3 ENVIRONMENTAL STATUS QUO

3.1 Climate

3.1.1 Regional climate

Rand Carbide is situated in eMalahleni in the western part of the Mpumalanga Highveld. A typical Highveld-Type climate characterised by mild to hot and humid summers and cold, dry winters. Rainfall typically occurs in the form of thunderstorms during the summer months. The annual rainfall, which falls mainly during summer, varies between 550 and 800 mm.

3.1.2 Rainfall

The average monthly rainfall, in mm, provided by the South African Weather Services (Witbank/eMalahleni Municipality Station No 0515412-2; 1970 - 2002) is given below in Table 3-1. The rainfall season starts in September and lasts to April but the wet season is considered to be October to March (higher rainfalls). Extreme rainfall events occur from November to January and can result in up to 300 mm/month of rain. Zero rainfall has also been recorded for all months of the year in drought periods.

Table 3-1: Climatic data

Month	Temperature °C		Rainfall mm/month		Evaporation mm/month	
	Min	*Max*	*Witbank *(mean)*	*Fraction of annual (%)*	*Bethal 0478867 (1968-1987)*	*Witbank Dam B1E001*
January	15.3	26.2	138.4	19.7	179.8	178
February	15.1	24.9	97.1	13.9	151.1	149
March	12.5	22.7	87.2	12.4	147.8	147
April	9.2	20.9	37.1	5.3	111.1	113
May	7	18.7	9.6	1.4	94.8	95
June	4.3	18.2	5.8	0.8	79.2	77
July	3.8	17.2	3.5	0.5	89.0	84
August	6.5	20.8	7.2	1.0	132.0	112
September	10.1	24.3	26.6	3.8	167.0	145
October	12	25	77.8	11.1	186.6	175
November	13.4	24.8	111.8	15.9	167.6	165
December	14.3	25.5	98.8	14.1	195.9	182
Average	*10.3*	*22.4*	*58.4*	-	*141.8*	*135.2*
ANNUAL	-	-	***700.9***	-	***1 701.9***	***1 622***

*Witbank Municipality Station No 0515412-2; 1970 – 2002

3.1.3 Evaporation

Evaporation data has been received from the SA Weather Services for Station number 0478867 at Bethal and B1E001 near the Witbank Dam. The annual average evaporation for the period 1968 to 1987 is 1 702 mm/year. The minimum evaporation of 59.6 mm was recorded in March 1976, while the maximum of 264.4 mm was recorded during December 1972. Monthly evaporation is presented above in Table 3-1. It is important to note here that evaporation exceeds rainfall for all months of the year and the area could therefore be classified as water deficit.

The mean annual S-pan evaporation is indicated in WR2005 to range between 1 600 and 1 700 mm/annum, whilst the A-pan evaporation is indicated to range between 1 800 and 2 000 mm/annum. Mean monthly evaporation is also highly seasonal with the majority of evaporation occurring during the summer months.

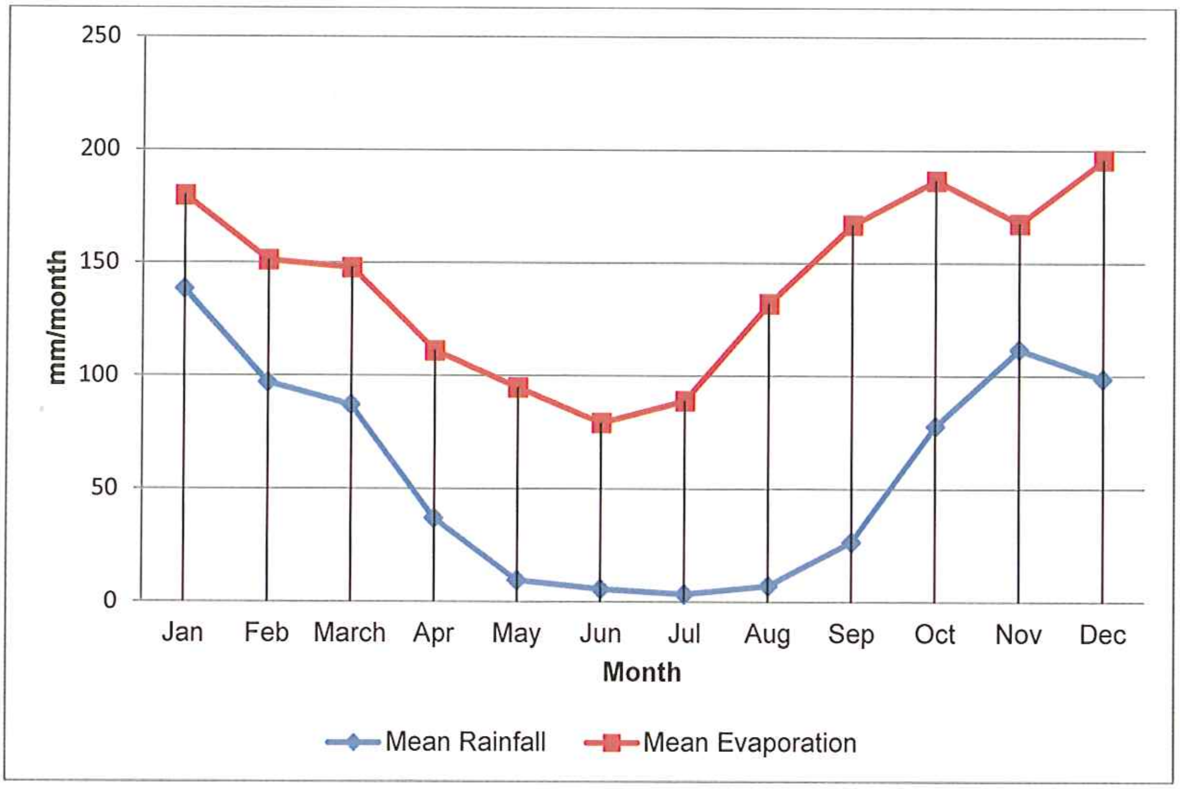


Figure 3-1: Rain and evaporation

3.1.4 Temperature

Monthly minimum and maximum temperatures recorded (in degrees Celsius) for the area is provided in Table 3-1 above. According to the table, July was the coldest on average with a minimum of 3.8°C while January had the highest average temperature with a maximum average of 26.2°C.

3.2 Soil and land capability

3.2.1 Soils

The surface at Rand Carbide consists initially of a brownish orange to light brown slightly clayey soil. Large areas of the soil have been removed during the construction of the plant area and several other surface activities. The soil across the northern extent of the site varies between 1 and 3m thick and is underlain by a brownish-red to brown clay layer of varying thickness. The clay layer varies between 0 m (not penetrated during drilling) and 9 m as recorded at borehole RCG-B5.

The soil and clay layers at Rand Carbide are underlain by fine to mostly medium grained reddish brown rhyolites of the Selons River Formation of the Rooiberg Group. The geochemistry of the rhyolite drill chips sampled from borehole RCG-B3 was analysed and is given in Table 3-2.

Table 3-2: Geochemistry of Rhyolite sampled from borehole RCG-B3 (JMA, 2012)

RCG-B3	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	H_2O	Total
Weight %	76.63%	0.25%	11.45%	4.18%	0.15%	0.39%	0.33%	2.17%	4.86%	0.05%	100.46%

The geochemical analysis indicates that the rhyolite is significantly rich in SiO_2 as well as Al_2O_3. The chemical composition is important, as this will have an effect on the chemical image of the groundwater itself.

Gijima Ast took samples and had the soil around the EMB plant analysed using the NIOSH (National Institute for Occupational Safety and Health) method 7300. The conclusion was made that the risk of soil and groundwater pollution at the EMB plant is low based on the low levels of contaminants detected in the sampled soils. The soils contained no poly aromatic hydrocarbons, volatile organic compounds (VOC), cyanide or hexavalent Chromium (Cr(VI)).

The soils contained high concentrations of Aluminium (Al), Calcium (Ca), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn), Sodium (Na) with the following in lower quantities: Barium (Ba), Chromium (Cr), Sulphur (S), Titanium (Ti) and Zinc (Zn). A detailed soil assessment may be required to establish any localised contamination on the site.

3.2.2 Land use

Current land use for the Rand Carbide property is industrial (1926 – current), predominantly for ferrosilicon and silicon metal production.

Surrounding land use includes industrial and commercial uses as well as residential areas (refer to Figure 1-2).

3.3 Topography and surface water

3.3.1 Topography

Rand Carbide is located on the Highveld Region of the Mpumalanga Province. The regional topography slopes in both a north-westerly as well as north-easterly direction away from the topographical higher southern extent of the study area. The surrounding landscape is dominated by slight to moderately undulating plains, including some low hills and pan depressions.

