / geohydrological investigative boreholes drilled during this groundwater specialist study. Several large scale faults have however been identified and delineated within the study area as indicated in the 2012 Mining Works Programme.

The nature and extent of the associated highly fractured and permeable zones are defined by the geometry and extent of the faults and dykes. Although these preferential flow zones may potentially have high yields and high transmissivity values they have a limited storage capacity as well as restricted recharge characteristics. The preferential groundwater flow conditions encountered along the linear geological features within the extent of the study area, may due to their scale and interconnectivity, be regarded as porous groundwater flow zones within the delineated lateral aquifer boundaries.

2.11.3.6 Artificial Groundwater Zones (Mining Voids/Spoils)

The study area has been extensively mined for both platinum and the associated platinum group elements as well as for chromium, by both opencast and underground mining methods. The voids created during these mining operations have a permanent impact on the regional groundwater flow characteristics within the groundwater management area, as well as the chemistry and availability thereof.

The areas that have been mined by either opencast or underground mining methods, as well as the areas that have been fully or partially rehabilitated create artificial voids within the geological and geohydrological environment which increases the porosity and storativity of these geohydrological zones. During the operation of the mining activities groundwater flowing into the underground mine workings is pumped out, which lowers the natural groundwater levels adjacent to the aquifers and alters the natural local flow characteristics thereof as well.

2.11.4 Hydraulic Aquifer Description

The hydraulic aquifer description relates to the parameters which determine the hydraulic groundwater properties, such as the occurrence, availability, storage and movement of the groundwater within the shallow weathered zone aquifer systems present within the study area.

2.11.4.1 Borehole Yields

Blow yields were obtained from each of the 15 geological / geohydrological investigative boreholes during the drilling of the boreholes.

The blow yields recorded were obtained from the shallow weathered zone aquifers present within the study area. With regards to the borehole blow yield distribution the following is important:

- No information regarding the blow yields of the existing boreholes was available.
- The recorded borehole blow yields are heterogeneously distributed and vary between 0.1 l/s and 10.0 l/s, with an average total blow yield of 1.3 l/s for the boreholes. The geometric mean blow yield is calculated as 0.6 l/s and the harmonic mean blow yield is calculated as 0.4 l/s.
- Borehole BGW-9 (adjacent to the Jig Tailings Facility) had the highest blow yield (10.0 l/s) followed by borehole BGW-5 (adjacent to the storm water dam), BGW-15 (adjacent to Furnace 3) and borehole BGW-8 (adjacent to the Matlapyane Stream) which had a blow yields of 2.0 l/s, 1.5 l/s and 1.0 l/s respectively.
- The borehole blow yields within the plant management area (west of the Boshoek Station tarred road) range between 0.1 l/s and 2.0 l/s with an average blow yield of 0.8 l/s.
- The borehole blow yields within the mining management area range between 0.2 l/s and 0.5 l/s with an average blow yield of 0.4 l/s.
- The borehole blow yield distribution indicates that the blow yields recorded within the plant management area (west of the Boshoek Station tarred road) are higher than the blow yields recorded within the mining management area.

2.11.4.2 Aquifer Permeability / Transmissivity

The average hydraulic conductivity of the shallow weathered zone aquifers adjacent to the boreholes is taken as the arithmetic mean of the permeability's calculated at the 15 hydrogeological investigative boreholes using the Hvorslev and Bouwer & Rice analysis methods, both of which are applicable to weathered zone aquifers. With reference to the calculated permeabilities of the shallow weathered zones aquifers present within the study area, the following is important:

- There is a large variation in the calculated permeability values and distribution across the site. The variation in permeability is related to the differing degrees to which the underlying norites, anorthosites and pyroxenites have been weathered and fractured.
- The average calculated aquifer permeabilities varied between 0.03 m/day and 3.15 m/day with an average calculated permeability of 0.59 m/day.
- Due to the heterogeneities inherent to weathered zone aquifers, statistical assessments indicate that the hydraulic parameter distribution will be log-normally distributed and that the actual k-value for the aquifer is bound by the calculated geometric and the harmonic means.
- Based on the analyses of the slug tests conducted, a bulk hydraulic conductivity of around 0.30 m/day is assigned for the shallow weathered zone aquifers within the study area.

With reference to the calculated transmissivity values of the shallow weathered zones aquifers present within the study area, the following is important:

- The calculated aquifer transmissivities varied between 0.28 m^2/day and 53.01 m^2/day with an average calculated transmissivity of 7.97 m^2/day. The calculated aquifer transmissivities are heterogeneously distributed within the study area.
- A bulk transmissivity value of 7.5 m^2/day is assigned for the shallow weathered zone aquifers within the study area.

2.11.4.3 Aquifer Storativity

The storativity of the shallow weathered zone aquifers at GMBS is taken to be approximately 0.002. The saturated interstice types or storage medium of the aquifer are the interstices and fractures present below the groundwater level, as a result of weathering and the weathering related fracturing of the host rock.

2.11.4.4 Aquifer Porosity

The porosity of an aquifer is the ratio of the void space to the total volume of the aquifer. The porosity gives is an indication of the amount of water in the subsurface, but does not represent the volume that can be released from or taken into storage. The ratio between the volume of water that can be drained from the aquifer and the total volume of the aquifer is referred to as the effective porosity. The effective porosity in the weathered zone aquifers at GMBS is indicated to vary between 0.01 and 0.07, with a bulk probable effective porosity value of 0.05.

2.11.5 Aquifer Dynamics

2.11.5.1 Rainfall Recharge

The recharge to the shallow weathered zone aquifers within the study area will occur primarily through infiltration of the rain water and surface water bodies. The mean annual recharge to the groundwater system is estimated to be between 30 mm and 55 mm per annum and is calculated as between 5% and 8% of the MAP.

Due to the nature of certain anthropogenic surface features, such as unlined surface water and slimes dams as well as rehabilitated and un-rehabilitated pits, larger recharge volumes within the extents of their surface footprints may occur. Areas that have been covered at the surface with infrastructure, buildings and paving etc. will deplete the natural recharge volumes to the underlying groundwater resource.

2.11.5.2 Groundwater Level Depths and Fluctuations

The groundwater levels within the study area (1 km radius from delineated properties) were recorded between November 2012 and March 2013. Where accessible the groundwater levels were recorded at the 15 existing serviceable monitoring boreholes, at the 15 additional geohydrological investigative boreholes (BGW-) as well as at 36 private boreholes (BGE-) located within an approximate 1 km radius of the GMBS properties. The localities of the 66 boreholes identified are indicated in Figure 2.11.5.2(a).

The groundwater levels recorded within the study area varied between 3.37 m and 32.99 m with an average depth of 14.08 m. The groundwater levels recorded at several of the boreholes have been affected by the opencast mining operations as well as local groundwater abstraction at and specifically at privately owned boreholes adjacent to the GMBS operations. It is unknown how long the boreholes had been abstracted for and to what degree the water levels recorded in the abstraction boreholes are in fact representative of the groundwater levels in the adjacent aquifers.

The natural groundwater levels within the study area are expected to range between 3.37 m and 18.76 m with an average groundwater level depth of around 10.66 m assigned to the shallow weathered zone aquifers. The calculation of the natural groundwater level depth excludes the groundwater levels recorded at the areas that have been influenced by aquifer dewatering associated with abstraction of the groundwater for domestic, agricultural and mining related uses and operations.

With reference to the recorded groundwater levels within the shallow weathered zones aquifers present within the study area, the following is important:

- The groundwater levels recorded from 15 monitoring boreholes within the plant management area (west of the Boshoek Station tarred road) range between 3.37 mbgl (GCS-3) and 18.76 mbgl (BGW-6) with an average groundwater level depth of 7.88 mbgl.
- The groundwater levels recorded from 7 boreholes within the mining management areas range between 16.39 mbgl (BGE-12) and 23.07 mbgl (BGW-12) with an average groundwater level depth of 19.68 mbgl.
- It is observed that the natural groundwater levels within the shallow weathered zone aquifers immediately adjacent to the opencast mining operations have been affected due to aquifer dewatering associated with the operation of the opencast mining operations.
- No groundwater level data was obtained or provided for the adjacent properties to the east of GMBS mining activities.
- Several of the privately owned boreholes (BGE-) adjacent to the GMBS operations were fitted with pumps and were being used as groundwater abstraction points. The groundwater levels recorded at these boreholes do therefore not necessarily reflect the natural groundwater levels as the water levels in the boreholes have been affected as a result of the abstraction from the boreholes. This is specifically the case where groundwater abstraction rates exceed the potential yield of the boreholes.

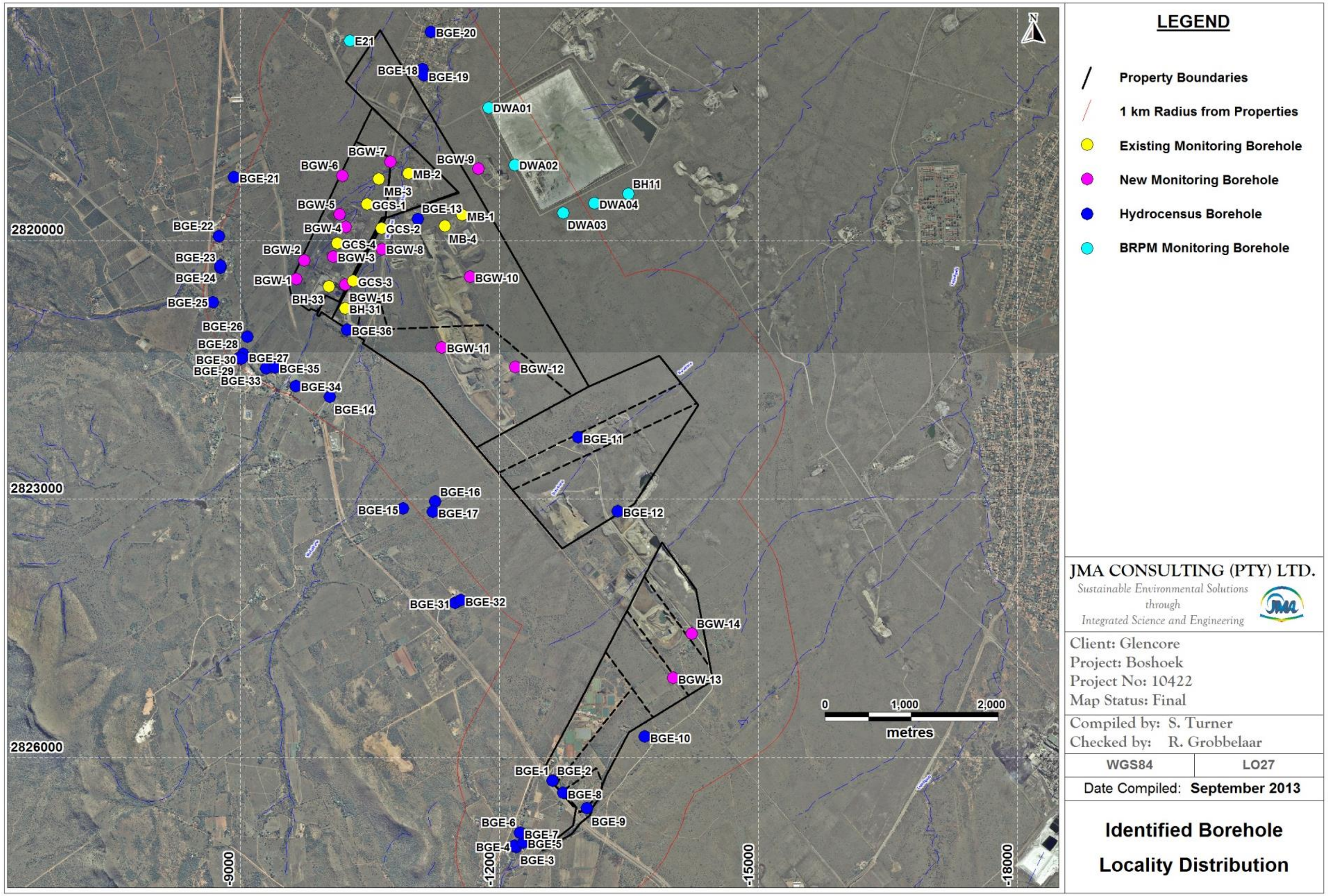

Figure 2.11.5.2(a): Identified Borehole Localities

- In order to provide an accurate assessment of the groundwater levels (depth to the groundwater table) on the properties adjacent to the GMBS operations, it would be required that no groundwater be abstracted from the specific privately owned boreholes for at least 5 days prior to the recording of the water levels at these boreholes.

At a storage value of 0.002 the groundwater level response to 1 mm of rainfall will be 0.5 m. This indicates that for every 2 mm of rainfall recharge the change in groundwater storage would manifest as a rise in the water level of 1 m. In view of the fact that not all the recharge will take place at the same time but rather spread out over the summer months, natural groundwater level fluctuations in excess of 5 m to 8 m per annum is not expected.

2.11.5.3 Groundwater Elevations and Gradients

The groundwater elevations within the study area were calculated by subtracting the measured groundwater level depths from the surface elevations. The groundwater elevation distribution is depicted on Figure 2.11.5.3(a).

An assessment of the calculated groundwater elevations depicts that there is an 87.82 % correlation between the observed groundwater elevations and the respective surface elevations. This includes the boreholes that are currently being used as groundwater abstraction points.

A re-assessment of the calculated groundwater elevations recorded, excluding the groundwater levels recorded at the boreholes which are used as groundwater abstraction points and adjacent to the opencast mining operations indicates that there is a 95.06 % correlation between the indicated natural groundwater elevations and the respective surface elevations. This is expected for the unconfined to semi-unconfined shallow weathered zone aquifers and indicates that the natural groundwater elevations within the shallow weathered zone aquifers generally mimic those of the surface topography.

Based on the observed natural groundwater elevations, it is indicated that the natural hydraulic gradient ranges between 0.005 and 0.017 with a bulk hydraulic gradient of 0.013 assigned to the study area.