The site itself generally slopes towards the north east, with the highest elevation being 1 608 metres above mean sea level (mamsl) in the south western corner of the site and the lowest elevation being 1 556 mamsl in the north eastern corner of the site. The gradient was calculated at approximately 1:20 over roughly 1.1 km (average gradient of 0.05). The south-eastern extent of Rand Carbide has the steepest gradient (0.14) in a northerly direction, whilst the western region has the gentlest gradient (0.03) towards the north-east.

The natural surface topography at Rand Carbide has been altered within the plant area in order to build on level surface foundations. This is evident by the rock cuttings seen to the south of the furnaces as well as other localities within the plant area.

3.3.2 Surface water environment

Water Management Area (WMA): Olifants (WMA 4); 54 550 km^2

Sub-catchment: Upper Olifants River (Loskop Dam); 12 285 km^2

Quaternary catchment: B11J

Quaternary Catchment Area: 269 km^2

Mean Annual Precipitation (MAP): 682 mm for catchment
701 mm for Witbank area

Surface water resources: Olifants River (4 km north east)
Doornpoort Dam (7.5 km east)

Closest surface watercourse: Seasonal stream originating from a spring
200m north east
Non-perennial stream discharges to Olifants River – 5km north east

3.3.3 Surface water hydrology

The site generally drains towards the north east towards the Olifants River. Various catchment ponds are located on the site which collects storm water runoff.

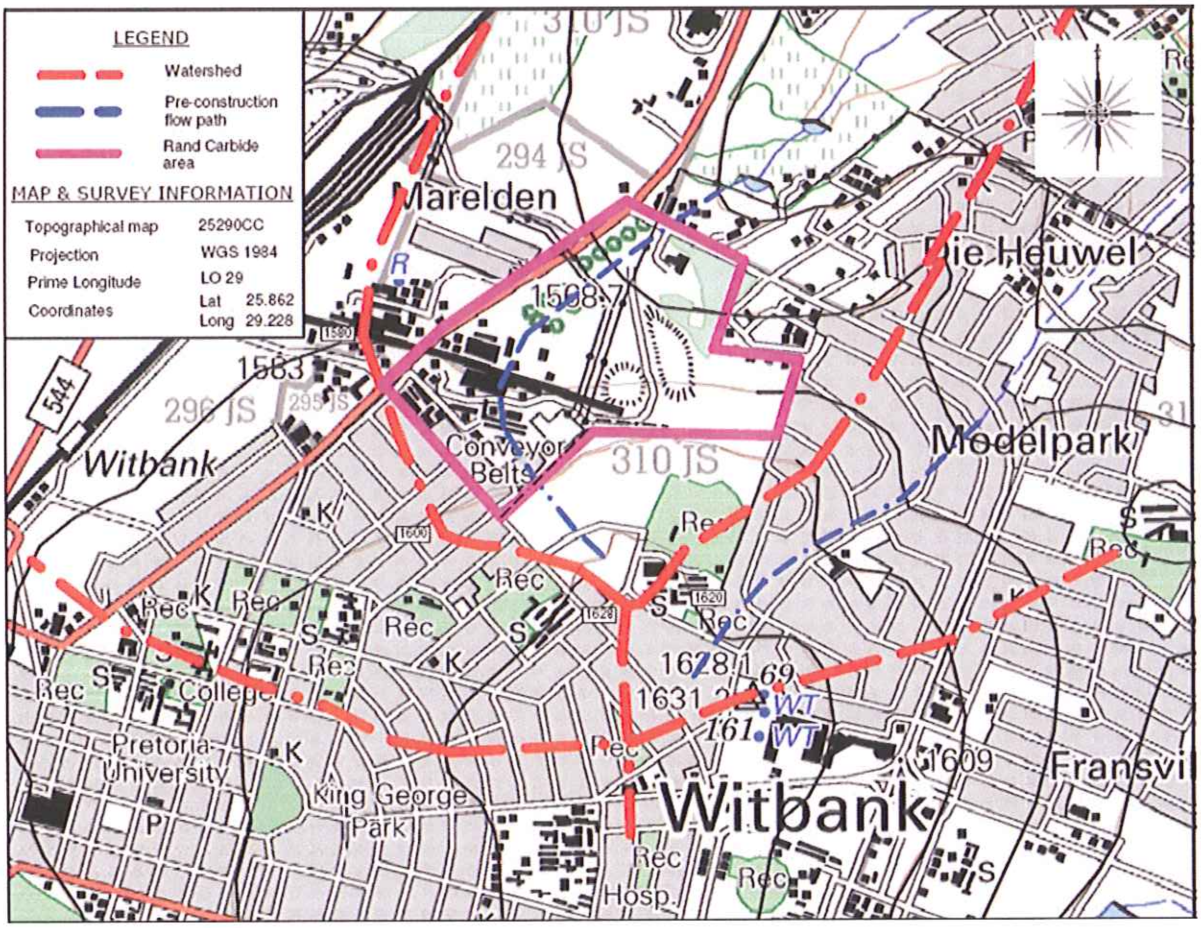


Figure 3-2: Surface hydrology around Rand Carbide (E-tek, 2011)

3.3.4 Surface water quality

Selected surface water samples were analysed between April 2007 and January 2011.

Table 3-3: Water quality for water supply source

Constituents:	eMalahleni municipal water from Witbank Dam
pH	7.67
EC (mS/m)	58
TDS (mg/l)	397
Calcium (mg/l Ca)	50
Magnesium (mg/l Mg)	31
Sodium (mg/l Na)	32
Potassium (mg/l K)	6.1
Nitrate & Nitrite (mg/l as N)	0.34
Sulphate (mg/l SO_4)	174
Chloride (mg/l Cl)	25
Fluoride (mg/l as F)	0.52
Iron (mg/l as Fe)	0.10
Manganese (mg/l as Mn)	0.16
Aluminium (mg/l as Al)	0.04
Quantity used (m^3/month)	7 500
Cost (R/m^3)	7.30

Notes:
* Data from 2011 only.

Table 3-4: Water quality for storm water runoff (April 2011)

Constituents:	Catchment ponds		Main dam
	1	4	Harry's dam
pH	8.0	7.71	7.97
EC (mS/m)	79	78	75
TDS (mg/l)	600	596	544
Calcium (mg/l Ca)	112	108	95
Magnesium (mg/l Mg)	27	27	22
Sodium (mg/l Na)	37	37	38
Potassium (mg/l K)	12	12	20
Nitrate & Nitrite (mg/l N)	1.3	1.2	-
Sulphate (mg/l SO_4)	193	183	180
Chloride (mg/l Cl)	28	32	47
Fluoride (mg/l as F)	0.40	0.68	0.59
Iron (mg/l as Fe)	0.09	0.07	-
Manganese (mg/l as Mn)	0.32	0.02	-
Aluminium (mg/l as Al)	0.08	0.12	0.01
Zinc (mg/l as Cd)	0.03	0.09	0.02
Copper (mg/l as Cu)	< 0.01	< 0.01	0.02
Chemical Oxygen Demand (mg/l COD)	30	30	34

Table 3-5: Spring water quality

Constituents:	Springs		
	E furnace	F furnace	B Conveyor sump (embankment)
pH	8.35	8.13	8.01
EC (mS/m)	108	455	67.4
TDS (mg/l)	750	3 542	452
Calcium (mg/l Ca)	101	331	82.5
Magnesium (mg/l Mg)	33.6	138	20.6
Sodium (mg/l Na)	83.5	475	27.3
Potassium (mg/l K)	12.8	125	12.7
Nitrate & Nitrite (mg/l NO_3 as N)	3.9	7.2	1.8
Sulphate (mg/l SO_4)	287	1 740	144
Chloride (mg/l Cl)	56	356	23
Fluoride (mg/l as F)	0.34	4.5	< 0.2
Iron (mg/l as Fe)	0.01	4.05	0.04
Manganese (mg/l as Mn)	0.27	0.29	< 0.01
Aluminium (mg/l as Al)	< 0.01	0.54	< 0.01
Chemical Oxygen Demand (mg/l COD)	24	112	20
Water quantity (m^3/month)	3.6	3.6	14.4

Table 3-6: Other surface water qualities (April 2007 - January 2011)

Monitoring point:	TDS (mg/l):	SO_4 (mg/l):	Cl (mg/l):	Ca (mg/l):	Mg (mg/l):	Fe (mg/l):	Mn (mg/l):	pH (range)
Wash bay	526	193	31	66	27.1	0.88	0.27	6.4 – 8.0
Panorama	312	70	60	36	13.9	0.01	0.05	6.5 – 7.9
Swartbos	1 059	418	99	132	47.1	0.01	0.22	6.6 – 7.5
Standard for comparison purposes								
SANS 241 Class I	1 000	400	200	150	70	0.2	0.1	5.0 – 9.5

3.3.5 Mean annual runoff (MAR)

Hydrological Evaporation Zone:	4A
Hydrozone:	J
Area of quaternary catchment B11J:	269 km^2
Area under investigation:	0.162km^2
Mean Annual Precipitation (MAP):	645 mm
Mean Annual Evaporation (MAE):	1 621 mm
Mean Annual Runoff (B11J):	13 100 000 m^3
MAR into Rand Carbide storm water control dam:	7 889 m^3

Table 3-7: Mean Annual Runoff in m³ (E-Tek, 2011)

Month:	Stockpile area: ($0.0169km^2$)	Waste Dump: ($0.52km^2$)	Storm water dam: ($0.162km^2$)	Affected areas:
October	35	106	331	472
November	119	366	1 142	1 627
December	115	354	1 103	1 573
January	139	428	1 334	1 901
February	150	463	1 442	2 055
March	100	309	963	1 373
April	57	174	542	772
May	38	116	360	514
June	24	73	226	322
July	18	55	172	245
August	15	45	141	201
September	14	43	133	190
TOTAL	**824**	**2 532**	**7 889**	**11 245**

3.3.6 Surface water users

Major water users in the Upper Olifants Catchment include:

- Irrigation;
- Urban and industrial uses;
- Rural uses; and
- Mining.

Municipal water is supplied to the area and no surface water users in close proximity were identified.

3.3.7 Sensitive areas

No sensitive areas in close proximity to the site were identified. A drainage line originates 300 m north east of the site and feeds into the Olifants River.

Ten (10) wetland areas are located in the quaternary catchment but not in close proximity to the site (Aurecon, SANBI, Department of Environmental Affairs, Department of Water Affairs, Department of Agriculture, Forestry and Fisheries; Working for Wetlands, Phase 1 – Planning; Report 5146a/105782; Ref 2010/Phase 1/Report/05-MPU-Final; August 2010).

Table 3-8: Wetlands in quaternary catchment B11J

Wetland Number	Wetland Name	Longitude	Latitude
B11J-01	Kalbasfontein 01	29° 16' 27"	-25° 45' 56"
B11J-02	Kalbasfontein 02	29° 16' 29"	-25° 45' 56"
B11J-03	Kalbasfontein 03	29° 15' 44"	-25° 47' 34"
B11J-04	Erfdeel Pan	29° 21' 54"	-25° 46' 44"
B11J-05	Elandspruit	29° 21' 32"	-25° 47' 50"
B11J-06	Kromdraai	29° 15' 31"	-25° 50' 11"
B11J-07	Doringpoort	29° 19' 51"	-25° 51' 40"
B11J-08	Witbank NR 01	29° 17' 00"	-25° 53' 09"
B11J-09	Elandspruit Pan	29° 23' 29"	-25° 48' 13"
B11J-10	Witbank NR 02	29° 19' 26"	-25° 52' 43"

3.4 Geology and geohydrology (refer to JMA, 2012 study)

3.4.1 Geology (adapted from JMA, 2012)

The Witbank area is underlain by a basement complex of porphyritic ryolite of the Selons River Formation, Rooiberg Group of Proterozoic rocks. This is unconformably overlain by the Vryheid Formation, Ecca Group of sedimentary rocks, comprising sandstone, shale and coal seams. To the South of Witbank, the Vryheid Formation is extensively intruded by Jurassic age dolerite dykes and sills, emplaced between 150 and 190 million years ago.

The regional geology is discussed with reference to the 1:250 000 geological map series of South Africa (Sheet 2528 Pretoria, 1978) as per clipped region in Figure 3-3.

The occurrence and movement of groundwater, as well as the groundwater quality, are functions of the geological host rock in which the groundwater occurs, including the alteration thereof as a result of human activities, such as industrial activities.

Rand Carbide is underlain by porphyritic red rhyolite of the Selons River Formation of the Rooiberg Group. The volcanic Rooiberg group is part of the Bushveld Magmatic Province, a voluminous suite of Precambrian magmatic rocks that also includes the Lebowa Granite Suite as well as the laterally extensive Rustenburg Layered Suite.

The Rooiberg Group comprises of volcanic units that are up to 400 m thick (Harmer and Von Gruenewaldt, 1991), together with interbedded, thin, laterally extensive sediment strata. Most of the volcanic units of the Rooiberg Group are composed of a fine-grained groundmass with variable proportions of phenocrysts, porphyroblasts and amygdales. The general Geochemistry of the Rooiberg is associated with an increase in SiO_2 and a decrease in MgO, whilst moving upward in the Succession. The increase in SiO_2 can rise to values of average 74.9 weight % in the upper most Formation of the Rooiberg Group (Buchanan, 2006).

The surface geology to the north-east of Rand Carbide consists of shales, sandstones and conglomerates of the Loskop Formation. It is indicated that the Loskop Formation has later been intruded by predominantly north-west striking diabase dykes. The surface geology to the west and north-west of Rand Carbide consists of sedimentary rocks of the Vryheid Formation, which forms part of the Ecca Group of the Karroo Supergroup.

The Vryheid Formation sedimentary lithologies lie unconformably on top of the Rooiberg Group and generically consist of gritty sandstone mudstone, shale and coal layers within the study area. The Vryheid Formation has been extensively mined for coal by both opencast and underground mining operations

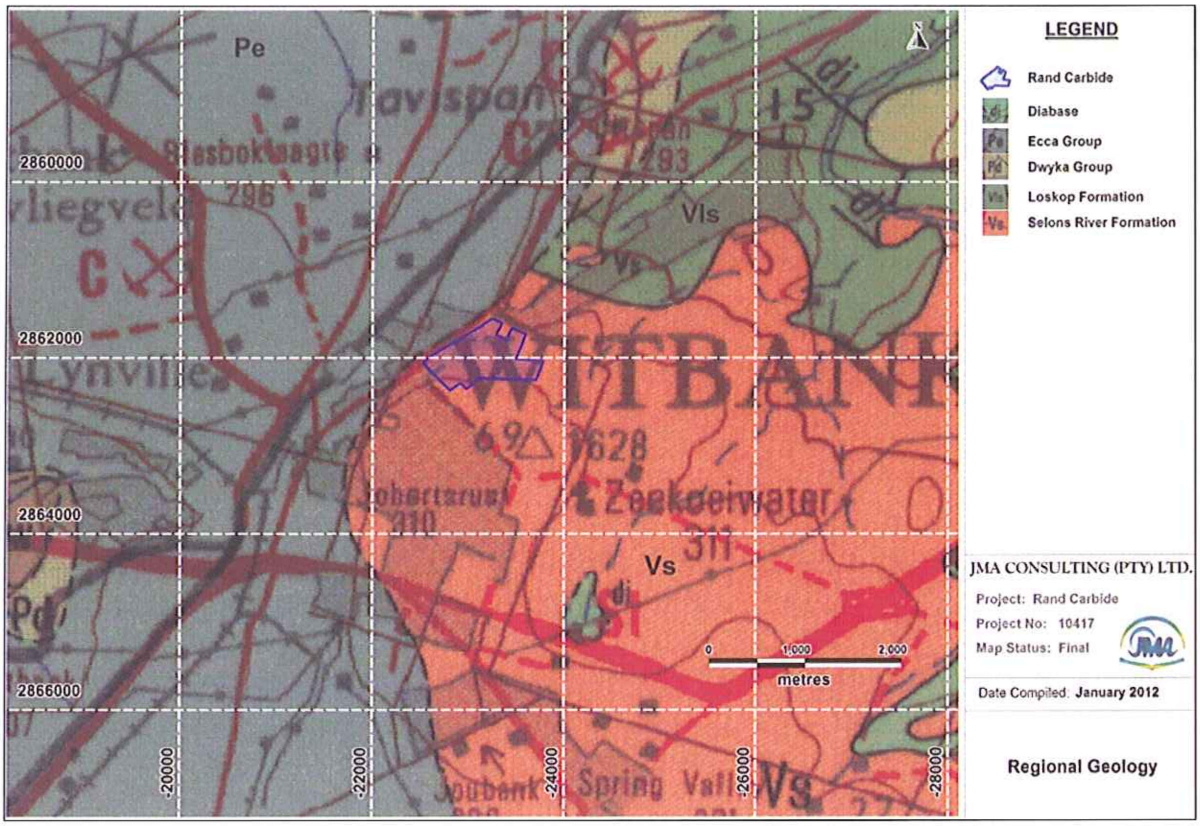


Figure 3-3: Regional geology (JMA, 2012)

3.4.2 Geohydrology (JMA, 2012)

The regional geohydrology of the study is addressed with reference to the available information relevant clipped region of the published 1:500 000 Hydrogeological Map Series of the Republic of South Africa – Sheet 2526 Johannesburg, 1999, depicted as Figure 3-4.

The regional geohydrological attributes of the study area are clearly a function of the geological formation distribution. Two (2) distinctly separate stratigraphic sequences (Pe and Vb) occur within the groundwater management area, each with their own geohydrological manifestations.