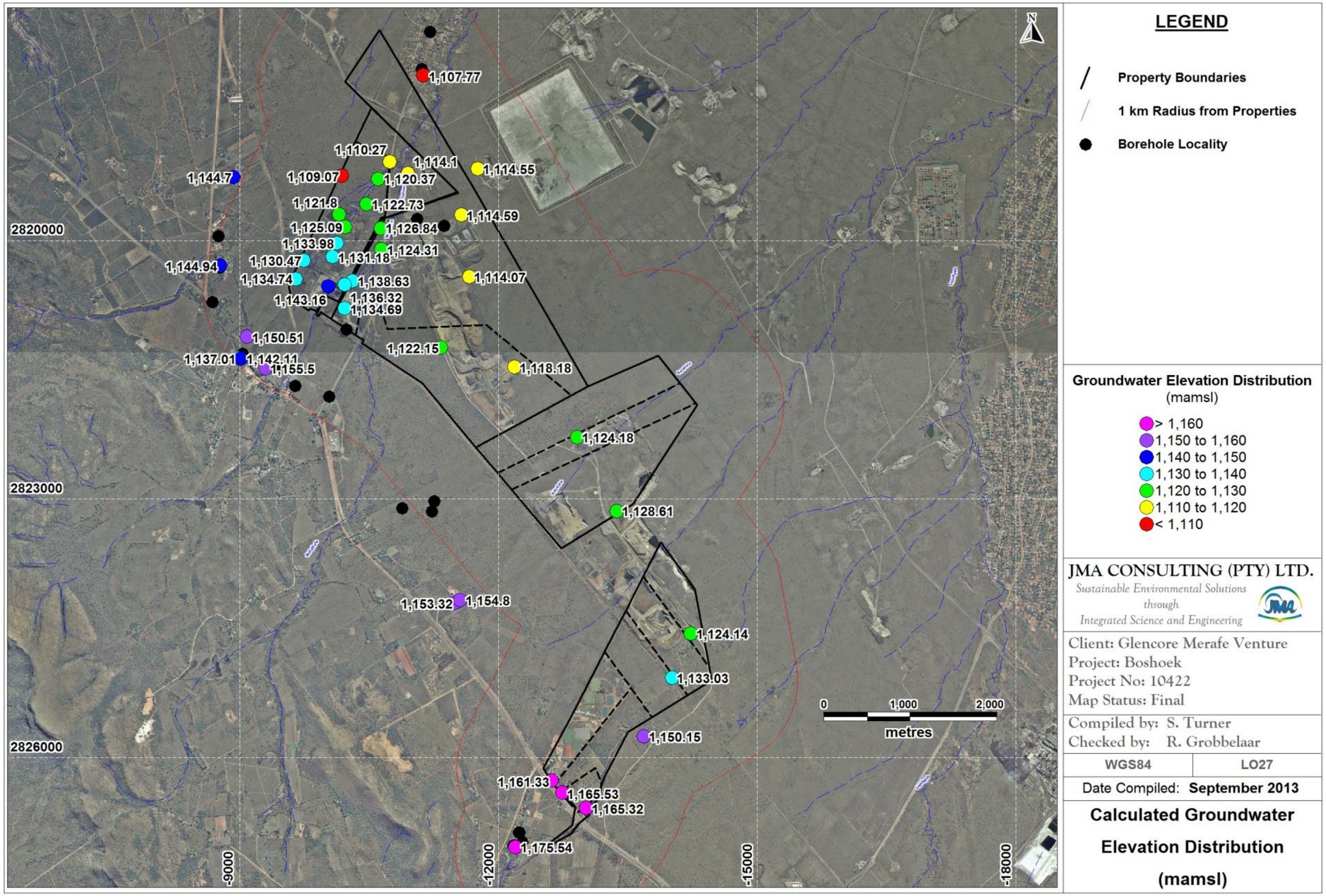

Figure 2.11.5.3(a): Groundwater Elevations

2.11.5.4 Groundwater Flow Directions and Flow Velocities

The groundwater flow directions were interpolated using the Kriging interpolation method of the groundwater elevations and are depicted on Figure 2.11.5.4(a). The groundwater flow/seepage velocity represents the most realistic expression of the actual groundwater flow velocity. The average seepage velocity calculated for the majority of the study area is 28.47 m/year, towards the north-east.

2.11.6 The Groundwater Reserve

The groundwater reserve was obtained from the Department of Water Affairs and includes groundwater quality and quantity requirements that are to be complied with for each quaternary catchment. The current groundwater reserve for the A22F (Ref: 26/8/3/3/146) stipulates that a preliminary determination of the groundwater Reserve was approved by the Chief Director: Resource Directed Measures on the 31st July 2009 in response to a previous related application.

2.11.6.1 Groundwater Quantity Reserve

The ground water quantity reserve indicates that the quaternary catchment receives an estimated average annual groundwater recharge of 26.66 million m^3 (Mm^3) across the catchment area of 1,688.3 km^2 of which 3.46 Mm^3/annum is required for the Reserve. The Ecological Water Requirements (EWR) and Basic Human Needs (BHN) requirements for the A22F quaternary catchment are 2.25 Mm^3/annum (8.4% of recharge) and 1.21 Mm^3/annum (4.5% of recharge) respectively. A summary of the Reserve for the A22F quaternary catchment is indicated in Table 2.11.6.1(a).

Table 2.11.6.1(a): Summary of the Reserve (Ref: 26/8/3/3/146)

Catchment	Area (km^2)	Recharge (Mm^3/a)	Population	Baseflow (Mm^3/a)	EWR (Mm^3/a)	BHN Reserve (Mm^3/a)	Reserve as % of Recharge
A22F	1 688.3	26.66*	133 147	3.75**	2.25	1.21	12.98

* **Estimated using the GRAII dataset.** Recharge is calculated at 2.61% of MAP of 604 mm/annum. Bredenkamp et. al. 1995.

** **Estimated using the Herold Method (GRDM Version 3.3).** Herold, 1980.

The reserve states that the current and previous applications together with the Reserve add up to 5.28 Mm^3/annum or 19.8% of the recharge (26.66 Mm^3/annum). GMBS has an existing water use license (03/A22F/ACGIJ/580) which states in Appendix II that "*This license authorises the taking of a maximum quantity of 448,891 m^3/annum from the underground water, for mining, domestic and mineral processing purposes, as set out in Table 1* [of the Water Use License]". This volume is the total volume licensed in terms of Section 21(a) for 9 individual water uses at GMBS and accumulates to 12.97% of the Reserve, only 8.50% of the current and previous applications licensed together with the Reserve and only 1.68% of the recharge within the A22F quaternary catchment.

The following recommendations are made in the groundwater reserve (Ref: 26/8/3/3/146):

i) No groundwater abstraction may take place within 100 m of a river, spring or wetland. This distance may however be increased by the Regional Office if deemed necessary.
ii) Future license applications in this area should be referred to the Chief Director: Resource Directed Measures to verify the applicability of the level of Reserve determination in relation to the specific license application.
iii) Due to the low confidence of this reserve determination, the results should not be used to evaluate medium to high impact water use activities.
iv) Due to the high number of proposed mine waste and wastewater disposal activities, the applicant should ensure that measures of minimizing potential groundwater pollution are put in place.

2.11.6.2 Groundwater Quality Reserve

The groundwater quality component of the Reserve (Ref: 26/8/3/3/1069) for the A22F quaternary catchment is based on data obtained from the National Groundwater Database (NGDB). The stipulated ambient groundwater quality was determined from the statistical analysis of between 46 and 52 datasets from the catchment. The ambient groundwater quality in quaternary catchment A22F falls within Class 0 of the DWAF water quality classification. Class 0 is indicated to represent water suitable for long term domestic use.

The preliminary determination of the Reserve for water quality in terms of Section 17(1) of the National Water Act is summarized in Table 8.5.2(a), Table 8.5.2(b) and Table 8.5.2(c) for the General Chemistry, Physical Water Quality and Toxic Substances and Complex Mixtures respectively.

Section 17(1) of the National Water Act relates to the Preliminary determinations of Reserve and states that "*Until a system for classifying water resources has been prescribed or a class of water resource has been determined, the Minister –*
(a) may, for all or part of a water resource; and
(b) must, before authorizing the use of water under section 22(5), make a preliminary determination of the reserve".

Section 22(5) of the National Water Act states that "A responsible authority may, subject to section 17, authorise the use of water before -
(a) a national water resource strategy has been established;
(b) a catchment management strategy in respect of the water resource in question has been established;
(c) a classification system for water resources has been established;
(d) the class and resource quality objectives for the water resource in question have been determined; or
(e) the Reserve for the water resource in question has been finally determined".

Table 2.11.6.2(a): General Chemistry

Parameter	Ambient Groundwater Quality[1)]	Basic Human Needs Reserve[2)]	Groundwater Quality Reserve[3)]
EC (mS/m)	58.05	<150	63.86
Sodium (mg/l)	28.27	<200	31.10
Magnesium (mg/l)	20.74	<70	22.81
Calcium (mg/l)	43.75	<150	48.13
Chloride (mg/l)	18.63	<200	20.49
Sulphate (mg/l)	25.99	<400	28.59
Nitrate (mg/l)	0.24	<10	0.26
Fluoride (mg/l)	0.48	<1.5	0.53

[1)] Based on data obtained from the National Groundwater Database. Values reported at statistical median of each parameter.
[2)] Ref: *Quality of Domestic Water Supplies, Volume 1: Assessment Guide, 2nd Ed.1998*. Water Research Commission Report No: TT 101/98. Pretoria, South Africa (Set for a Class 1).
[3)] Ref. Where a difference in the water quality values for the ambient groundwater quality and basic human needs was found, the lesser or more protective value was selected for the groundwater quality Reserve. Where the ambient groundwater quality was selected as the groundwater quality Reserve, the value was scaled up by 10 per cent.

Table 2.11.6.2(b): Physical Water Quality

Parameter	Ambient Groundwater Quality[1)]	Basic Human Needs Reserve[2)]	Groundwater Quality Reserve
pH	7.88	5.0 – 9.5	6 – 9.5

[1)] Based on data obtained from the National Groundwater Database. Values reported at statistical median of each parameter.
[2)] Ref: *Quality of Domestic Water Supplies, Volume 1: Assessment Guide, 2nd Ed.1998*. Water Research Commission Report No: TT 101/98. Pretoria, South Africa.

Table 2.11.6.2(c): Toxic Substances and Complex Mixtures

Parameter	Ambient Groundwater Quality	Basic Human Needs Reserve[1)]	Groundwater Quality Reserve
Toxics	Not Provided	< TWQR	

TWQR denotes Target Water Quality Range
[1)] Ref: South African Water Quality Guidelines, Volume 1: Domestic Water Use, 2nd Ed. 1996. Department of Water Affairs and Forestry. Pretoria, South Africa.

The Reserve (Ref: 26/8/3/3/1069) for the A22F quaternary catchment, dated 30/07/2009 states that "*It should be pointed out that occasionally water quality at specific sites may exceed the broader and generic groundwater quality Reserve determined for the catchment, due to the natural spatial water quality variations dictated by the geology in which the water occurs. Under these circumstances, site specific data should be obtained and used to determine the more representative local ambient groundwater quality conditions at the site. This Directorate should be notified of such instance, so as to revise the reserve accordingly*".

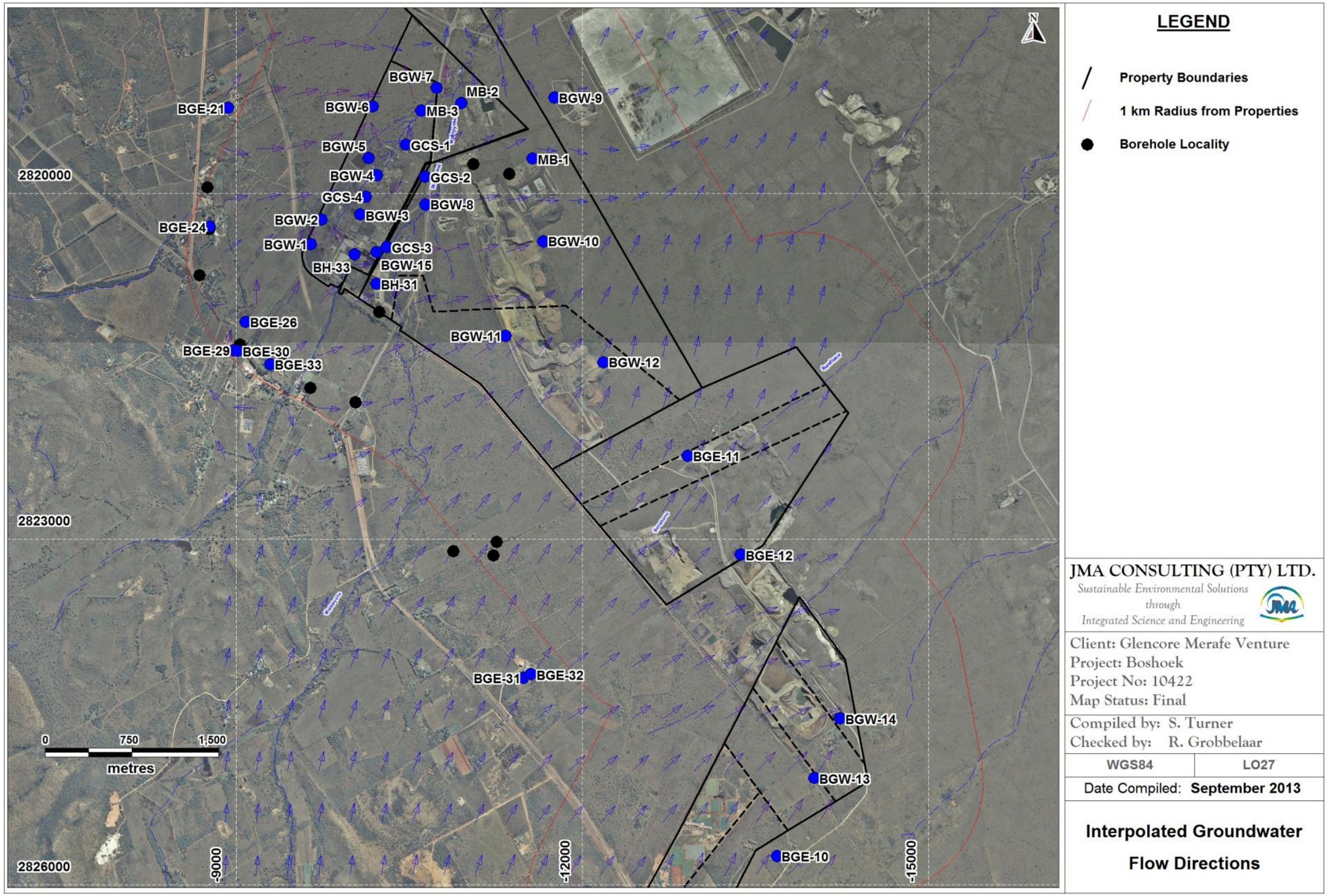

Figure 2.11.5.4(a): Interpolated Regional Groundwater Flow Directions

2.11.7 Aquifer Hydrochemistry

2.11.7.1 Background Groundwater Quality

The expected background groundwater quality assigned to the study area was determined using selected groundwater qualities sampled during the groundwater hydrocensus assessment and geohydrological field investigations conducted within the study area between November 2012 and March 2013. Groundwater samples were collected from 22 privately owned external user boreholes (BGE-) identified during the groundwater hydrocensus, 10 existing groundwater monitoring boreholes (GCS-, MB-) and 15 additional geohydrological investigative / monitoring boreholes (BGW-) at GMBS in total.

The 47 groundwater samples collected were scrutinized and samples that were identified to represent background groundwater qualities were selected according to the following criteria:

- Locality - The boreholes are not to be located immediately adjacent to any surface activities that are deemed to have already had an impact on the quality of the groundwater sampled at the borehole.
- TDS. The groundwater samples should have TDS concentrations of less than 600 mg/l,
- SO_4. The groundwater samples should have SO_4 concentrations of less than 100 mg/l.
- Na. The groundwater samples should have Na concentrations of less than 55 mg/l.

The assessment of the background groundwater qualities for each of the elements analysed for are listed in Table 2.11.7.1(a) and have been assessed with regards to SANS 241:2011 - Drinking Water Standard.

Table 2.11.7.1(a): Expected Background Groundwater Quality

Element	Unit	Minimum	Average	Maximum	Standard Deviation	Max + 1 SD	SANS 241:2011
pH	-	6.80	7.55	8.50	0.33	6.47, 8.83	≥ 5 to ≤ 9.7
EC	mS/m	18.4	52.8	90.5	17.5	108.0	≤ 170
TDS	mg/l	100	358	580	105	685	≤ 1200
Ca	mg/l	10.60	24.78	47.70	9.34	57.04	≤ 150; ≤ 300*
Mg	mg/l	14.40	50.29	97.80	22.50	120.30	≤ 70; ≤ 100*
Na	mg/l	5.15	14.63	54.70	9.71	64.41	≤ 200
K	mg/l	0.37	1.82	16.60	2.52	19.12	≤ 50; ≤ 100*
T.Alk	mg/l	100.0	262.8	500.0	111.9	611.9	
Cl	mg/l	5.00	16.95	65.00	13.27	78.27	≤ 300
SO_4	mg/l	5.00	15.00	43.00	10.17	53.17	≤ 500
Si	mg/l	15.50	38.10	50.60	6.54	57.14	
NO_3	mg/l	0.20	3.01	18.00	3.51	21.51	≤ 11
NO_2	mg/l	0.10	0.11	0.30	0.03	0.33	≤ 0.9
Al	mg/l	0.00	0.24	1.52	0.37	1.89	≤ 0.3
F	mg/l	0.20	0.21	0.60	0.06	0.66	≤ 1.5
Fe	mg/l	0.01	2.44	16.20	4.62	20.82	≤ 2
Mn	mg/l	0.00	0.12	2.13	0.37	2.50	≤ 0.1
NH_4	mg/l	0.20	0.21	0.40	0.03	0.43	≤ 1.5
Zn	mg/l	<0.01	0.03	0.34	0.07	0.41	≤ 5; ≤ 10*

Element	Unit	Minimum	Average	Maximum	Standard Deviation	Max + 1 SD	SANS 241:2011
Cr	mg/l	0.001	0.015	0.137	0.029	0.166	$\leq$ 0.05
Cr^{6+}	mg/l	0.010	0.014	0.122	0.019	0.141	
Ag	mg/l	0.001	0.001	0.001	0.000	0.001	
As	mg/l	0.001	0.001	0.001	0.000	0.001	$\leq$ 0.01
Au	mg/l	<0.001	0.004	0.045	0.009	0.054	
B	mg/l	0.001	0.001	0.001	0.000	0.001	
Ba	mg/l	0.001	0.006	0.033	0.007	0.040	
Be	mg/l	0.006	0.079	0.340	0.074	0.414	
Bi	mg/l	0.001	0.001	0.001	0.000	0.001	
Cd	mg/l	0.001	0.001	0.001	0.000	0.001	$\leq$ 0.003
Ce	mg/l	<0.001	<0.001	0.001	0.000	0.001	
Co	mg/l	<0.001	0.001	0.003	0.001	0.004	$\leq$ 0.5
Cs	mg/l	0.001	0.003	0.013	0.003	0.016	
Cu	mg/l	0.001	0.001	0.001	0.000	0.001	$\leq$ 2
Ga	mg/l	0.001	0.005	0.024	0.006	0.030	
Ge	mg/l	0.001	0.001	0.001	0.000	0.001	
Hf	mg/l	0.001	0.001	0.001	0.000	0.001	
Hg	mg/l	0.001	0.001	0.001	0.000	0.001	$\leq$ 0.006
Ho	mg/l	<0.001	<0.001	<0.001	0.000	<0.001	
Ir	mg/l	0.001	0.001	0.001	0.000	0.001	
La	mg/l	0.001	0.001	0.001	0.000	0.001	
Li	mg/l	0.001	0.001	0.010	0.001	0.011	
Mo	mg/l	0.001	0.002	0.005	0.001	0.006	
Nb	mg/l	0.001	0.001	0.003	0.000	0.003	
Nd	mg/l	0.001	0.001	0.001	0.000	0.001	
Ni	mg/l	0.001	0.001	0.008	0.001	0.009	$\leq$ 0.07
Pb	mg/l	<0.001	0.006	0.028	0.008	0.036	$\leq$ 0.01
PO_4	mg/l	0.001	0.007	0.114	0.020	0.134	
Pt	mg/l	0.200	0.200	0.200	0.000	0.200	
Rb	mg/l	0.001	0.001	0.001	0.000	0.001	
Sb	mg/l	0.001	0.006	0.057	0.010	0.067	$\leq$ 0.02
Sc	mg/l	0.003	0.011	0.053	0.010	0.063	
Se	mg/l	0.001	0.001	0.001	0.000	0.001	$\leq$ 0.01
Sn	mg/l	0.001	0.001	0.001	0.000	0.001	
Sr	mg/l	0.021	0.139	0.633	0.118	0.751	
Ta	mg/l	0.001	0.001	0.001	0.000	0.001	
Te	mg/l	0.001	0.001	0.001	0.000	0.001	
Th	mg/l	<0.001	<0.001	0.001	0.000	0.001	
Ti	mg/l	0.050	0.052	0.102	0.009	0.111	
Tl	mg/l	0.001	0.001	0.001	0.000	0.001	
U	mg/l	<0.001	0.001	0.005	0.001	0.006	$\leq$ 0.015
V	mg/l	0.001	0.009	0.043	0.009	0.052	$\leq$ 0.2
W	mg/l	0.001	0.001	0.003	0.000	0.003	
Y	mg/l	0.001	0.001	0.001	0.000	0.001	
Zr	mg/l	0.001	0.001	0.001	0.000	0.001	

*** Elemental Concentrations assessed with regards to SANS 241:2006 (Edition 6.1)**

It is important to note that the groundwater qualities may fluctuate between the seasons and between respective groundwater sampling runs. Representative groundwater qualities can therefore not be assigned to an aquifer or area of investigation based on only 1 sampling run. Statistical analyses of the chemistry of the groundwater sampled at the 37 boreholes between November 2012 and March 2013 was performed during which the minimum, average, maximum and standard deviations of the elemental concentrations were calculated.

The expected elemental concentrations selected for the background groundwater quality is therefore taken as the sum of the maximum concentration recorded and the standard deviation calculated for that element (Max + 1 SD) to account for potential concentration fluctuations.

The major elements that have total (unfiltered) concentrations in at least one of the background groundwater samples collected that exceeds the SANS 241:2011 limits are Fe, Mn, Al, Cr and NO_3. Although no limit is set in SANS 241:2011 for Mg, it is indicated that the total (unfiltered) Mg concentrations recorded in the background groundwater samples are also slightly elevated.

The expected background groundwater quality determined for the study area is deemed relevant and should be used and referred to with regards to formal groundwater impact and risk assessments for the study area as well as during future groundwater quality reserve determinations.

Hydrochemical imaging of expected background groundwater samples collected from within the study area was performed during which Piper and Durov Diagrams were compiled. The resulting Piper and Durov Diagrams of the expected background groundwater quality are indicated as Figure 2.11.7.1(a) and Figure 2.11.7.1 (b) respectively.

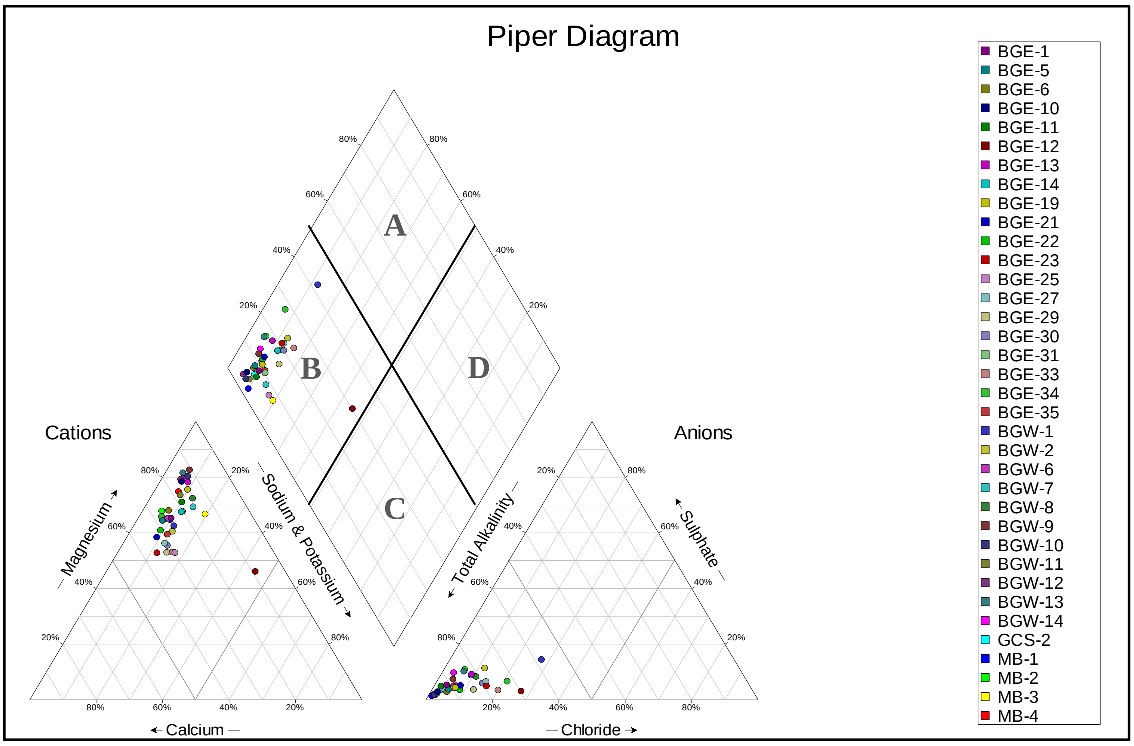

Figure 2.11.7.1(a): Background Groundwater Quality – Piper Diagram

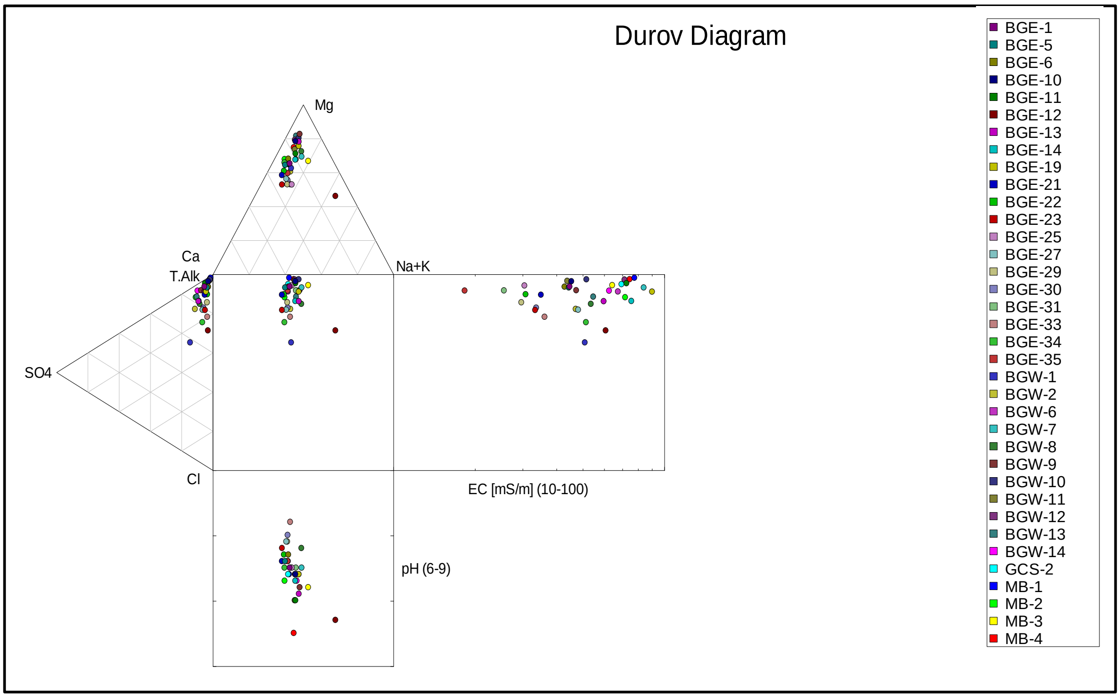

Figure 2.11.7.1(b): Background Groundwater Quality – Durov Diagram

The expected background groundwater quality, based on the groundwater samples taken from within the study area, has a distinctly characteristic Type-B hydrochemical facie signature, with the dominant cation evidently being Mg^{2+} and the dominant anion being HCO_3^- (T.Alk).

The groundwater sampled from borehole BGE-12 has almost equivalent Mg^{2+} and Na^+ + K^+ concentrations and an increasing equivalent Chloride (Cl^-) concentration. Although still classified as having a Type-B hydrochemical facies it trends towards a Type-C hydrochemical facies.

The groundwater sampled from borehole BGW-1 and to a lesser degree borehole BGE-34 have increasing Cl^- concentrations. Although still classified as having Type-B hydrochemical facies' they trend towards having Type-A hydrochemical facies.

2.11.7.2 Current Groundwater Quality

The current groundwater quality is assessed with regards to the groundwater samples collected during the groundwater hydrocensus assessment and geohydrological field investigations conducted within the study area between November 2012 and March 2013.

The following has relevance with regards to the major elemental concentrations of the groundwater sampled within the study area:

- The pH is neutral and ranges between 6.8 and 8.5 with an average pH of 7.6.
- EC ranges between 18.4 mS/m and 292 mS/m with an average of 84.2 mS/m.
- TDS ranges significantly between 100 mg/l and 3106 mg/l with an average of 593 mg/l.

- Ca ranges between 10.6 mg/l and 155 mg/l with an average of 37.7 mg/l.
- Mg ranges between 14.4 mg/l and 356 mg/l with an average of 85.9 mg/l.
- Na ranges between 4.8 mg/l and 115 mg/l with an average of 19.0 mg/l.
- K ranges between 0.37 mg/l and 16.60 mg/l with an average of 1.87 mg/l.
- T.Alk ranges between 100 mg/l and 969 mg/l with an average of 311 mg/l.
- Cl ranges between 5.0 mg/l and 415 mg/l with an average of 49.4 mg/l.
- SO_4 ranges between 2.95 mg/l and 1050 mg/l with an average of 115 mg/l.
- NO_3 ranges between 0.2 mg/l and 18.0 mg/l with an average of 3.2 mg/l.

The qualities of the groundwater samples collected from the following boreholes at GMBS do not adhere to the requirements set to represent the expected background groundwater quality for the study area: GCS-1, GCS-3, GCS-4, BH 31, BH-33, BGW-4, BGW-5, BGW-15 and BGE-36.

This potentially indicates that the quality of these groundwater samples have already been adversely influenced by certain surface activities and operations on site. Future groundwater monitoring at these boreholes is required to determine long term groundwater quality trends as well to verify and quantify the potential level of impact on the groundwater resource within these areas.

Hydrochemical imaging of groundwater samples collected within the study area was performed during which Piper and Durov Diagrams were compiled. The resulting Piper and Durov Diagrams of the groundwater samples collected within the study area as well as the samples collected at GMBS are depicted as Figures 2.11.7.2(a), 2.11.7.2(b), 2.11.7.2(c) and 2.11.7.2(d), respectively.

The current groundwater quality, based on the groundwater samples taken from within the study area, has a characteristic Type-B hydrochemical facie signature, with the dominant cation evidently being Mg^{2+} and the dominant anion being HCO_3^-(T.Alk). Increasing equivalent Cl^- and SO_4^{2-} concentrations are observed in the current groundwater quality as well.

The groundwater samples taken from boreholes BGW-15 and GCS-3 have a distinct Type-A hydrochemical facie signature, with the dominant anions being Cl^- and SO_4^{2-}. These groundwater samples have a different hydrochemical facies signature to that of the background groundwater samples collected. SO_4^{2-} and Cl^- are deemed conservative elements and an increase in these concentrations indicate the potential impact on the groundwater quality sampled from these boreholes.

The groundwater samples taken from boreholes BGW-5, BGW-4, BH-31, GCS-1, BGW-3, BGW-1, GCS-4, BH-33 and to a lesser degree BGE-20, BGE-36 and BGE-12 have increasing Cl^- and SO_4^{2-}. concentrations. The increase in the equivalent Cl^- and SO_4^{2-} concentrations recorded in these boreholes indicate the potential impact on these groundwater qualities as well.