Geohydrological Zone 1: Ecca Group

The western extent of the regional study area is underlain by the sedimentary lithologies of the Ecca Group - denoted by Pe on the map.

Within this zone the groundwater occurs primarily within the weathered zone as well as in joints and fractures of the competent arenaceous rocks, related to tensional or compressional stresses and offloading.

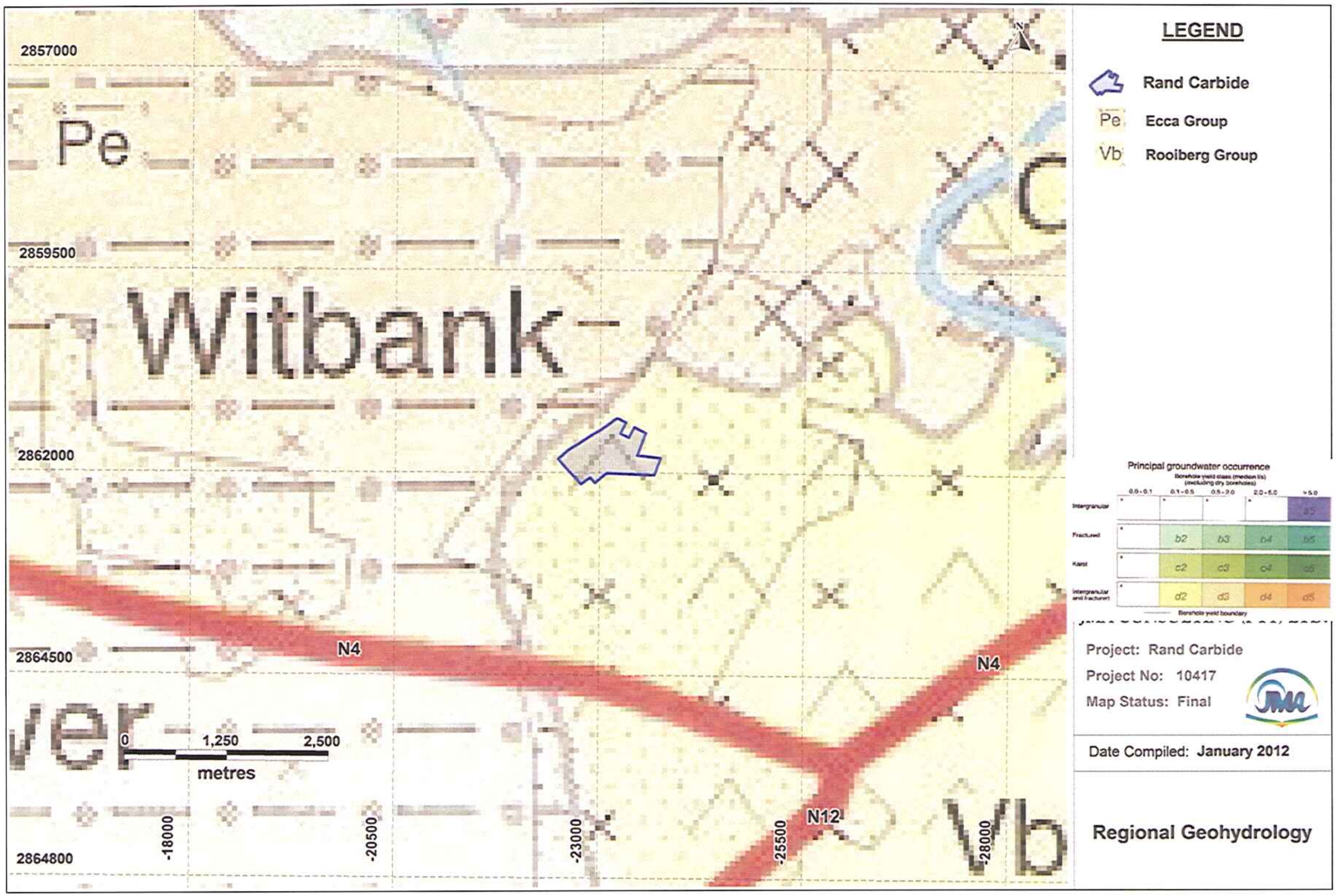


Figure 3-4: Regional geohydrology (JMA, 2012)

The borehole yielding potential within this geohydrological zone is classified as d3, which implies a median yield which varies between 0.5 l/s and 2.0 l/s. No large scale groundwater abstraction is indicated to occur from these intergranular and fractured aquifers within the bounds of the study area. The groundwater potential for the western area is between 40 and 60%, which indicates the probability of drilling a successful borehole (yield > 0.1 l/s) whilst the probability of obtaining a yield in excess of 2 l/s is between 10% and 20%.

The mean annual recharge (MAR) to the groundwater system in the western parts of the study area is estimated to be between 50 mm and 70 mm per annum, which relates to about 8% of the mean annual precipitation (MAP). The groundwater contribution to surface stream base flow is relatively low, estimated at between 10 mm to 25 mm per annum (Vegter, 1995).

The aquifer storativity (S) for the intergranular fractured Karroo aquifers in this part of the study area is estimated to be less than 0.001. The saturated interstice types (storage medium) are fractures which are restricted principally to the zone directly below the groundwater level. The groundwater is classified to be of the hydrochemical type B, with dominant cations Ca^{2+} and Mg^{2+} and dominant anion being HCO_3^- (Vegter, 1995).

Geohydrological Zone 2: Rooiberg Group

The Rand Carbide site is underlain by the rhyolites of Selons River Formation of the Rooiberg Group - denoted by Vb on the map. Within this zone the groundwater occurs primarily within the shallow weathered zone as well as in localized fractures of the competent lithological units.

The borehole yielding potential within this geohydrological zone is classified as d2, which implies a median yield that varies between 0.1 l/s and 0.5 l/s. No large scale groundwater abstraction is indicated to occur from these intergranular and fractured aquifers within the bounds of the study area. The groundwater potential for the western area is given as between 40 and 60%, which indicates the probability of drilling a successful borehole (yield > 0.1 l/s) whilst the probability of obtaining a yield in excess of 2 l/s is given as between 10% and 20%.

The mean annual recharge (MAR) to the groundwater system in the western parts of the study area is estimated to be between 45 mm and 60 mm per annum, which relates to between 6% and 7% of the mean annual precipitation (MAP). The groundwater contribution to surface stream base flow is relatively low, estimated at between 10 mm to 25 mm per annum (Vegter, 1995).

The aquifer storativity (S) for the intergranular and fractures Rooiberg Group aquifers in the study area is estimated to be less than 0.001. The saturated interstice types (storage medium) are pores and fractures restricted principally to the zone directly below the groundwater level. Groundwater rest levels in the Rooiberg Group are typically between 10 and 30 mbgl and the groundwater quality is typically excellent with average EC values of 34 mS/m and a pH of 7.1. The groundwater is classified to be of the hydrochemical type B, with dominant cations Ca^{2+} and Mg^{2+} and dominant anion being HCO_3^- (Vegter, 1995).

3.4.3 Aquifer characterisation

Aquifer types: With reference to the local geology of the site, it is regarded that the primary aquifer type present at Rand Carbide is a laterally extensive weathered zone aquifer. This weathered zone aquifer occurs within the weathered and weathering related fractured zone of the rhyolites and extends across the entire study area. Although clay was penetrated in several of the boreholes drilled at Rand Carbide, a laterally extensive perched aquifer system is not indicated to be developed on site.

The thickness of the weathering and related fracturing zone recorded at the eleven (11) boreholes drilled at Rand Carbide varies between 4 m and 18 m with an average vertical thickness of 10.68 m. This aquifer zone will store and transport the bulk of the groundwater in this area. This aquifer will display unconfined to semi-unconfined piezometric conditions and may as a result, potentially be highly susceptible to surface induced activities and impacts.

Fractures below the weathered zone / fresh bedrock interface were intersected in four of the boreholes drilled at Rand Carbide. These fractured zones may be highly transmissive zones and show confined to semi-confined piezometric conditions.

Aquifer zones: Due to the absence of laterally extensive perched aquifer conditions, the aquifer zones within the shallow weathered zone aquifers penetrated at Rand Carbide are comprehensively described in terms of unconfined to semi-unconfined unsaturated and saturated aquifer zones.

Unsaturated Zone:

Due to the nature of the shallow weathered zone aquifer at Rand Carbide, the top of the unsaturated zone is defined by the land surface, whilst the bottom of the unsaturated zone is defined by the groundwater table/level. The thickness of the unsaturated zone is therefore defined as the depth to the groundwater level recorded at the boreholes. The thickness of the unsaturated zone was calculated using the groundwater levels recorded at the 11 groundwater monitoring boreholes during December 2011. The vertical thickness of the unsaturated zone ranges between 0.00 m (artesian groundwater level) and 14.70 m with a calculated average vertical thickness of 5.72 m.