Table 2.11.7.2(a): Current Groundwater Quality – Macro Constituents

Sample No	Sample Date	pH	EC	TDS	Ca	Mg	Na	K	T.Alk	Cl	SO_4
		-	mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
BGE-1	20130129	7.50	44.9	306	24.20	38.70	10.60	1.81	224	7.00	12.00
BGE-5	20130129	7.40	44.6	294	27.30	38.40	8.51	1.36	244	10.00	9.00
BGE-6	20130129	7.30	43.0	302	22.40	38.30	8.06	1.23	220	9.00	6.00
BGE-10	20130129	7.60	45.6	316	16.10	51.10	8.09	0.86	264	5.00	7.00
BGE-11	20130130	8.00	72.8	418	32.30	74.80	20.60	1.17	416	8.00	20.00
BGE-12	20130130	8.30	61.0	358	11.10	34.50	54.70	16.60	232	65.00	9.00
BGE-13	20130130	7.90	60.0	410	17.80	63.90	13.40	0.90	276	23.00	29.00
BGE-14	20130130	7.70	75.9	516	33.80	67.40	22.40	1.61	336	28.00	34.00
BGE-19	20130131	7.60	90.5	580	31.10	97.80	24.40	1.13	476	27.00	21.00
BGE-20	20130131	7.70	108.0	726	37.10	117.00	21.10	1.08	432	45.00	109.00
BGE-21	20130131	7.40	35.2	264	23.80	25.90	7.27	1.18	148	10.00	8.00
BGE-22	20130131	7.30	30.9	222	19.10	23.40	6.00	1.39	140	10.00	5.00
BGE-23	20130131	7.20	33.5	250	23.70	21.50	8.73	1.35	124	18.00	7.00
BGE-25	20130131	7.50	30.6	242	18.70	20.10	12.50	0.53	148	5.00	5.00
BGE-27	20130131	7.10	48.3	336	30.50	33.30	13.30	2.15	196	27.00	15.00
BGE-29	20130131	7.10	29.8	228	19.20	19.10	9.40	1.71	128	14.00	5.00
BGE-30	20130131	7.00	33.8	256	21.10	23.00	10.00	1.94	132	17.00	9.00
BGE-31	20130201	7.50	25.7	182	10.60	21.70	6.51	1.94	116	6.00	5.00
BGE-33	20130201	6.80	36.3	282	22.80	23.90	13.50	1.38	148	28.00	6.00
BGE-34	20130226	7.50	51.6	376	29.60	43.20	8.32	1.09	212	45.00	18.00
BGE-35	20130226	7.40	18.4	100	11.50	14.40	5.15	0.73	100	5.00	5.00
BGE-36	20130226	7.80	45.1	332	19.90	47.40	8.41	0.99	212	18.00	20.00
BGW-1	20130225	7.50	51.1	374	26.50	39.70	13.60	2.62	140	48.00	33.00
BGW-2	20130225	7.50	47.3	332	27.30	37.40	14.40	1.68	208	24.00	29.00
BGW-3	20130225	7.20	118.0	776	48.60	124.00	21.90	0.44	412	114.00	106.00
BGW-4	20130225	7.30	136.0	982	61.40	139.00	43.40	0.94	408	140.00	184.00
BGW-5	20130225	7.50	124.0	848	66.70	115.00	31.00	1.93	352	113.00	184.00
BGW-6	20130226	7.40	67.7	502	46.10	70.90	18.40	1.81	400	21.00	22.00
BGW-7	20130226	7.50	84.3	570	33.60	87.80	35.20	1.19	500	21.00	17.00
BGW-8	20130225	7.20	53.8	396	18.20	54.40	17.80	1.90	260	26.00	25.00
BGW-9	20130226	7.80	47.5	332	11.90	56.80	8.81	1.02	256	10.00	20.00
BGW-10	20130226	7.60	51.8	330	16.00	64.00	10.47	2.32	324	5.00	5.00
BGW-11	20130312	8.00	44.0	332	19.40	48.70	9.81	2.41	252	5.00	5.00
BGW-12	20130312	7.60	71.6	448	26.90	87.00	11.90	1.93	416	7.00	6.00
BGW-13	20130312	7.60	54.9	366	17.40	66.00	7.99	1.38	244	14.00	28.00
BGW-14	20130312	7.70	62.8	448	20.60	75.20	11.30	1.40	248	8.00	26.00
BGW-15	20130312	7.40	292.0	2222	112.00	311.00	115.00	1.50	280	415.00	842.00
BH-31	20121112	7.60	99.4	720	89.30	81.50	13.20	0.96	332	52.00	163.00
BH-33	20121112	7.50	106.0	708	79.20	87.90	17.40	0.57	388	87.00	94.00
GCS-1	20121112	8.10	88.1	638	61.30	70.00	21.80	1.59	312	57.00	136.00
GCS-2	20121113	7.60	69.8	440	40.50	61.90	17.20	0.37	388	11.00	13.00
GCS-3	20121112	7.20	258.0	1984	155.00	356.00	12.40	0.73	378	375.00	759.00
GCS-4	20121113	7.50	135.0	838	126.00	107.00	34.70	1.40	496	78.00	170.00
MB-1	20121113	7.60	77.9	386	47.70	73.80	21.60	1.34	456	5.00	5.00
MB-2	20121113	7.70	72.0	470	44.40	69.40	11.60	0.96	348	20.00	43.00
MB-3	20130226	7.80	64.5	444	21.80	64.20	35.70	1.03	376	11.00	16.00
MB-4	20121113	8.50	74.8	500	31.90	81.60	15.70	0.84	416	6.00	7.00
BH11	20130116	7.81	226	1677	48.9	306	46.6	-	435	197	817
DWA01	20100707	8.33	76.3	366	12.4	72	22.8	0.829	377	8.11	24.1
DWA02	20100707	7.55	276	1830	92.5	307	16.8	2.02	515	97.6	1000
DWA03	20090113	7.89	176	829	21.5	158	19.8	15.8	969	27.6	2.95
DWA04	20081008	8.05	272	3106	48.9	331	33.3	1.43	494	215	1050
E21	20130116	7.39	56.3	272	31.3	50.6	7.74	0.441	276	5.94	7.65
SANS 241:2011 Limits		**≥ 5 to ≤ 9.7**	**≤ 170**	**≤ 1200**	***150; 300****	***70; 100****	**≤ 200**	***50; 100****		**≤ 300**	**≤ 500**

*** SANS 241:2006 (Edition 6.1)**

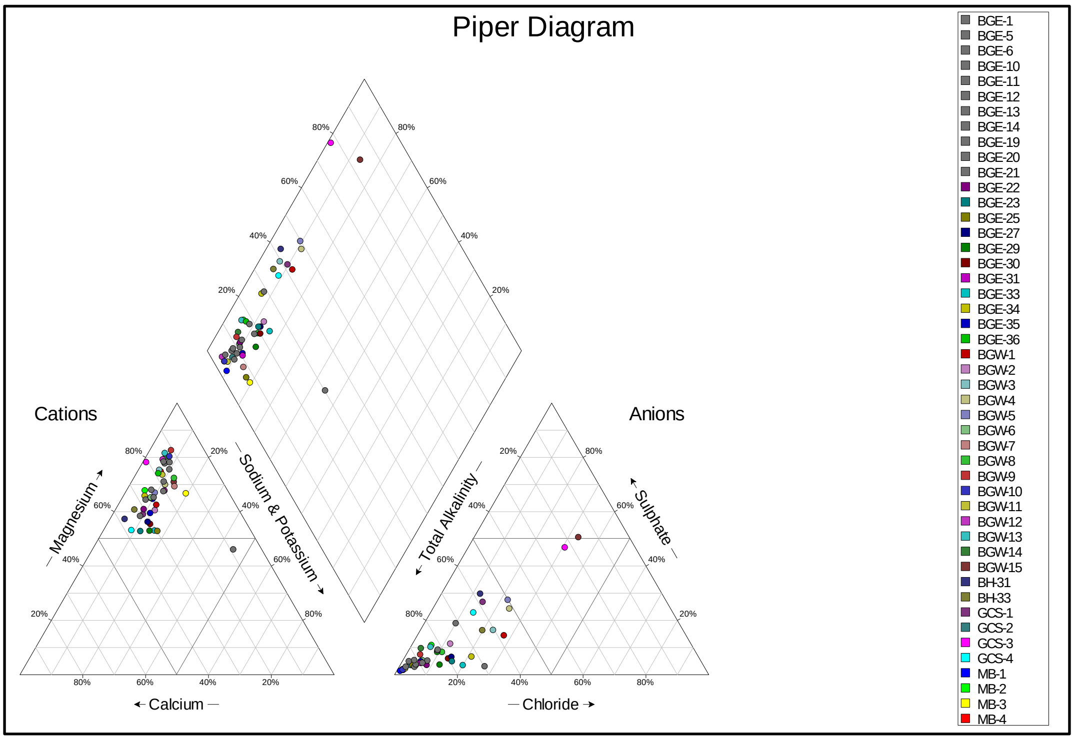

Figure 2.11.7.2(a): Current Groundwater Quality (Study Area) – Piper Diagram

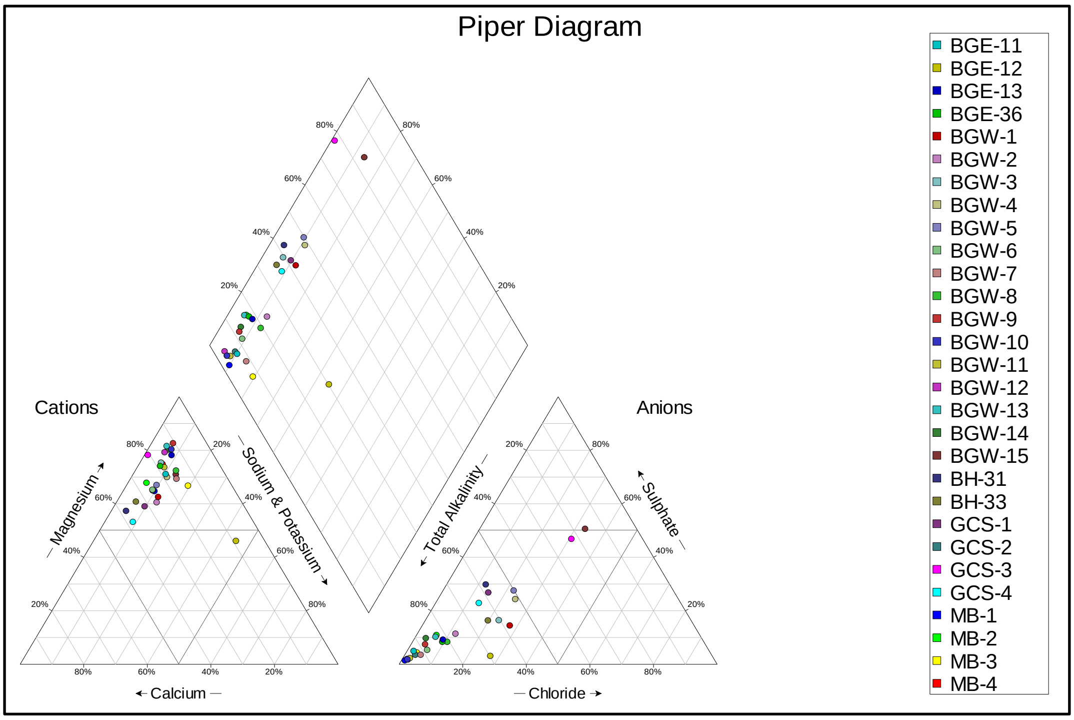

Figure 2.11.7.2(b): Current Groundwater Quality (GMBS Operations) – Piper Diagram

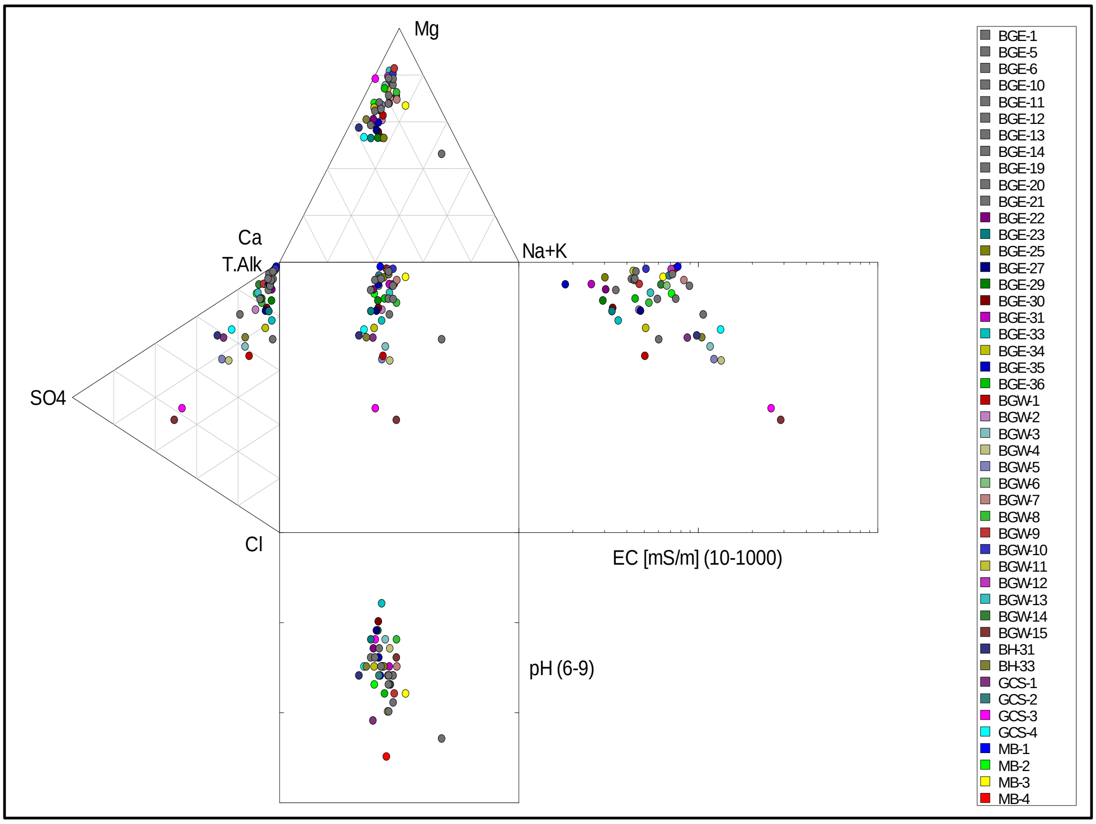

Figure 2.11.7.2(c): Current Groundwater Quality (Study Area) – Durov Diagram

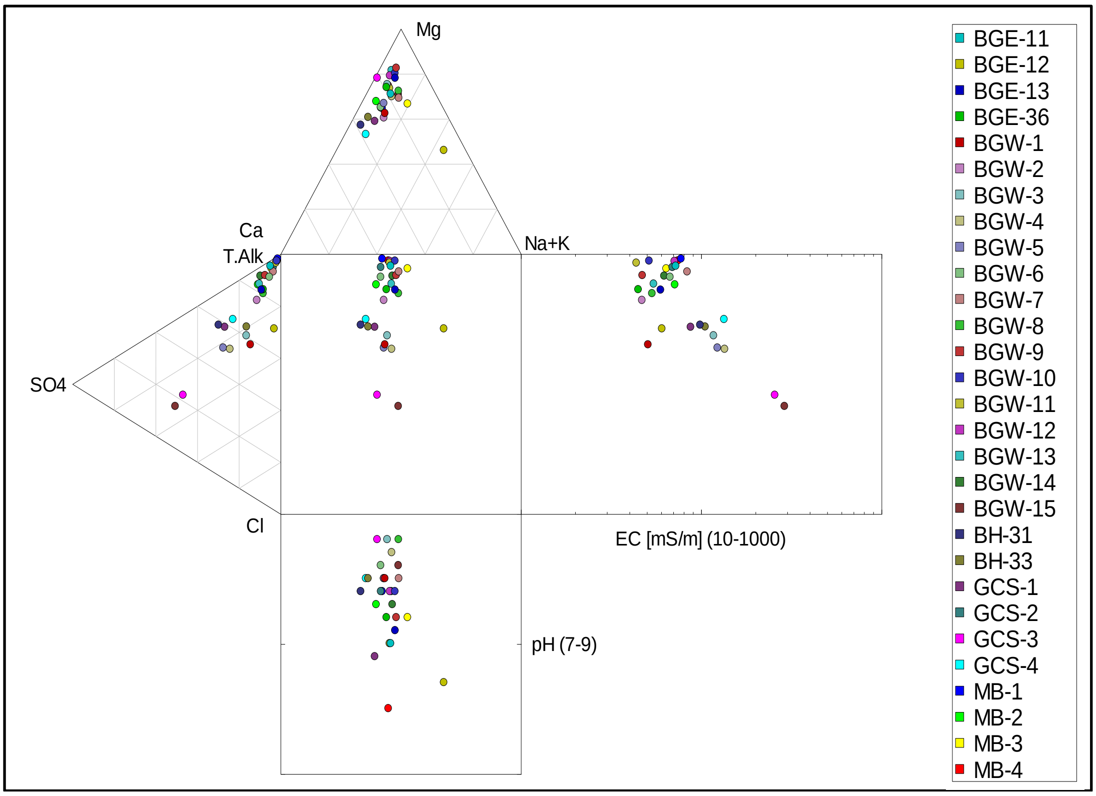

Figure 2.11.7.2(d): Current Groundwater Quality (GMBS Operations) – Durov Diagram

2.11.8 Groundwater Use

It was identified during the field investigations that groundwater is currently being abstracted (groundwater receptor) from 27 boreholes within the study area. In addition to the groundwater abstracted from the 27 identified boreholes, groundwater is also abstracted from the opencast mining operations' pits as well as from within the underground mining operations within the study area.

The groundwater abstracted from the private external user boreholes (BGE-) is used primarily as a second source of water for domestic use, gardening, small scale irrigation and livestock watering purposes. The volumes of groundwater abstracted from each of these boreholes were not made available during the groundwater hydrocensus' conducted adjacent to the GMBS operations.

Glencore Merafe Boshoek Mine and Smelter currently has a water use license that allows the following volumes of groundwater to be abstracted from each of the respective boreholes:

- BGE-11: 1 080 m^3/annum
- BGE-13: 1 096 m^3/annum
- BH-31: 3 650 m^3/annum
- BH-33: 1 825 m^3/annum
- GCS-1: 90 520 m^3/annum
- GCS-3: 90 000 m^3/annum

The groundwater abstracted from boreholes BGE-11 and BGE-13 is used as domestic water supply for the Andru Mining and Benhaus Mining personnel on site. The groundwater that is permitted to be abstracted at boreholes BH-31, BH-33, GCS-1 and GCS-3 is used as an additional supply of process water associated with the GMBS ferrochrome beneficiation plant and associated activities.

The water use license also permits Glencore Merafe to abstract 160 000 m^3/annum and 720 m^3/annum of groundwater at their northern and southern opencast mining operations as well. The groundwater abstracted at the opencast mining operations is required for aquifer dewatering associated with the operation of the opencast mining activities.

It is indicated that groundwater will continue to be abstracted from within the study area as an additional source of water from the private boreholes.

Groundwater will furthermore continue to be abstracted for aquifer dewatering and as a source of process water for as long as the mining and industrial activities are operational within the study area.

2.11.9 Aquifer Classification

A formal aquifer classification for the GMBS aquifers was done in accordance with the formal DWAF (1995) "South African Aquifer System Management Classification" protocol.

The aquifers underlying the GMBS site are classified as **minor aquifer** systems, contrary to earlier classifications which indicated them to be major aquifers.

The earlier classification delineated extensive areas where it was erroneously assumed that areas associated with surface water drainage lines would imply major aquifers to be present. Although these areas may represent preferential recharge zones, and in association with prefential ground water zones along geological faults, may result in individual high yielding boreholes to be drilled, it does not render the bulk aquifer zone a major aquifer.

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yielded a Groundwater Quality Management Index of 6 for the shallow weathered zone aquifers systems at GMBS, indicating that **medium** level groundwater protection is required.

2.12 SURFACE WATER BASELINE

Inprocon Consulting Engineers was appointed by JMA Consulting to conduct a detailed surface water base line assessment for the Glencore Merafe Boshoek Mine and Smelter (GMBS) project. The surface water specialist report containing the base line description is attached as **APPENDIX 2.12 (A)** to this report. Below is a summary of this assessment.

The Surface Water Baseline study focusses on the quantitative investigation of the existing surface water regional environment and in the vicinity of the site. The general climatic parameters that include temperature and wind are not of major concern for surface water related matters but rather rainfall, rainfall distribution, mean annual precipitation, mean annual evaporation and monthly runoff volumes are part of the assessment of the surface water baseline environment. The sub-catchment yield and surface water quality at the site are further covered in the baseline scope. The baseline environment also includes the prediction of the expected flood peaks for the sub-catchments considering the probability of occurrence.

2.12.1 Location and Hydrological Topography of Site

The GMBS site is located 30 km to the north-west of Rustenburg in the North West Province. The area is 2.5 to 3 km north of the Magalies Mountain range. GMBS is within the A22F quaternary catchment that is also within the Crocodile (West) and Marico Water Management Area. Runoff from the catchments near the site drains towards the Matlopyane and Leragane Streams that are two of the many branches of the Elands River. The Elands River and the Hex River are the primary streams that feed the Vaalkop dam. The site resides in the A22F quaternary catchment.

2.12.2 Climate/Meteorology

The climate of the region is typical of the middelveld climate zone. During the summer the average midday temperatures for Rustenburg range from 19.3°C in June to 29.4°C in January but cool slightly down during the evening at low to mid-teens. Summer (mid-October to mid-February) is characterised by hot, sunny weather often with afternoon thunderstorms of short duration. In winter (May to July) day time temperatures range in the band from 19°C to early twenties dropping the mercury at night on average to 1.7°C in July, which is the coldest month.. Frost occurrence during winter occurs but is not common. The rainfall occurs mostly in summer – some 85% of the annual being recorded during this period. There is a distinct seasonal variation in rainfall and the evaporation follows a far less spikey variation but also has some seasonal trend during the year.

Rainfall stations within a 25 km radius of the site and with record length of more than 30 years were considered. Station no. 511 400 Rustenburg Police Station has been regarded as baseline for the mean annual precipitation (MAP) which average to 665 mm. The locality and length of record were appropriate to regard it representative for the site. However the site falls in a region with varying MAP between 600 and 700mm.

The mean monthly rainfall has been assumed using the average monthly distribution determined from the historic rainfall record at Rustenburg Pol. This is also compared with the average monthly rainfall for the applicable A2G rainfall zone in which the site resides. The rainfall monthly distribution has a 128mm high in the months of January and a 5mm low during July.

Dirty runoff from affected plant areas must be contained in appropriate sized impoundments that have a capacity to intercept the expected operational runoffs and a reserve volume to contain runoff from a 24 hour 100 year flood. The rainfall depths of extreme events with a 10%, 5%, 2%, 1% and 0.5% risk of occurrence has been indicated.

The Mean annual evaporation (MAE) for Evaporation Zone 2B in with the site resides is given in WR2005 as 1800 mm for S-pan evaporation. The monthly rate of evaporation has been used as indicated by WR90. The conversion from pan evaporation to open lake conditions according WR90 is also indicated. The MAE for open lakes is 1512 mm. From September to March 85% of the MAE occurs.

2.12.3 Surface Water Hydrology

The North West Regional office of the Department of Water Affairs that is situated at the Hartebeespoort Dam is the water regulating authority.

The Matlapyane and Leragane are the main streams in the vicinity of GMBS and also the receiving water body. All streams near the site are short-lived courses with water flow during the wet season. Both streams discharge in to the Elands River. Some small drainage lines are found near the opencast mine area. The total upslope catchment of GMBS is 72.6 km^2. The drainage density for the streams is 0.5 km/km^2. Any surface mining related activities will thus require run-off diversion or suitable storm water runoff measures.

The mean annual runoff (MAR) for the 72.6 km^2 catchment yields 1.044 million cubic meters. This 4.3% of the MAR of the A22F quaternary catchment.

The average dry weather flow for the three driest months within a hydrological year for each of the catchment upstream of the site totals to 5.1 l/s. This is equivalent to 440 m^3 per day on average. The average dry weather flow is only an indication of the average flow rate and not implying the existence of a constant flow over any dry month. These rates indicate the expected average volume of runoff on average during the driest months.

The peak floods with a risk of occurrence of 1%, 2% and 5% have been calculated. The catchments are regarded hydrological small and appropriate methods that deal with such sized catchments have been used. The Matlapyane Stream just to the downstream boundary of GMBS property has a flood peak of 137.7 m^3/s with a 1 % risk. The Matlapyane north and its tributary running next to the Furnace Plant site has each respectively 84.8 m^3/s and 77.4 m^3/s peak flows with a 1% risk of occurrence. It is required by Regulation GN 704 clause 4, that all mining and related mining activities must be located outside the 100 year flood lines or 100 m offset zone measured from the centre of the a stream.

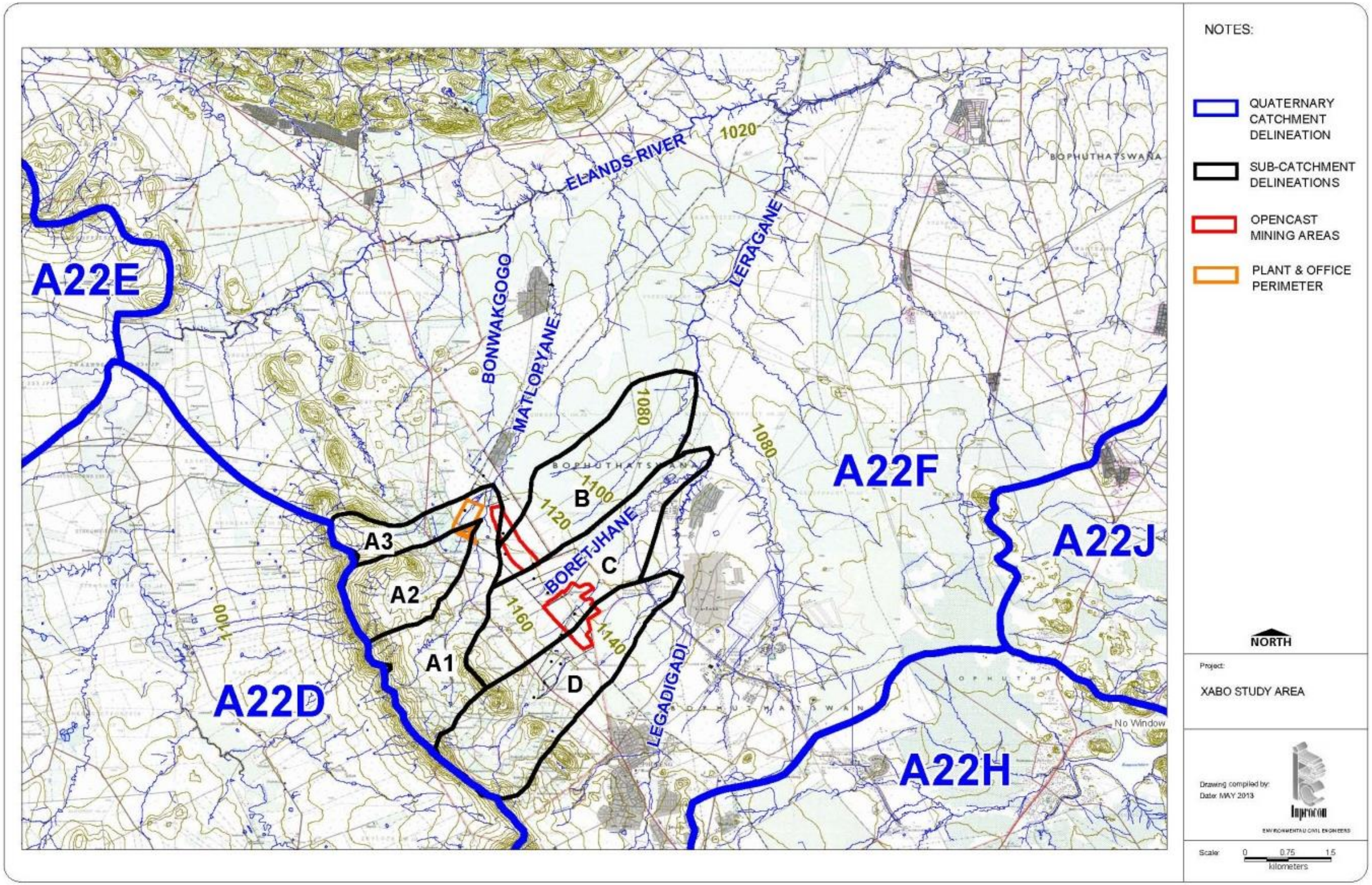

Figure 2.12.3 (a): **Sub-catchments relevant to the GMBS Site**

In the case of catchments upslope of the open cast areas on the farms Bultfontein 259JQ and Boekenhoudfontein 260JQ (catchments labelled “c” and “d”) the peak flows will mainly appear as sheet flow across the front of the catchment facing the mining area. Therefore any activity causing disturbances cutting across the drainage direction must provide for such peak flow during extreme events.

For the determination of flood volumes triangular hydrographs were assumed with the peak flow occurring at the time of concentration (Tc) and the recession limb of the hydrograph having a run out time at 3 times the Tc. The flood volumes for the subject sites are expressed in Ml. For the Matlapyane upstream of the site north boundary the flood volume of the 1 in 100 year flood is 1442 Ml.

The scope further also entails the modelling and delineation of 100 year flood lines for the streams crossing or passing close to the study area. The only streams in the vicinity of the GMBS that are well manifested in terms of a defined flow channel are the Matlapyane and its tributary flowing next to the Furnaces Plant area. The main stream was divided in an Upper reach and Lower Reach with the spilt positioned where the tributary joins the main Matlapyane stream just to the north of the Furnaces Plant.

The flood lines for these two streams were modelled employing the HEC-RAS software. The HEC-RAS software was developed at the Hydrologic Engineering Centre (HEC), which is a division of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers. The software performs one-dimensional steady and unsteady state river flow calculations.

Stream cross sections were extracted at 20m river station distances from a digital terrain model compiled from the aerial survey of the site. Model Maker software was used for the extraction of stream sections as well as importing the output of HEC-RAS for the 3D flood lines polylines.

The Matlapyane stream and tributary are quite obstructed with the rail crossing, provincial road crossings (2 in the vicinity of the plant), water impoundments next the plant area and mining access and open cast workings. During extreme flood conditions only large portal bridges and road embankments will have an impact on the flood line profile whilst small culverts will be completely overtopped. Therefor small culverts were excluded and only large obstructions were considered.

The meandering, widening and narrowing nature of the larger streams causing mixed flow conditions with stream sections having super critical (rapid) flow and sections having sub critical (mild flow) flow. The water surface is during flood events is impacted by the damming effect caused by the road and rail embankments. The road and rail culverts have been designed for smaller floods than the 100 year floods which is common for the class of roads and rail service in the vicinity of the site. Long sections of the surface water profiles of the streams indicate the damming at the crossing embankments and earth dam walls in the tributary stream.

The 100-Year flood lines are indicated for the Matlapyane stream in the vicinity of the GMBS site. The required 100m offsets measures from the stream centrelines are also indicated.