Saturated Zone:

The saturated zone of the shallow weathered zone aquifer at Rand Carbide is defined at the top by the groundwater table/level and at the bottom by the weathered/fractured and fresh bedrock interface. The saturated aquifer thickness of the shallow weathered zone aquifer is therefore calculated by subtracting the measured groundwater level depth from the weathered or weathering related fractured depth as recorded at the groundwater monitoring boreholes during December 2011. The thickness of the saturated zone is calculated to vary between 0.00 m and 15.53 m with an average vertical thickness of 8.33 m.

Aquifer permeability: The hydraulic conductivity or permeability (k-value) of an aquifer is a measure of the ease with which groundwater can pass through the aquifer system. The permeability is defined as the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at perpendicular to the flow direction and is expressed in m/day. The bulk permeability for the shallow weathered zone aquifer at Rand Carbide was optimized during the numerical groundwater modelling and was verified to be 0.04 m/day.

Aquifer transmissivity: The transmissivity (T) of an aquifer represents the groundwater flow potential through the entire saturated zone. The transmissivity is defined as the rate at which water is passed through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average permeability and the thickness of the saturated portion of the aquifer (D). The transmissivity is thus calculated as **T=k*D** (m^2/day). The bulk transmissivity for the shallow weathered zone aquifer at Rand Carbide was determined from the optimized aquifer permeability during the numerical groundwater modelling and is calculated to range between 0.02 m^2/day and 3.65 m^2/day with an expected bulk transmissivity of 0.60 m^2/day.

Aquifer storativity: The storativity (S) of an aquifer is defined as the volume of water that an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit hydraulic gradient. The bulk storativity of the shallow weathered zone aquifer at Rand Carbide was taken as 0.002. The optimized storativity as determined from the groundwater model is 0.002.

Aquifer porosity: The porosity of an aquifer is the ratio of the void space to the total volume of the aquifer. The porosity gives 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. Effective porosity is a measure of total volume of interconnected pores and is important as it plays a governing role in groundwater flow velocity. The effective porosity is the same as the specific yield for the unconfined shallow weathered zone aquifer at Rand Carbide. The effective porosity within the weathered zone aquifers within the study area vary between 0.01 and 0.07, with a bulk probable value of 0.03.

Aquifer boundary: The aquifer boundary (in this case based on hydraulic barriers) determines the extent of the groundwater zone that could potentially be affected by surface activities. See Figure 3-5 and Figure 3-10 where it was used as input to the model.

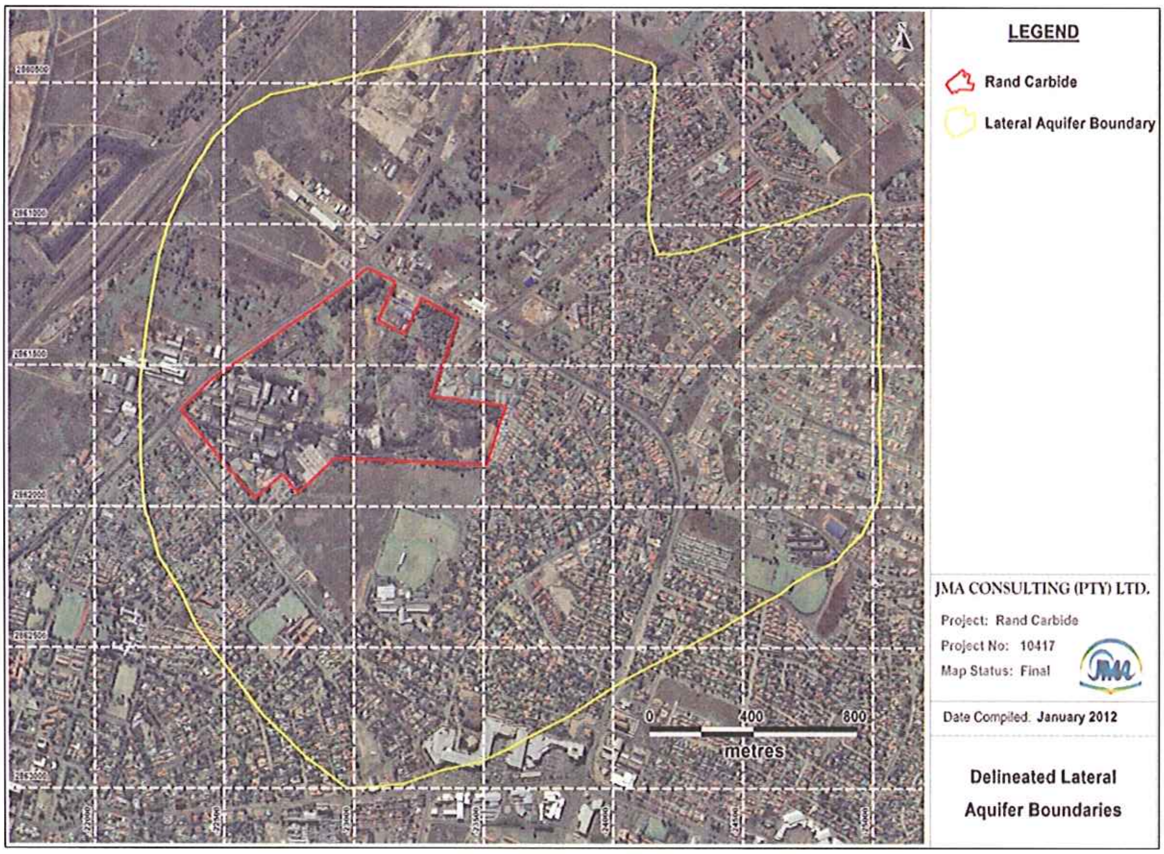


Figure 3-5: Aquifer boundary (JMA, 2012)

Rainfall recharge: Recharge to the shallow weathered zone aquifers within the study area occurs annually as a result of the infiltration of precipitation and is expressed in terms of a percentage of the mean annual precipitation (MAP). The mean annual recharge to the groundwater system at Rand Carbide is estimated to be between 1% and 3% of the MAP and is calculated as between 7 mm and 21 mm per annum.

Groundwater level depths and fluctuations: The groundwater levels recorded at Rand Carbide during December 2011 ranged between 0.00 mbgl, in which case the groundwater level is artesian, and 14.70 mbgl, with an average groundwater level depth of 5.72 mbgl. At a bulk storage value of 0.002, the groundwater level response to 1 mm of rainfall would be 0.50 m. The maximum possible fluctuation in groundwater level would then of course be in the order of between 3.5 m and 10.5 m for Rand Carbide. In view of the fact that all the recharge will not take place at the same time but more spread out over the summer months, natural groundwater level fluctuations in excess of 2 m/annum to 5 m/annum is not expected.

Borehole yields: Borehole blow yields were recorded for 7 of the 11 boreholes drilled during the two drilling programmes (1989 and 2011) conducted at Rand Carbide. The remaining four (4) boreholes were "dry" and blow yields could thus not be recorded at these boreholes.

The blow yields recorded varied between 0.10 l/s and 1.10 l/s, with an average blow yield of 0.43 l/s. The yields from six (6) of the boreholes were obtained from within the weathered zone of the shallow weathered zone aquifer. The blow yield recorded at borehole RCG-B7 (1.10 l/s) was however from a water strike intersection from a fracture below the weathering depth of the borehole at a depth of between 23 m and 26 m.

Aquifer classification: The shallow weathered zone aquifer at Rand Carbide is conservatively classified as a Minor Aquifer System due to its low permeability and limited use for abstraction. The shallow weathered zone aquifer system is therefore assigned 2 points, according to the Aquifer System Management Classification (DWAF, 1995).

There are no special structural aquifer attributes at Rand Carbide associated with the Second Variable Classification of the shallow weathered zone aquifers. The total points assigned to the shallow weathered zone aquifer system therefore remains 2.

Although weathered zone aquifers are normally highly vulnerable to surface induced impacts, no severe impacts could be delineated within the weathered zone aquifers at Rand Carbide. The vulnerability of the aquifer with regards to contamination thereof resulting from a surface induced source, in terms of the above and given the current groundwater qualities, is assigned a value of 1, indicating a low aquifer vulnerability.

The groundwater quality management classification is made with regards to the aquifer vulnerability. The indicated level of groundwater protection is derived from the Groundwater Quality Management Index (GQM Index) and is calculated as follows:

GQM Index	=	Aquifer System Management x Aquifer Vulnerability Classification
	=	2 x 1
	=	2

The GQM Index is used to determine the level of groundwater protection that is required for the shallow weathered zone aquifer systems present at Rand Carbide and is indicated as a low level groundwater protection required.

3.4.4 Groundwater quality

Table 3-9: Chemical Analysis of groundwater samples (Apr 2007 - Jan 2011)

Monitoring point:	TDS (mg/l):	SO_4 (mg/l):	Cl (mg/l):	Ca (mg/l):	Mg (mg/l):	Fe (mg/l):	Mn (mg/l):	pH (range)
Lab borehole	289	82	40	27	11.8	7.14	0.28	6.0 – 6.6
BH 1	348	150	9	76	12.9	0.19	1.73	6.5 – 7.3
BH 2	188	14	9	40	2.9	0.17	0.06	6.9 – 8.1
BH 3	150	13	4	29	2.2	0.36	0.11	7.4 – 8.2
BH 4	560	245	65	40	29.8	0.01	0.36	7.1 – 8.0
BH 5	720	349	65	85	47.5	0.17	0.23	6.9 – 8.0
BH 6	520	142	103	46	23.5	0.01	0.41	7.0 – 7.9
Standard for comparison purposes								
SANS 241 Class I	1 000	400	200	150	70	0.2	0.1	5.0 – 9.5

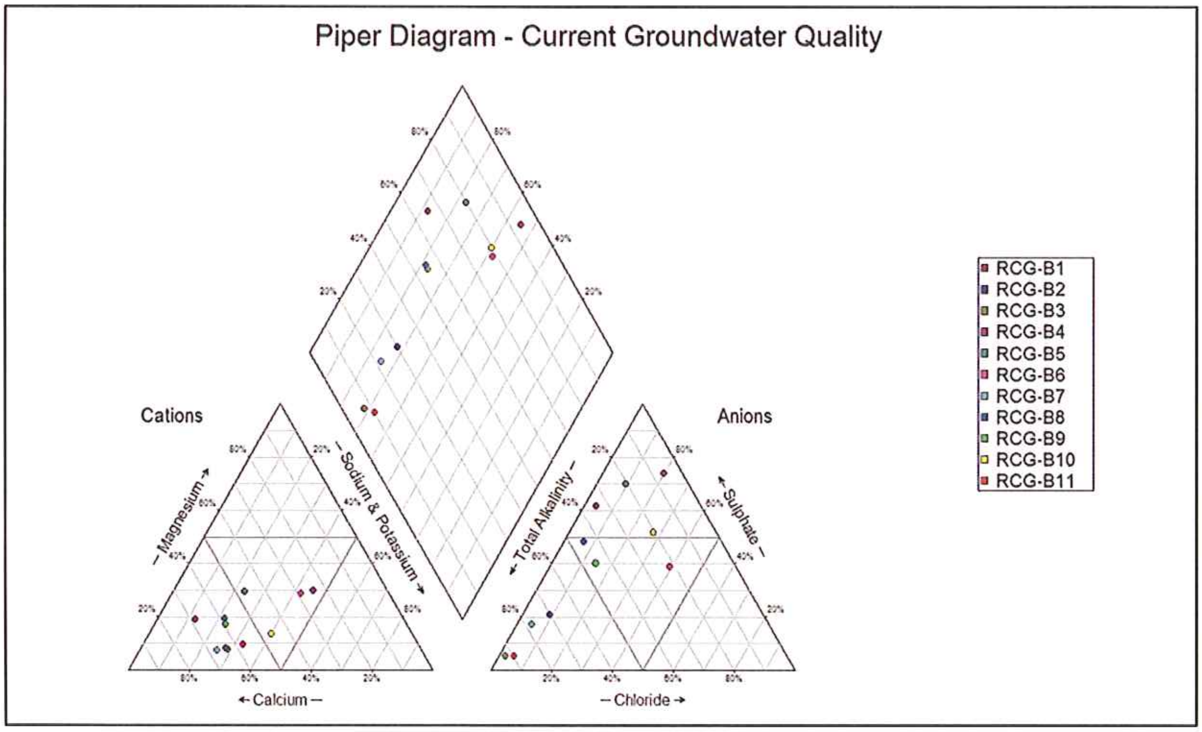


Figure 3-6: Current (Dec 2011) groundwater quality (JMA, 2012)

The Piper Diagram indicates that the current groundwater quality has a scattered hydrochemical image, with 7 of the groundwater samples collected at Rand Carbide characterised as having a Type-A hydrochemical image, whilst 4 samples have Type-B hydrochemical images (Figure 3-6). Interesting to note is that the groundwater sampled from the two boreholes with artesian water levels (RCG-B7 and RCG-B11) are both classified as having a Type-B hydrochemical image. The dominant (milliequivalent) cations within the groundwater is Ca^{2+} followed by Na^+ and K^+ whilst the dominant anions range between HCO_3^- and SO_4^{2-}.

The pH of the current groundwater quality at Rand carbide ranges between 6.35 and 7.87 with an average of 7.25. The EC ranges between 23.2mS/m and 141 mS/m with an average of 69.2 mS/m and an average TDS of 463 mg/l.

It is observed in the geochemistry of the groundwater sampled during December 2011 that the TDS concentrations show a positive correlation with an increase in the SO_4 and Ca concentrations. The elevated TDS observed in the shallow weathered zone aquifer across the northern extent of the Rand Carbide appears to be related to localised increases in the SO_4 and Ca concentrations. Na and Cl also show good positive correlations in the groundwater samples collected during December 2011.

It is suspected that the slight increases in the Ca and SO_4 concentrations recorded at the spring/fountain as well as in boreholes RCG-B5, RCG-B6 and RCG-B10 may be related to surface induced contamination sources. This will however need to be verified during future groundwater monitoring at Rand Carbide.

The variables TDS, Cl and SO_4 are deemed to be conservative in the sense that they cannot further breakdown and elevated concentrations may depict surface induced impacts on the natural (background) groundwater quality.

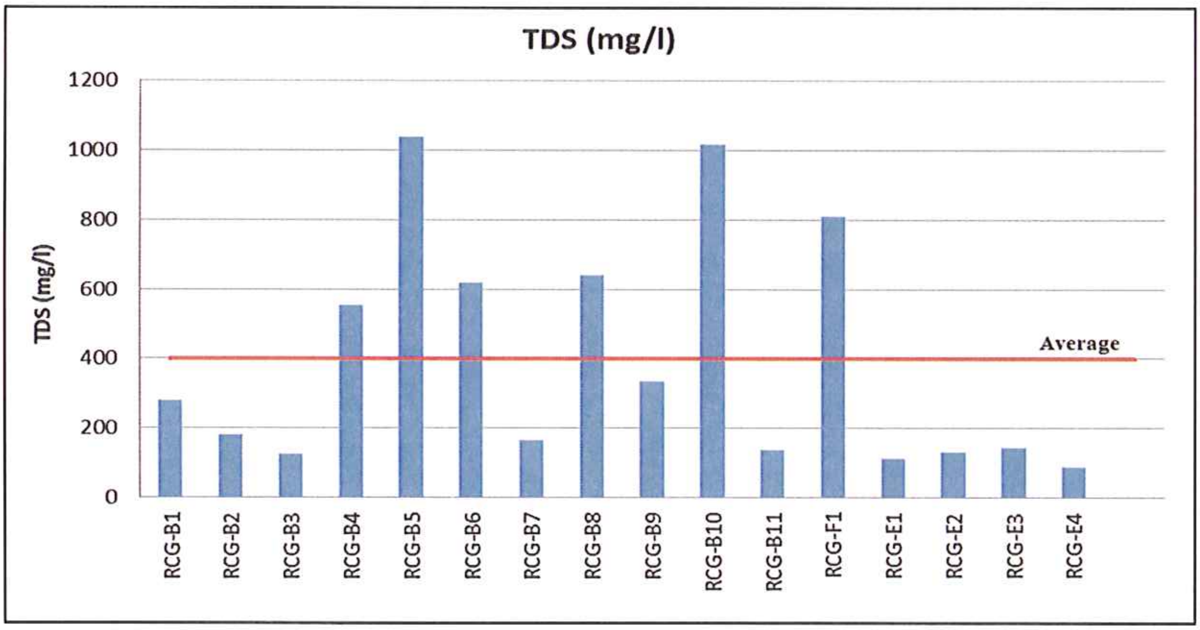


Figure 3-7: Current groundwater quality – TDS concentrations in December 2011 (JMA, 2012)

The boreholes and fountain that exceed the average (red line in Figure 3-7) are all located down-gradient from potential surface sources of contamination on the Rand Carbide site. Although not fully quantified, it potentially indicates that the historic waste dump and raw material stockpile areas may be viewed as potential surface sources from which impacts on the groundwater systems may originate. This condition can however only be verified through the continual monitoring of the groundwater quality down gradient from these facilities. In terms of the worst case scenario adopted, these areas are viewed as potential surface contamination sources and are incorporated as such in the groundwater model during the groundwater impact assessment.

3.4.5 Hydro-census

A groundwater hydrocensus was performed within a 500m radius from the Rand Carbide site. During the hydrocensus, 1 fountain/spring and six (6) boreholes were located. Two (2) of the identified boreholes (RCG-E5 & RCG-E6) were blocked/destroyed and groundwater samples could therefore not be collected from these. Samples were however, collected at the fountain/spring (RCG-F1) and the four (4) boreholes (RCG-E1 to RCG-E4).