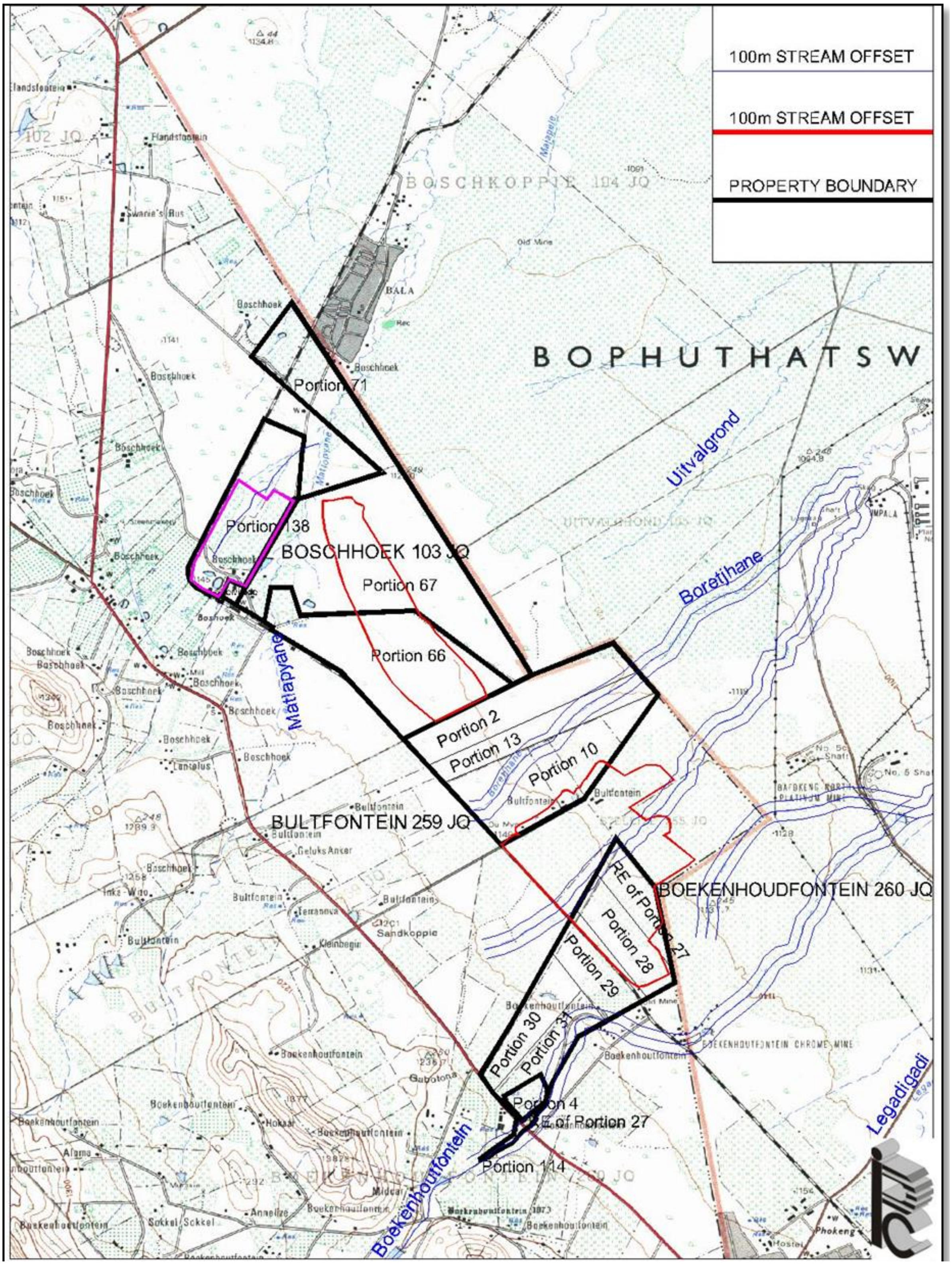

Figure 2.12.3 (b): 100 m Buffer Zones for Drainage Lines

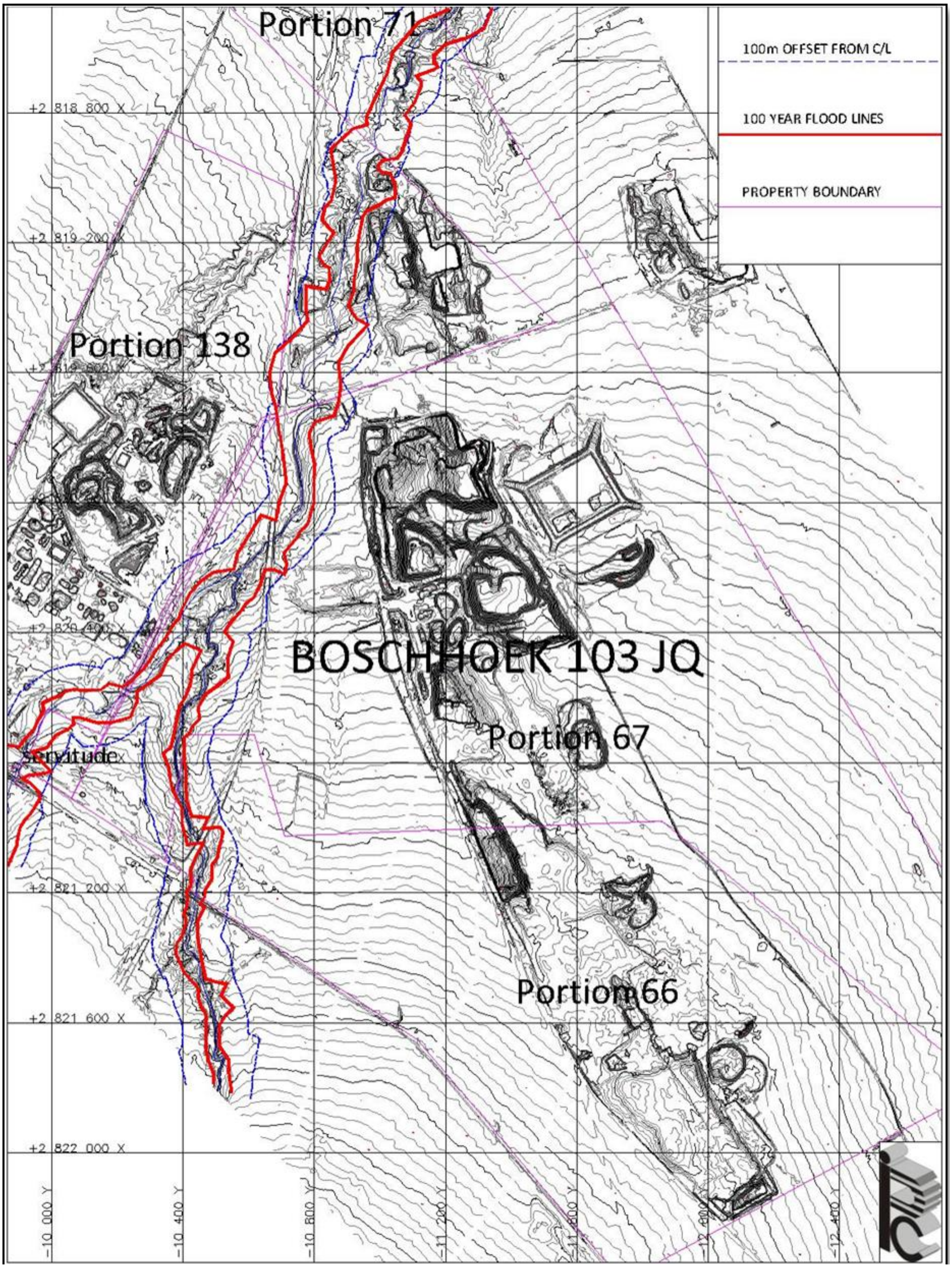

Figure 2.12.3 (c): **100 Year Flood lines for the Matlapyane Stream Lines**

The flood lines are not fixed and are based on conditions as on 11 March 2012. It is observed that the 100 year flood lines falls within the 100m off set distance on both banks of the streams. The drainage lines near Bultfontein and Boekenhoudfontein where open cast mining is performed are not well defined. It also appears that sheetflow drainage is apparent. The considering factor will be that all mining obstructions must be outside the 100 m offset zone as the flood lines will also be within the offset zone. The offset lines have been indicated for all streams near the site. No formal water course alterations were observed.

2.12.4 Surface Water Quality

The current surface water quality at GMBS is addressed with regards to the quality of the surface water sampled during November 2012 for the purpose of this surface water baseline assessment.

The surface water samples collected for the potential pollution sources and receptor surface water courses respectively were done at 19 locations. It is necessary to understand the source quality (composition and variability) as it could influence what is observed in the streams. The stream Matlapyane and Matlhapyane are the same stream and names were derived from various sources and are used interchangeable.

The water constituent concentrations of the surface water samples collected are listed in Table 2.12.4(a) through to Table 2.12.4(d) and have been assessed with regards to the SANS 241:2006 Drinking Water Standard. The SANS 241:2006 Drinking Water Standard specifies two classes of drinking water quality, namely Class I and Class II, defined in terms of the microbiological, physical, organoleptic and chemical parameters. The assessment with regards to the SANS 241:2006 Drinking Water Standard is done, simply to provide an indication of the "fitness for use" of the surface water.

Table 2.12.4(a): Current Surface Water Quality (SANS 241:2006 Drinking Water Standard Compliance)

Sample No.	Date Sampled	pH	EC	TDS	Ca	Mg	Na	K	Si	T.Alk	Cl	SO_4	NO_3	F	Al	Fe	Mn
XBSW-1	20121113	7.30	6.1	52	3.34	2.74	1.84	0.20	6.24	24.00	5.00	5.00	0.20	0.20	0.18	1.44	0.02
XBSW-2	20121113	7.10	7.0	62	4.04	3.11	2.03	1.22	5.60	32.00	5.00	5.00	0.20	0.20	0.03	0.80	0.01
XBSW-3	20121113	7.20	8.1	70	4.05	3.77	2.40	1.80	5.29	32.00	5.00	5.00	0.20	0.20	0.11	0.70	0.02
XBSW-4	20121113	7.60	16.7	120	6.77	8.25	6.08	2.76	6.59	60.00	9.00	13.00	0.20	0.20	0.06	0.21	0.00
XBSW-6	20121113	8.40	91.6	608	46.80	82.00	28.70	4.80	23.70	364.00	39.00	77.00	13.00	0.30	0.00	0.01	0.00
XBSW-7	20121113	8.40	342.0	2334	41.30	155.00	375.00	264.00	21.50	996.00	242.00	518.00	15.00	3.30	1.72	2.35	0.11
XBSW-8	20121113	6.90	415.0	2834	181.00	135.00	505.00	119.00	5.75	96.00	526.00	1153.00	40.00	20.00	0.21	2.17	0.06
XBSW-9	20121113	8.30	229.0	1530	54.10	104.00	237.00	123.00	10.60	404.00	175.00	611.00	15.00	1.70	2.01	2.20	0.05
XBSW-10	20121113	7.70	425.0	2900	176.00	133.00	520.00	137.00	6.68	244.00	523.00	982.00	43.00	14.00	0.14	1.43	0.04
XBSW-11	20121113	8.60	408.0	2800	46.10	162.00	461.00	325.00	22.50	1268.00	307.00	603.00	16.00	3.60	0.28	0.92	0.05
XBSW-12	20121113	9.20	160.0	1090	8.28	113.00	113.00	53.70	2.42	304.00	129.00	369.00	6.80	3.90	0.01	0.01	0.00
XBSW-13	20121113	8.70	608.0	4702	62.20	177.00	804.00	577.00	19.60	1100.00	304.00	1928.00	44.00	1.90	0.01	0.07	0.02
XBSW-14	20121113	8.80	242.0	1670	36.80	124.00	242.00	146.00	21.20	740.00	164.00	362.00	19.00	1.20	0.01	0.06	0.00
XBSW-15	20130228	9.50	509.0	3432	5.90	31.10	800.00	486.00	17.67	600.00	531.00	809.00	17.00	2.40	1.16	0.51	0.06
XBSW-16	20130228	9.60	1139.0	8406	5.10	104.00	1830.00	1370.00	20.40	2280.00	997.00	1740.00	155.00	3.00	1.07	1.12	0.06
XBSW-17	20130129	7.20	22.0	168	9.00	22.00	6.00	4.70	64.30	68.00	14.00	22.00	0.20	0.20	7.92	19.50	0.55
XBSW-18	20130130	7.70	131.0	936	38.10	132.00	16.40	4.87	38.80	340.00	9.00	24.00	100.00	0.20	0.08	0.01	0.05
XBSW-19	20130130	8.20	92.4	598	19.00	97.90	21.80	1.09	36.80	268.00	12.00	29.00	56.00	0.20	0.06	0.01	0.00

Table 2.12.4(b): Current Surface Water Quality Continued (SANS 241:2006 Drinking Water Standard Compliance)

Sample No.	Date Sampled	NH_4	Ag	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cr6+	Cs	Cu	Ga
XBSW-1	20121113	0.20	0.001	0.001	0.001	0.003	0.009	0.001	0.001	0.0001	0.001	0.001	0.006	0.010	0.001	0.001	0.001
XBSW-2	20121113	0.20	0.001	0.001	0.001	0.004	0.010	0.001	0.001	0.0001	0.001	0.001	0.005	0.010	0.001	0.001	0.001
XBSW-3	20121113	0.20	0.001	0.001	0.001	0.006	0.008	0.001	0.001	0.0001	0.001	0.001	0.007	0.010	0.001	0.001	0.001
XBSW-4	20121113	0.20	0.001	0.001	0.001	0.007	0.011	0.001	0.001	0.0001	0.001	0.001	0.004	0.010	0.001	0.001	0.001
XBSW-6	20121113	0.20	0.001	0.001	0.001	0.024	0.028	0.001	0.001	0.0001	0.001	0.001	0.061	0.070	0.001	0.001	0.001
XBSW-7	20121113	4.80	0.001	0.003	0.001	0.197	0.020	0.001	0.001	0.0001	0.001	0.007	0.263	0.039	0.020	0.006	0.016
XBSW-8	20121113	10.00	0.001	0.002	0.001	0.113	0.007	0.001	0.001	0.0001	0.001	0.003	1.450	0.010	0.004	0.007	0.001
XBSW-9	20121113	0.60	0.001	0.001	0.001	0.085	0.007	0.001	0.001	0.0001	0.001	0.003	0.334	0.010	0.001	0.003	0.002
XBSW-10	20121113	12.00	0.001	0.001	0.001	0.113	0.010	0.001	0.001	0.0001	0.001	0.003	0.160	0.010	0.005	0.007	0.001
XBSW-11	20121113	23.00	0.001	0.003	0.001	0.208	0.016	0.001	0.001	0.0001	0.001	0.007	0.217	0.010	0.022	0.007	0.012
XBSW-12	20121113	0.60	0.001	0.001	0.001	0.054	0.004	0.001	0.001	0.0001	0.001	0.001	0.005	0.010	0.001	0.001	0.001
XBSW-13	20121113	18.00	0.001	0.002	0.001	0.286	0.022	0.001	0.001	0.0001	0.001	0.006	0.358	0.329	0.027	0.007	0.005
XBSW-14	20121113	2.40	0.001	0.003	0.001	0.102	0.024	0.001	0.001	0.0001	0.001	0.004	0.120	0.117	0.002	0.003	0.001
XBSW-15	20130228	0.20	0.001	0.007	0.001	0.165	0.025	0.001	0.001	0.0001	0.002	0.007	0.224	0.010	0.079	0.030	0.003
XBSW-16	20130228	0.20	0.001	0.009	0.001	0.355	0.025	0.001	0.001	0.0001	0.003	0.070	0.340	0.010	0.269	0.050	0.004
XBSW-17	20130129	0.40	0.001	0.001	0.001	0.014	0.418	0.001	0.001	0.0001	0.041	0.025	0.650	0.019	0.001	0.011	0.002
XBSW-18	20130130	1.10	0.001	0.001	0.001	0.008	0.129	0.001	0.001	0.0001	0.001	0.008	0.020	0.019	0.001	0.001	0.001
XBSW-19	20130130	0.20	0.001	0.001	0.001	0.007	0.158	0.001	0.001	0.0001	0.001	0.003	0.060	0.060	0.001	0.001	0.001

Table 2.12.4(c): Current Surface Water Quality Continued (SANS 241:2006 Drinking Water Standard Compliance)