The fountain/spring is located down-gradient (north-east) from the Rand carbide site and the six (6) boreholes identified are situated to the north-east and east of the site. No boreholes were identified within a 500m radius to the south and west of the Rand Carbide site. The fountain and boreholes identified during the hydrocensus are located on Figure 3-8.

Groundwater uses: No large scale groundwater abstraction is indicated to occur from these intergranular and fractured aquifers within the bounds of the study area. Only three (3) of the six (6) boreholes identified were in use. Groundwater abstracted from these three (3) boreholes is used for domestic and gardening purposes but no information of quantities abstracted was available. This use will continue indefinitely.

The fountain/spring is the source of a small stream which eventually (5km north east) drains into the Olifants River.

Groundwater quality: The water quality gives an indication of background groundwater quality, due to the fact that Rand Carbide is a "brown fields" site and the groundwater quality may potentially already have been impacted. The pH of the background groundwater quality is on average 6.73 with an average EC of 42.2mS/m and TDS of 257 mg/l – all within Class 0 of SANS 241:2006 Drinking Water Standard.

Potential groundwater use: Due to the low permeability's of the shallow weathered zone aquifer and low probability of drilling boreholes with yields in excess of 2 l/s as well as the availability of municipal water, the abstraction of groundwater within the study area is limited, despite the good background groundwater quality.

3.4.6 Potential pollution source identification

Chloride contamination: The preliminary evaluation of water quality aspects at Rand Carbide by Jasper Muller Associates in 1988, indicated chloride contamination (elevated chloride) in groundwater and surface water (V-notch at tarred road). Data was inconclusive.

Plant: The plant area is extensively covered with cement and concrete foundations and therefore not considered a major pollution source.

Raw material stockpiles: The majority of the raw material stockpiles are located directly on the surface. Raw materials can potentially leach contaminants that can contaminate soil and groundwater and were evaluated as potential sources of pollution. For this reason, all of the raw materials were sampled and analysed to determine their pollution potential. Twenty (20) different raw material samples were collected (December 2011) and the mineralogy and elemental composition was determined through XRD (X-ray diffraction) and XRF (X-ray fluorescence) as well as distilled water leach extract analysis.

Historic waste dump: The historic waste dump is not lined and has been disposed of directly on top of the land surface. The dump contains a mixture of materials (heterogeneous), some of which are considered hazardous. The dump is currently being processed.

Figure 3-8: Hydrocensus (JMA, 2012)

Table 3-10: Potential pollution from raw materials

<table>
<tr><th>Type:</th><th>Constituents of concern:</th><th>Pollution potential:</th></tr>
<tr><td>Quartzite – silicon/cobble</td><td>Si</td><td rowspan="11">XRD: Comprises largely graphite (C), calcite ($CaCO_3$), quartz (SiO_2) & silicon (Si), wustite (FeO) & barite ($BaSO_4$). Raw materials are relatively inert and are geochemically not readily broken down any further.
XRF: Majority of carbon enriched raw materials (charcoal, coal, petroleum coke, anthracite) ignite and burn up (loss on ignition). Several elemental concentration exceed that of rhyolite and upper crust lithologies (Rudnick & Gao, 2003) and could potentially impact on the environment, if release in its entirety (worst case scenario).
Distilled water leachate extract analysis: Concentrations predominantly fall within class I of SANS 241:2006 drinking water standard and indicate that no significant elemental concentrations are expected to leach out. Raw materials are not expected to generate leachate with adverse qualities as a result of precipitation coming into contact with the raw materials as they are stockpiled.</td></tr>
<tr><td>Coal – columbian; Keaton</td><td>C</td></tr>
<tr><td>Coke – petroleum</td><td>C</td></tr>
<tr><td>Charcoal – low/high ash; retort</td><td>C</td></tr>
<tr><td>Woodchips</td><td></td></tr>
<tr><td>Millscale</td><td></td></tr>
<tr><td>Barium sulphate ($BaSO_4$)</td><td>Ba, SO_4</td></tr>
<tr><td>Anthracite – raw & E.C.A</td><td>C</td></tr>
<tr><td>Zircon Manganese</td><td>Zr, Mn</td></tr>
<tr><td>Limestone</td><td>Ca, CO_3</td></tr>
<tr><td>Molten metal (Fe-Si / Si) briquettes & fines</td><td>Fe, Si</td></tr>
<tr><td>Silica sand</td><td>Si</td><td>None. No risk as material is inert. No tests conducted.</td></tr>
</table>

Other concerns and potential sources of contamination:

- **Off-site contamination:**
  - **Cyanamid:** Historically produced mining chemicals west-south-west of site.
  - **Komatsu:** Diesel spillages on northern portion of site.
  - **Other industries:** West of site.
- **On-site** (history of 85 years) **contamination:**
  - Historic carbide production.
  - Historical chemical storage and handling (pitch and other chemicals).
  - Historical production processes.
  - On-going percolation of surface water-borne pollution to marshland in northern area.
  - Waste dumping area.

3.4.7 Groundwater model (JMA, 2012)

Objective: The objective of the groundwater flow and transport model was to simulate the transport of a potential contamination plume in the aquifer from potential sources on surface at Rand Carbide as well as to determine the use of natural attenuation as a means of remediation.

Groundwater elevations: The groundwater elevations were calculated by subtracting the recorded groundwater level from the surveyed collar elevation. The calculated groundwater elevations were then statistically contoured using the Kriging interpolation method. The groundwater elevation contours generated are statistical representations of numerical values and as such will enable calculation of the quantum of the groundwater gradients and will also reflect the regional groundwater flow direction across the site.

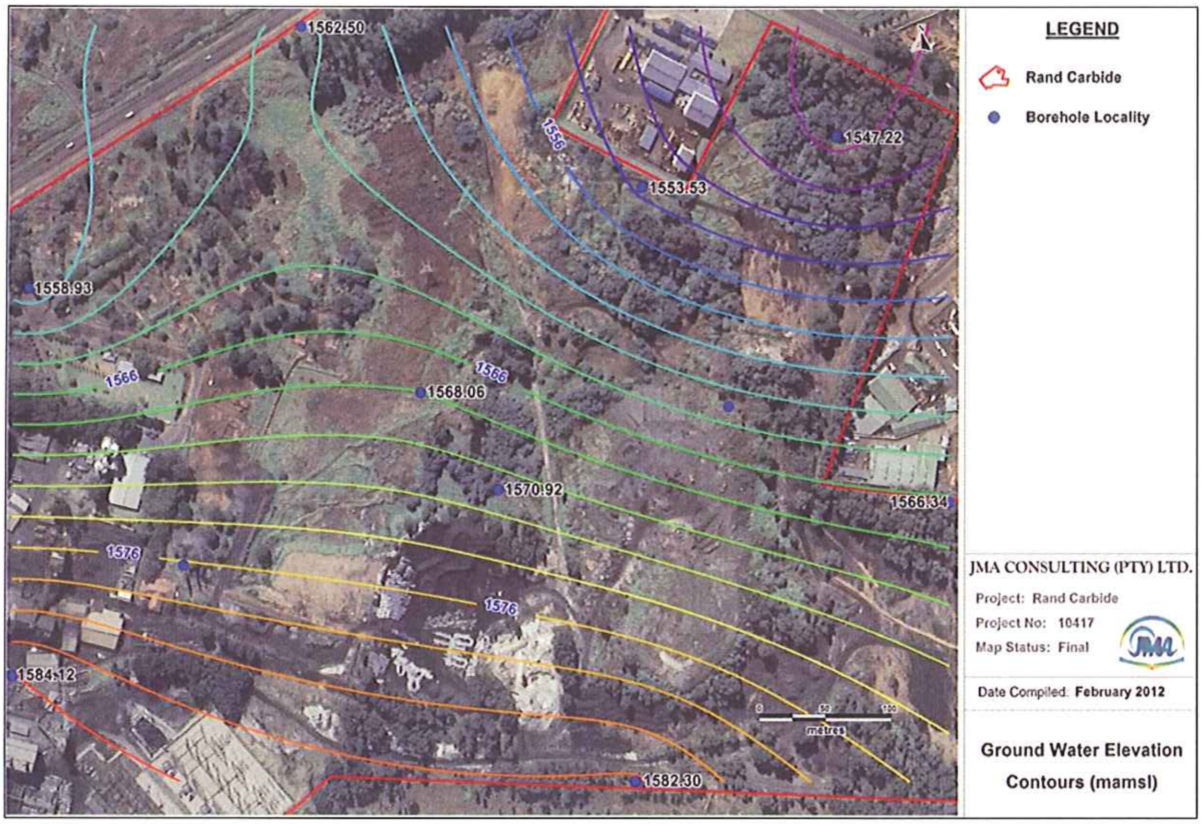


Figure 3-9: Groundwater elevations and contours (mamsl) (JMA, 2012)

Groundwater flow direction: Due to the nature of unconfined weathered zone aquifers, the groundwater flow directions are generally perpendicular to the surface contours and flow velocities are determined with reference to the calculated groundwater elevations (hydraulic heads) and associated gradients. The groundwater will flow from areas of high to low groundwater elevations at right angles to the groundwater elevation contours. The predominant groundwater flow direction at Rand Carbide is from the south towards the north and north-east. The recorded groundwater elevations show a good correlation with surface topography and the unconfined conditions were therefore assigned to the top layer (weathered zone) in the numerical groundwater model.