Sample No.	Date Sampled	Ge	Hf	Hg	Ho	Ir	La	Li	Mo	Nb	Nd	Ni	NO_2	Pb	PO_4	Pt	Rb
XBSW-1	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.100	0.001	0.200	0.001	0.001
XBSW-2	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.100	0.001	0.200	0.001	0.001
XBSW-3	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.100	0.001	0.200	0.001	0.001
XBSW-4	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.100	0.001	0.200	0.001	0.002
XBSW-6	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.300	0.001	0.200	0.001	0.009
XBSW-7	20121113	0.007	0.001	0.0001	0.001	0.001	0.001	0.062	0.003	0.001	0.002	0.025	14.000	0.001	0.200	0.001	1.960
XBSW-8	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.024	0.022	0.001	0.001	0.019	16.000	0.001	0.200	0.001	0.182
XBSW-9	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.057	0.003	0.001	0.001	0.009	4.800	0.001	0.200	0.001	0.150
XBSW-10	20121113	0.002	0.001	0.0002	0.001	0.001	0.001	0.027	0.017	0.001	0.001	0.014	14.000	0.001	0.200	0.001	0.822
XBSW-11	20121113	0.011	0.001	0.0001	0.001	0.001	0.001	0.068	0.004	0.001	0.001	0.023	13.000	0.001	0.200	0.001	2.430
XBSW-12	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.022	0.002	0.001	0.001	0.002	0.500	0.001	0.200	0.001	0.046
XBSW-13	20121113	0.005	0.001	0.0001	0.001	0.001	0.001	0.126	0.005	0.001	0.001	0.012	4.100	0.001	0.200	0.001	3.290
XBSW-14	20121113	0.001	0.001	0.0001	0.001	0.001	0.001	0.027	0.003	0.001	0.001	0.005	2.600	0.001	0.200	0.001	0.634
XBSW-15	20130228	0.001	0.001	0.0001	0.001	0.001	0.003	0.199	0.025	0.001	0.002	0.011	11.000	0.002	0.200	0.001	2.38
XBSW-16	20130228	0.001	0.001	0.0002	0.001	0.001	0.002	0.437	0.210	0.001	0.003	0.091	1.700	0.003	0.200	0.002	9.540
XBSW-17	20130129	0.001	0.001	0.0001	0.001	0.001	0.017	0.003	0.001	0.001	0.013	0.001	0.200	0.009	0.200	0.001	0.013
XBSW-18	20130130	0.001	0.001	0.0001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.005	0.600	0.001	0.200	0.002	0.024
XBSW-19	20130130	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.100	0.001	0.200	0.001	0.003

Table 2.12.4(d): Current Surface Water Quality Continued (SANS 241:2006 Drinking Water Standard Compliance)

Sample No.	Date Sampled	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
XBSW-1	20121113	0.001	0.003	0.001	0.001	0.005	0.001	0.001	0.0001	0.050	0.000	0.000	0.004	0.001	0.001	0.002	0.001
XBSW-2	20121113	0.001	0.002	0.001	0.001	0.006	0.001	0.001	0.0001	0.050	0.001	0.000	0.001	0.001	0.001	0.001	0.001
XBSW-3	20121113	0.001	0.002	0.001	0.001	0.006	0.001	0.001	0.0001	0.050	0.001	0.000	0.002	0.001	0.001	0.001	0.001
XBSW-4	20121113	0.001	0.003	0.001	0.001	0.011	0.001	0.001	0.0001	0.050	0.001	0.000	0.001	0.001	0.001	0.001	0.001
XBSW-6	20121113	0.001	0.012	0.002	0.001	0.045	0.001	0.001	0.0001	0.050	0.001	0.000	0.026	0.001	0.001	0.003	0.001
XBSW-7	20121113	0.006	0.010	0.027	0.001	0.048	0.001	0.001	0.0001	0.050	0.001	0.000	0.081	0.002	0.001	0.338	0.001
XBSW-8	20121113	0.001	0.003	0.036	0.001	0.142	0.001	0.001	0.0001	0.050	0.001	0.001	0.117	0.005	0.001	0.005	0.001
XBSW-9	20121113	0.001	0.005	0.023	0.001	0.030	0.001	0.001	0.0001	0.050	0.001	0.001	0.011	0.003	0.001	0.021	0.001
XBSW-10	20121113	0.002	0.003	0.032	0.001	0.285	0.001	0.001	0.0001	0.050	0.001	0.001	0.030	0.004	0.001	0.008	0.001
XBSW-11	20121113	0.007	0.008	0.028	0.001	0.055	0.001	0.001	0.0001	0.050	0.001	0.000	0.058	0.003	0.001	0.154	0.001
XBSW-12	20121113	0.001	0.001	0.013	0.001	0.009	0.001	0.001	0.0001	0.050	0.001	0.001	0.005	0.002	0.001	0.001	0.001
XBSW-13	20121113	0.004	0.007	0.034	0.001	0.114	0.001	0.001	0.0001	0.050	0.001	0.000	0.029	0.002	0.001	0.031	0.001
XBSW-14	20121113	0.003	0.007	0.022	0.001	0.072	0.001	0.001	0.0001	0.050	0.001	0.000	0.035	0.002	0.001	0.004	0.001
XBSW-15	20130228	0.034	0.008	0.012	0.001	0.043	0.001	0.001	0.0001	0.050	0.001	0.0050	0.418	0.011	0.001	0.051	0.001
XBSW-16	20130228	0.114	0.017	0.044	0.001	0.029	0.001	0.003	0.0002	0.085	0.001	0.010	0.360	0.022	0.001	0.150	0.002
XBSW-17	20130129	0.001	0.006	0.001	0.001	0.062	0.001	0.001	0.0004	0.050	0.001	0.000	0.016	0.001	0.001	0.077	0.001
XBSW-18	20130130	0.001	0.014	0.001	0.001	0.200	0.001	0.001	0.0001	0.050	0.001	0.001	0.009	0.001	0.001	0.010	0.001
XBSW-19	20130130	0.001	0.007	0.001	0.001	0.161	0.001	0.001	0.0001	0.050	0.001	0.002	0.018	0.001	0.001	0.007	0.001

The Class I variable concentrations indicate those which are considered to be "acceptable for lifetime consumption" and indicate the recommended compliance limit. The Class II variable concentrations are considered to represent an acceptable drinking water quality if "consumed for a limited period of time" and indicates the maximum allowable limit for a limited duration of time. This class specifies a water quality range that poses an increasing risk on consumers, dependent on the concentration of the variable within the specified range. Variable concentrations that exceed the Class II concentrations are deemed as unfit for human consumption.

Variable concentrations in the surface water sampled that fall within Class I of the SANS 241:2006 Drinking Water Standard are indicated in Green and are classified having concentrations that are "Fully Compliant" with regards to the SANS 241:2006 Drinking Water Standard.

Variable concentrations that fall within Class II are indicated in Orange and are classified as having concentrations that are "Marginally Compliant" with regards to the SANS 241:2006 Drinking Water Standard.

Variable concentrations that exceed the Class II concentrations are indicated in Red and are classified as having concentrations that are "Non-Compliant" with regards to the SANS 241:2006 Drinking Water Standard.

The values given in black indicate the variables that do not have stipulated concentrations within the SANS 241:2006 Drinking Water Standard against which they may be classified.

The surface water samples from the potential pollution sources on site (XBSW-7 through to XBSW-16) generally have multiple concentrations that exceed the Class II concentrations of the SANS 241:2006 Drinking Water Standard.

At the Southern Opencast Pit (XBSW-18), the Ammonia concentration falls within the Class II range, while both the Magnesium and Nitrate concentrations exceed the Class II value ranges.

At the Northern Opencast Pit (XBSW-19), the Magnesium concentration falls within the Class II range, while the Nitrate concentration exceeds the Class II value range. Class II concentrations were also observed for both Magnesium and Nitrate at the Quarry (XBSW-6).

The water samples collected from the Matlhapyane (upstream and downstream) as well as the two midstream dams generally have concentrations that fall within Class I of the SANS 241:2006 Drinking Water Standard. Class II concentrations were however observed for Iron in all four these samples. No flow was observed in the Matlhapyane at far downstream sampling locality XBSW-5.

A little further upstream from this point at the Matlhapyane Stream Ponding Area (XBSW-17), Class II concentrations were observed for Manganese, while the concentrations for Aluminium, Iron and Total Chromium all exceed the Class II value ranges. However from the water quality data measured it can be concluded that during the rainy season the Mathlapyane stream is in a fairly good state.

A dry sample run conducted in the winter months will reveal what impact if any exists due to the current operations at Boshoek.

The number of surface water monitoring points must be expanded as some flows upstream of the Furnace Plant site (Matlapyane Tributory) and downstream of the mining areas at Bultfontein and Boekenhoudfontein require to be included in the monitoring plan. Additional sampling points are suggested.

2.12.5 Surface Water Use

The registered surface water use in close proximity is mainly mining related with small scale irrigation. Mining of platinum and its associated platina group of minerals have become the dominant land-use in the catchment. Near the site, apart from mining and the rural settlements (Rasimone, Frischgewaagd & Chaneng situated north of GMBS, Mogono and Ga-Luka to the East and Pudunong, Phokeng and Masobobane to the south-east of GMBS), dry land crops, raising livestock and possibly some small-scale irrigation from farm dams appear to be the other land-uses.

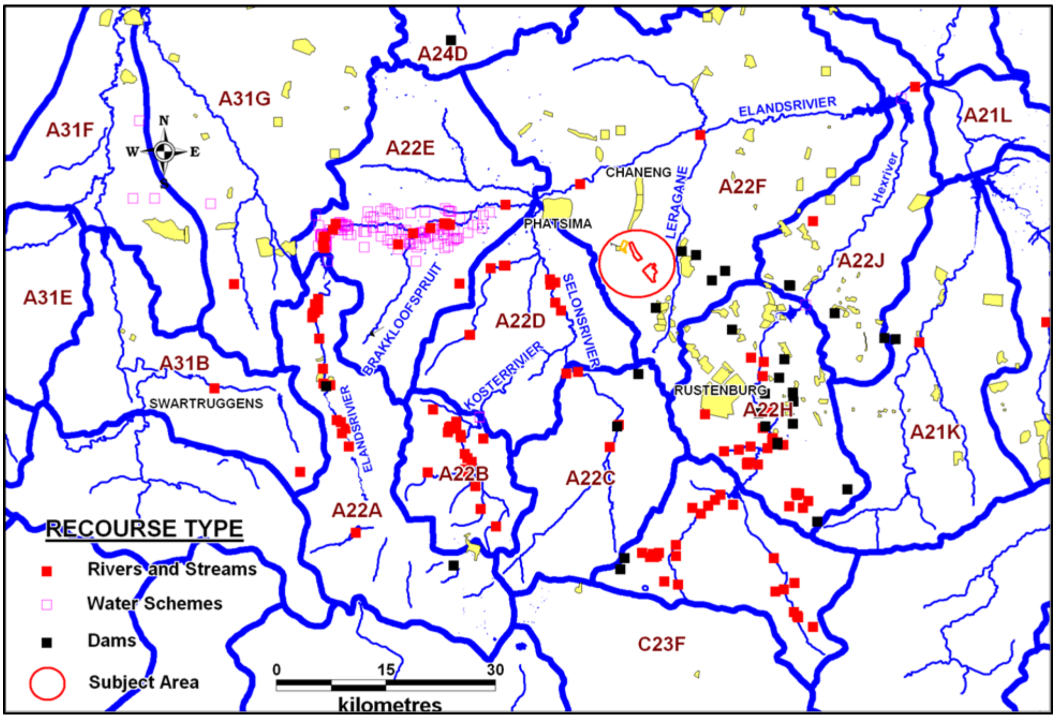

Figure 2.12.5 (a): Map Indicating Registered Surface Water Use

2.13 PLANT LIFE BASELINE

Scientific Aquatic Services (SAS) was appointed to conduct a floral assessment as part of the EIA and EMPR Addendum process for the Glencore Merafe Boshoek Mine and Smelter (GMBS). Refer to **APPENDIX 2.13 (A)** for the comprehensive Plant Life Specialist Report. The study area is briefly discussed below as well as the main findings of the plant life study.

The GMBS Operations are located approximately 30 km to the north-west of Rustenburg in the North West Province of South Africa. The site falls within the Rustenburg Local Municipality within the Bojanala Platinum District Municipality. The settlement of Boshoek is located within 1 km to the south-west of GMBS, with the settlements Rasimone, Frischgewaagd and Chaneng situated to the north, Mogono and Ga-Luka to the east and Pudunong, Phokeng and Masobobane to the south-east of GMBS. The R565 road is located immediately to the west of the study area. GMBS study area is flanked by the Magaliesberg Mountain Range to the west and south-west and by the Pilanesberg to the north.

The land use adjacent to GMBS is dominated by agricultural and mining related activities, leaving the surrounding areas largely transformed. The ecological assessment was therefore confined to the study area and did not include an ecological assessment of surrounding properties. The surrounding area was however considered as part of the desktop assessment of the area.

2.13.1 Habitat Units

Three habitat units were identified within the study area (see Figure 2.13.1 (a)), namely the Bushveld Habitat Unit (Figure 2.13.1 (b)), the Wetland Habitat Unit (Figure 2.13.1 (c)) and the Transformed Habitat Unit (Figure 2.13.1 (d)).

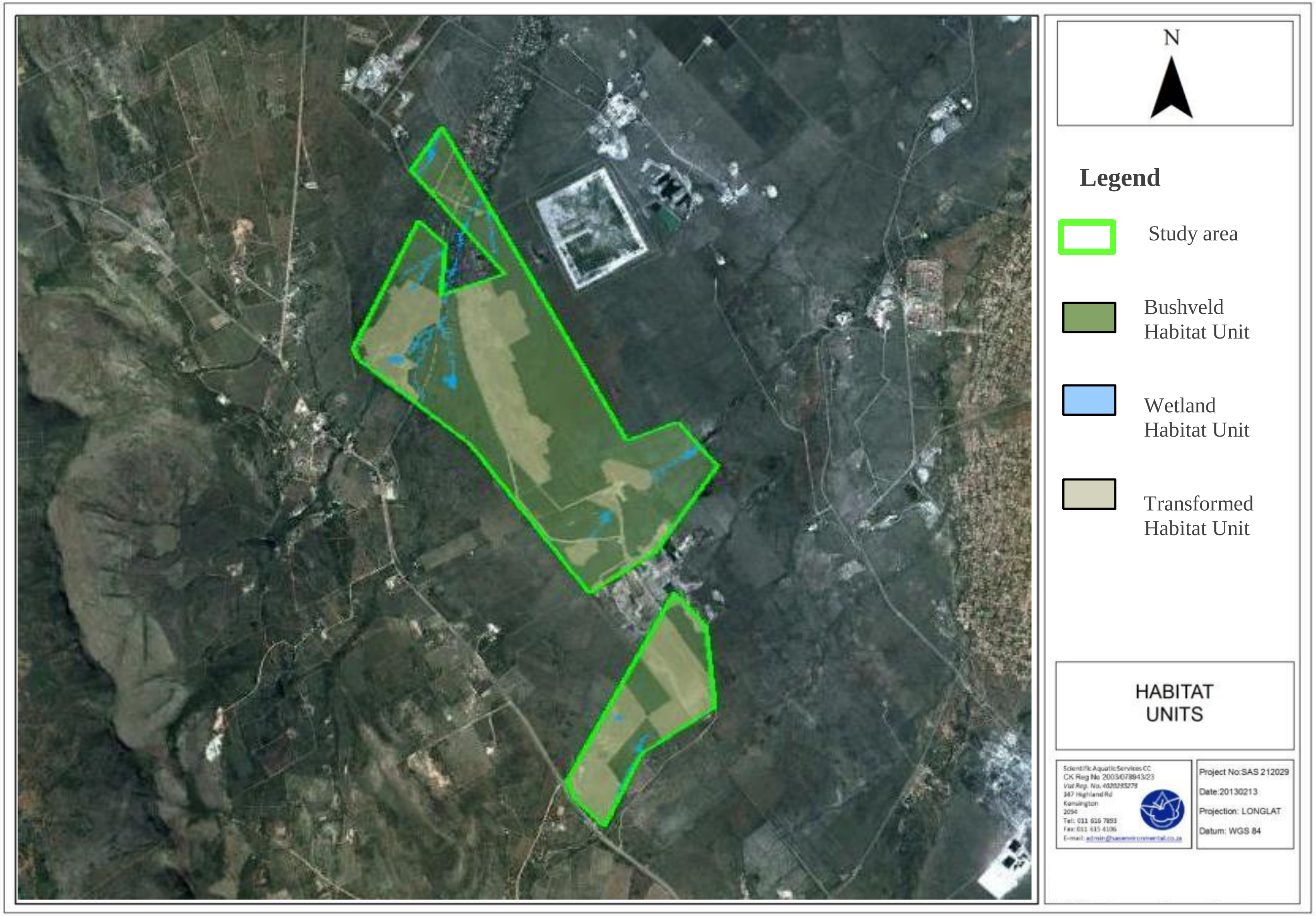

Figure 2.13.1 (a): Habitat Units identified within the study area.

Figure 2.13.1 (b): The Bushveld Habitat Unit covering the majority of the study area.

Figure 2.13.1 (c): The Wetland Habitat Unit present within the study area.

Figure 2.13.1 (d): The Transformed Habitat Unit associated within mining and mining-related infrastructure.

The Bushveld Habitat Unit covers the majority of the study area, while the Transformed Habitat Unit is limited to areas where mining and beneficiation activity and mining-related infrastructure has been constructed, as well as those areas impacted by recreational development and other infrastructure. The Wetland Habitat Unit is associated with the drainage features of the area.

Of these three habitat units, the Wetland Habitat Unit is deemed to be of high ecological sensitivity, while the Transformed Habitat Unit is deemed to be of low ecological sensitivity. The Bushveld Habitat Unit, having been exposed to historic anthropogenic activities such as crop cultivation and edge effects from mining activities, as well as impacts on vegetation structure due to overgrazing, trampling and bush encroachment, have also lowered the ecological sensitivity of this habitat unit.

2.13.2 Species of Concern

In terms of Red Data List (RDL) floral species, *Boophane disticha*, a plant species of concern, listed as 'Declining' by the International Union for the Conservation of Nature (IUCN) have been noted within the study area, occurring scattered throughout the Bushveld Habitat Unit. Apart from this species, no other RDL floral species were identified during the assessment and the possibility of such species being present is considered to be low due to historic and current disturbance in the majority of the study area.

Figure 2.13.2 (a): *Adansonia digitata* (baobab) trees within the Transformed Habitat Unit.

With reference to protected floral species, two specimens of *Adansonia digitata* (baobab) tree species (Figure 2.13.2 (a)), protected in terms of Section 12(d) of the National Forests Act No. 84 of 1998, were identified during the assessment within the Transformed Habitat Unit, occurring as a landscape specimen, while a number of protected *Sclerocarya birrea* subsp *africana* trees are located within the southeast of the Bushveld Habitat Unit. The latter species occur largely on the boundary and immediately outside of the study area and are not at immediate risk.

Overall levels of alien floral invasion are high within in the Transformed and Wetland Habitat Units and moderate to low within the Bushveld Habitat Unit. Dominant alien plant species include the tree species *Eucalyptus camaldulensis*, *Melia azedarach* and *Opuntia ficus-indica* and the forbs species *Tagetes minuta*, *Bidens pilosa*, *Flaveria bidentis*, *Ricinus communis* and *Amaranthus hybridus.*

A large number of medicinal plant species were noted within the Bushveld and Wetland Habitat Units and includes species such as *Hypoxis* sp., *Boophane disticha* and *Acacia karroo*. Medicinal plant species occur scattered throughout the study area and may be impacted by future mining activities.

2.13.3 Vegetation Index Score

The Vegetation Index Score (VIS) for each habitat unit identified was calculated as follows:

Habitat Unit	Score	Class	Motivation
Bushveld Habitat Unit	18	Class B/ Class C	This habitat unit, with large areas being intact, has experienced transformation through activities including mining edge effects, grazing, historic agricultural activities, bush encroachment and alien plant invasion
Wetland Habitat Unit	14	Class C/ Class D	Habitat relatively intact, however some disturbance has occurred with special mention of canalisation, stream diversions and water quality modifications due to surrounding mining activities as well as the presence of a number of alien plant species.
Transformed Habitat Unit	5	Class F	Areas completely modified through mining and landscaping activities.

2.13.4 Sensitivity Mapping

A sensitivity map has been developed for the study area, indicating areas considered to be of increased ecological importance. Figure 2.13.4 (a) shows the conceptual sensitivity map for the study area, focusing on the northern portion and Figure 2.13.4 (b) focusing on the southern portion. Sensitive areas are limited to the various wetlands features and associated buffer zones present within the study area.

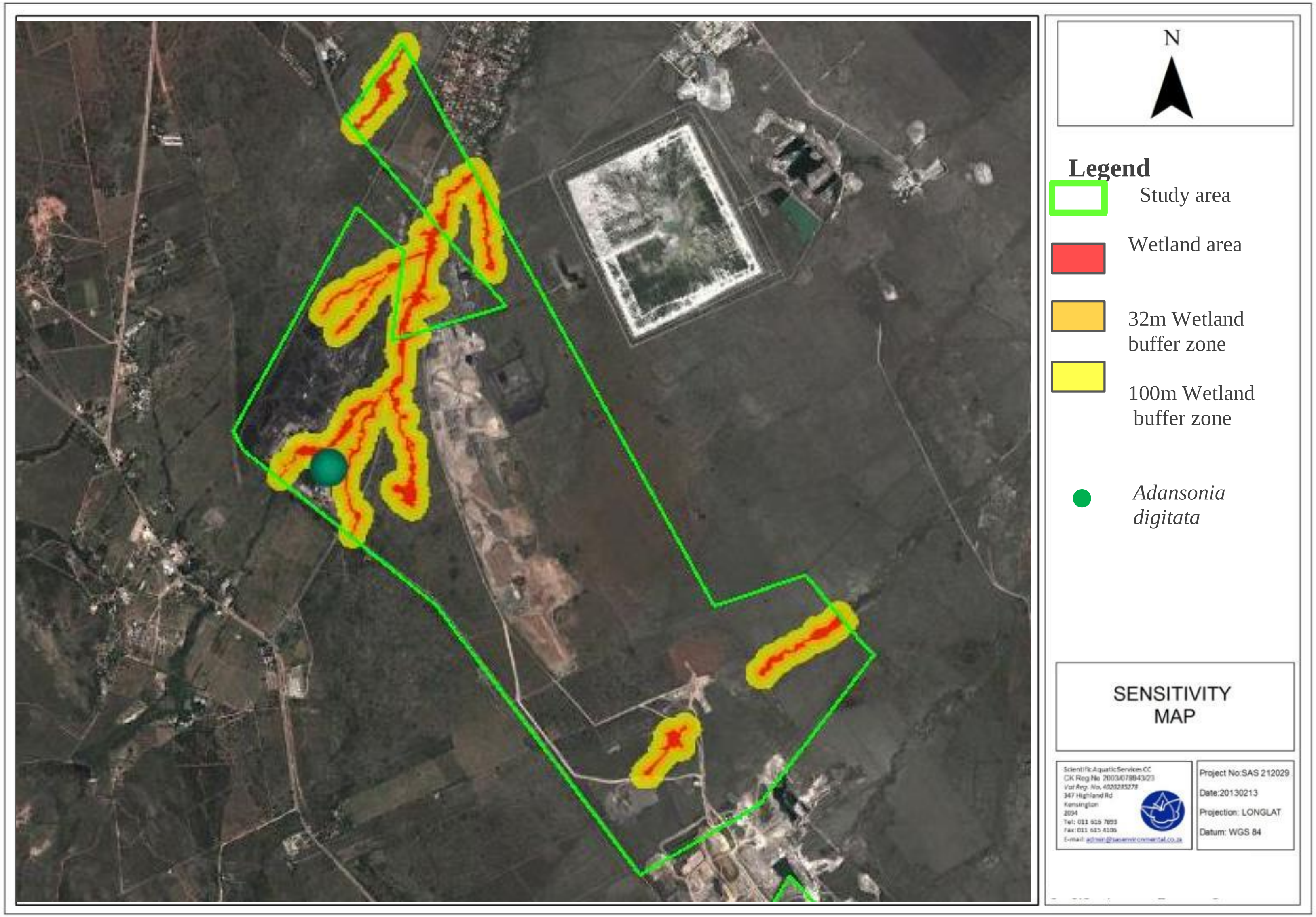

Figure 2.13.4 (a): Conceptual sensitivity map for the study area (northern portion).

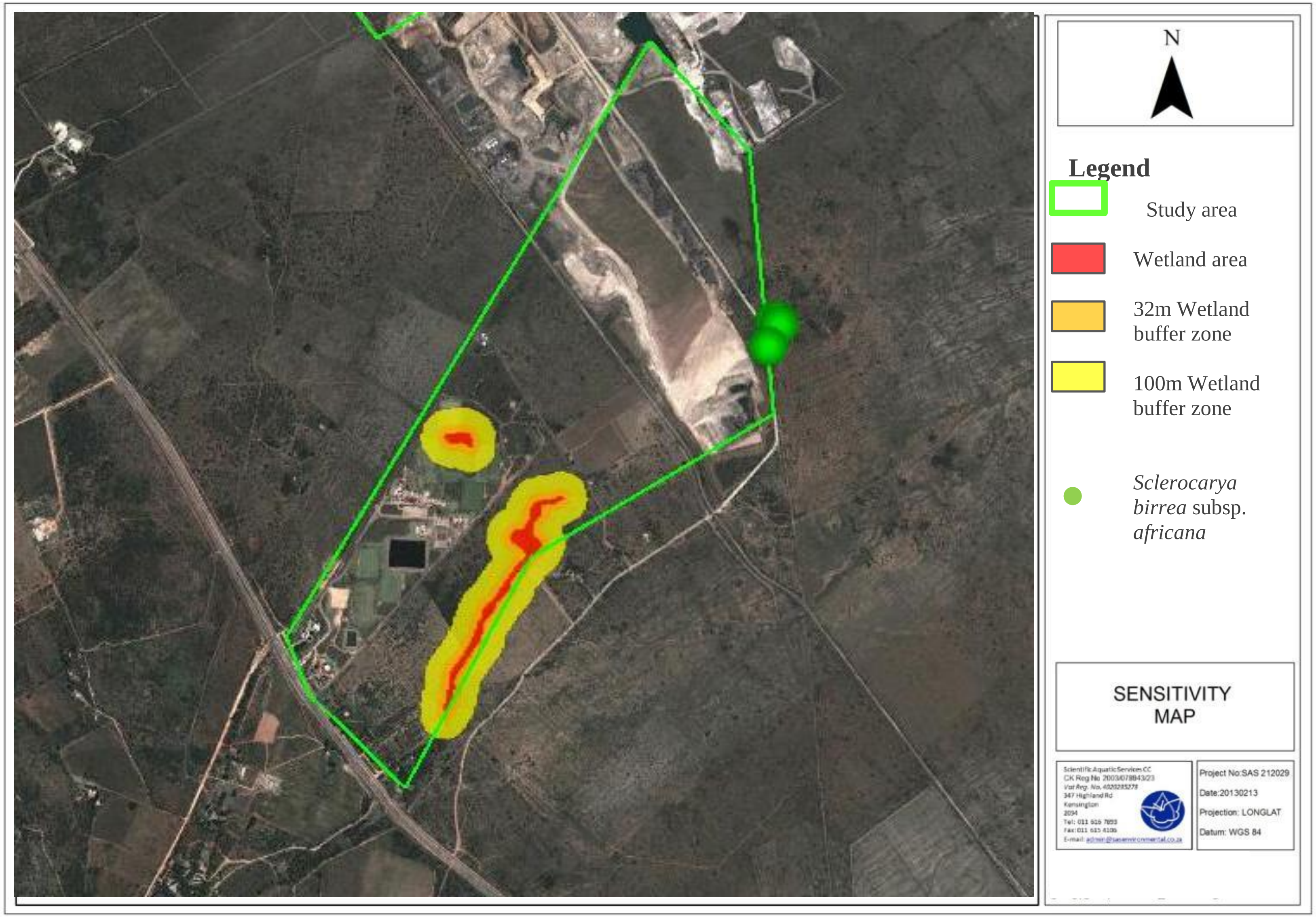

Figure 2.13.4 (a): Conceptual sensitivity map for the study area (northern portion).

2.14 ANIMAL LIFE BASELINE

Scientific Aquatic Services (SAS) was appointed to conduct a faunal assessment as part of the EIA and EMPR Addendum process for the Glencore Merafe Boshoek Mine and Plant (GMBS). This report in its entirety is attached as **APPENDIX 2.14 (A)**. However, a concise description of the main findings of the animal life study is given below.

In terms of the faunal habitat, habitat units comprise of predominantly grassland and bushveld habitat units which provides a limited diversity of habitat for faunal species within the subject property boundaries. The majority of the subject property has been transformed by livestock grazing and is considered to be at a low ecological sensitivity. The habitat integrity of the sensitive wetland areas within the subject property was low due to these wetland areas being dry during the assessment period. During the assessment period low faunal species diversity was thus encountered within the subject property.

2.14.1 Mammals survey

No Red Data List (RDL) mammals were observed during the site survey within the study area. In terms of conservation, the likelihood that any threatened mammal species that are listed by the North Western Province should be encountered within the study area is deemed low due to the high levels of human activity, use of land for grazing by communities, limited favourable faunal habitat availability, transformed habitat within the study area and the existing mining infrastructure within the study area.

2.14.2 Avifaunal survey

In addition, no threatened RDL birds were identified during this site survey. However, RDL avifaunal species listed in Table 2.14.2 (a) have a likelihood of flying onto the study area to forage or use as a migratory corridor, especially near the wetland habitat areas that is situated in the study area and which may provide good habitat for foraging in the rainy season.

Table 2.14.2 (a): North West Province RDL avifauna species with a Probability of Occurrence (POC) of more than 60%

Common Name	Scientific Name	NW SoER status	POC
African Grass Owl	*Tyto capensis*	VU	68
Peregrine Falcon	*Falco peregrinus*	R	67
Martial Eagle	*Polemaetus bellicosus*	VU	66
Secretary bird	*Sagittarius serpentarius*	NT	69
Red Winged Pratincole	*Glareola pratincola*	R	62

**VU = Vulnerable, NT = Near threatened, R = Rare.*

2.14.3 Reptile survey

Similarly, no RDL reptile species were identified during the site visit. One common non threatened reptile species, namely the Striped Skink (Mabuya striata) were identified throughout the study area. The South African Python (Python natalensis) does however have a high probability of occurring within the study area and may utilise the study area particularly for foraging and migratory purposes.

2.14.4 Amphibian survey

With reference to amphibians, no species were encountered during the October assessment period, while several common frog species were heard during the April 2012 assessment period namely the Common River frog (*Afrana angolensis*), the Red toad (*Schismaderma carens*), Guttural toad (*Amietophrynus gutturalis)* and Bubbling kassina (*Kassina senegalensis*). The only threatened RDL amphibian species identified within the North West Province is the Giant Bullfrog (*Pyxicephalus adspersus*), this amphibian species does not occur in the vicinity of the study area. The study area does not provide suitable or favourable wetland habitat to accommodate this threatened species.

2.14.5 Invertebrate survey

The insect survey compiled observed insect species that are common to the area. The abundance of insect species may without warning vary over time due to many factors. No RDL invertebrate species were observed within the study area during the site survey.

2.14.6 Spider and Scorpion

In relation to scorpions and spiders, no evidence was encountered of any RDL Mygalomorph arachnids (Trapdoor and Baboon spiders) and RDL scorpions within the study area, although it should be noted that these species are notoriously difficult to detect, however, if they do occur within the area they would be found within the limited rocky ridge habitat which surrounds the study area.

2.14.7 Red Data Sensitivity Index Score (RDSIS)

When determining the Red Data Sensitivity Index Score (RDSIS), no RDL faunal species were identified during the site survey. Seven RDL threatened species found to have a 60% or greater probability of being found in the study area and in the vicinity surrounding the study area are presented in the list below.

Table 2.14.7(a): Threatened faunal species with a 60% or greater Probability of Occurrence (POC) on the study area

Common Name	Species Name	Red List Status	POC
African Grass Owl	*Tyto capensis*	VU	68
Peregrine Falcon	*Falco peregrinus*	R	67
Martial Eagle	*Polemaetus bellicosus*	VU	66
Secretary bird	*Sagittarius serpentarius*	NT	69
Red Winged Pratincole	*Glareola pratincola*	R	62
South African Python	*Python natalensis*	VU	64

**POC = Probability of Occurrence*

Therefore, the RDSIS assessment of the study area provided a low score of 36%, indicating a low importance to RDL faunal species conservation specifically within the study area.