Groundwater flow velocity: The flow/seepage velocity (Vs) will be calculated as it represents the most realistic expression of the actual groundwater flow velocity. The specific seepage velocity will be influenced by the hydraulic gradient (i), effective porosity (n_e) and permeability (k) of the shallow weathered zone aquifer and will therefore continuously vary across the extent of the study area. Using the calculated average groundwater elevation gradient of 0.07, subject to the estimated bulk aquifer permeability of 0.04 m/day, and an effective porosity of 0.02 the average bulk groundwater seepage velocity for the shallow weathered zone aquifers at Rand Carbide is calculated as 0.14 m/day (51 m/year).

Modelling software: The software used during the groundwater modelling was Visual Modflow Premium 4.3, a graphical user interface for MODFLOW. MODFLOW is an acronym for the USGS Modular Three-Dimensional Groundwater Flow Model and groundwater flow within the aquifer is simulated using a block-centred finite-difference approach. Layers are simulated as confined, unconfined, or as a combination of both.

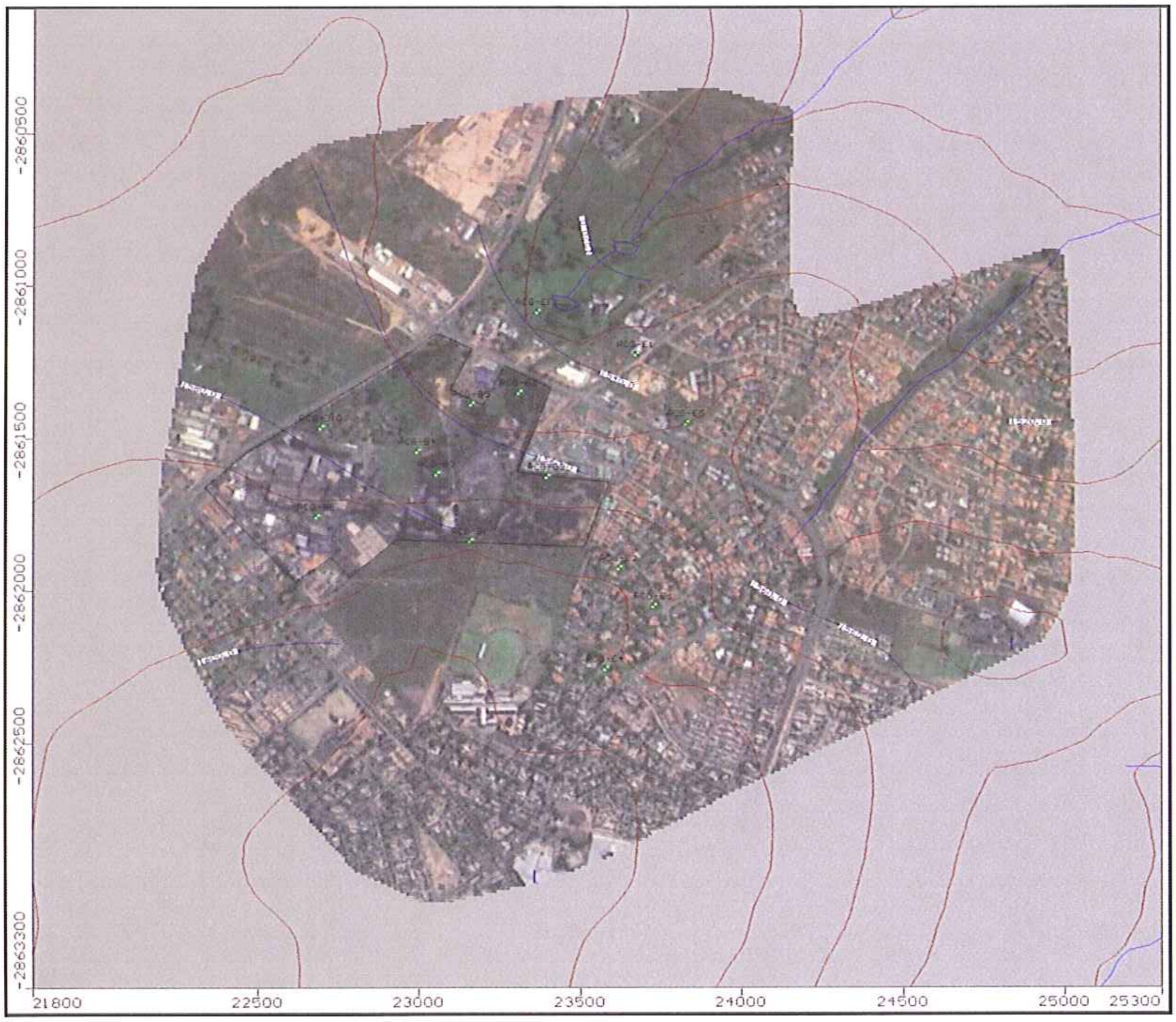


Figure 3-10: Model area (aquifer boundaries as per Figure 3-5) (JMA, 2012)

The aquifer boundaries assigned to the model are groundwater divides of the local sub-catchment area and have been incorporated into the model as drain boundaries.

Table 3-11: Model layer properties

Layer	Layer Type	Depth (m)	Porosity (fraction)	Effective Porosity (fraction)	Hydraulic Conductivity (m/day)
Layer 1: Shallow weathered zone aquifer	Unconfined /Confined	0 - 11	0.03	0.02	0.04
Layer 2: Fractured aquifer	Confined	11 - 100	0.01	0.001	0.004

In the transport model, Layer 2 was further subdivided into 9 sub layers - all with the same properties.

The initial head assigned to the steady state model was interpolated from the groundwater levels recorded in the aquifer during December 2011. The simulated steady state heads of the aquifer were then further used as the initial heads for the subsequent transient state models.

Recharge: The recharge to the aquifer was calibrated to range between 0 - 11 mm/year in the model which corresponds to a groundwater recharge of between 0 and 1.5% of the MAP.

Seepage: The recharge through the footprints of the delineated surface stockpile areas and waste dump was taken as 3% whilst in operation and as 1.5% after rehabilitation/closure.

Model scenarios:

1. Steady state model used to depict the modelled groundwater elevations and flow directions.
2. Transient state model used during the groundwater impact assessment to depict the potential development of a groundwater contamination plume as well as the natural attenuation thereof, once the identified impact sources have been removed over a 200 year period.

Steady state model: The steady state groundwater model indicates that the groundwater levels are the deepest at the topographical higher areas and shallowest at the topographically lower areas, close to surface water features and drainage lines (Figure 3-11). The groundwater elevation below Rand Carbide ranges between 1 590 mamsl and 1 540 mamsl according to the simulation and the groundwater flows in a north-easterly direction. The simulated average groundwater gradient below Rand Carbide is 0.06 in a north-easterly direction.

Transient state model: 200 years were run to observe the long-term impact. Seepage from sources has been simulated for a 100 year period.

Year 0 – 100: Recharge of 21mm/year; contaminant value of 100 mg/l
Year 101 – indefinite: After rehabilitation, recharge was taken as background and a contaminant value of 0% was used.

Contamination plume: Although no significant groundwater contamination plume could be delineated, it is suspected that the slightly elevated SO_4 (and probably Ca) concentrations observed in the groundwater is related to contamination from the one or more of the delineated surface contamination sources. The major contamination source is identified as the historical waste dump, which will however need to be verified during future groundwater monitoring programmes.

Existing contamination: It is indicated from the model results, that the simulated contamination plume was almost static from between 40 - 50 years and onwards when the contaminants that seeped from the sources were comparable to those that flow out at surface water features down gradient of the site and that very little groundwater contamination is deemed to have occurred at Rand Carbide over the past 100 years.

Future contamination: After 100 years (effectively 2026), all the potential pollution sources are deemed to have been completely removed and rehabilitated and the simulated pollution plume will decrease significantly after 10 years and is almost absent after 20 years. Based on the simulated results, it is deemed that removal and rehabilitation of the historical waste dump along with good housekeeping practices may be viewed as an effective groundwater management measure at Rand Carbide and will need to be continually verified during future groundwater monitoring.

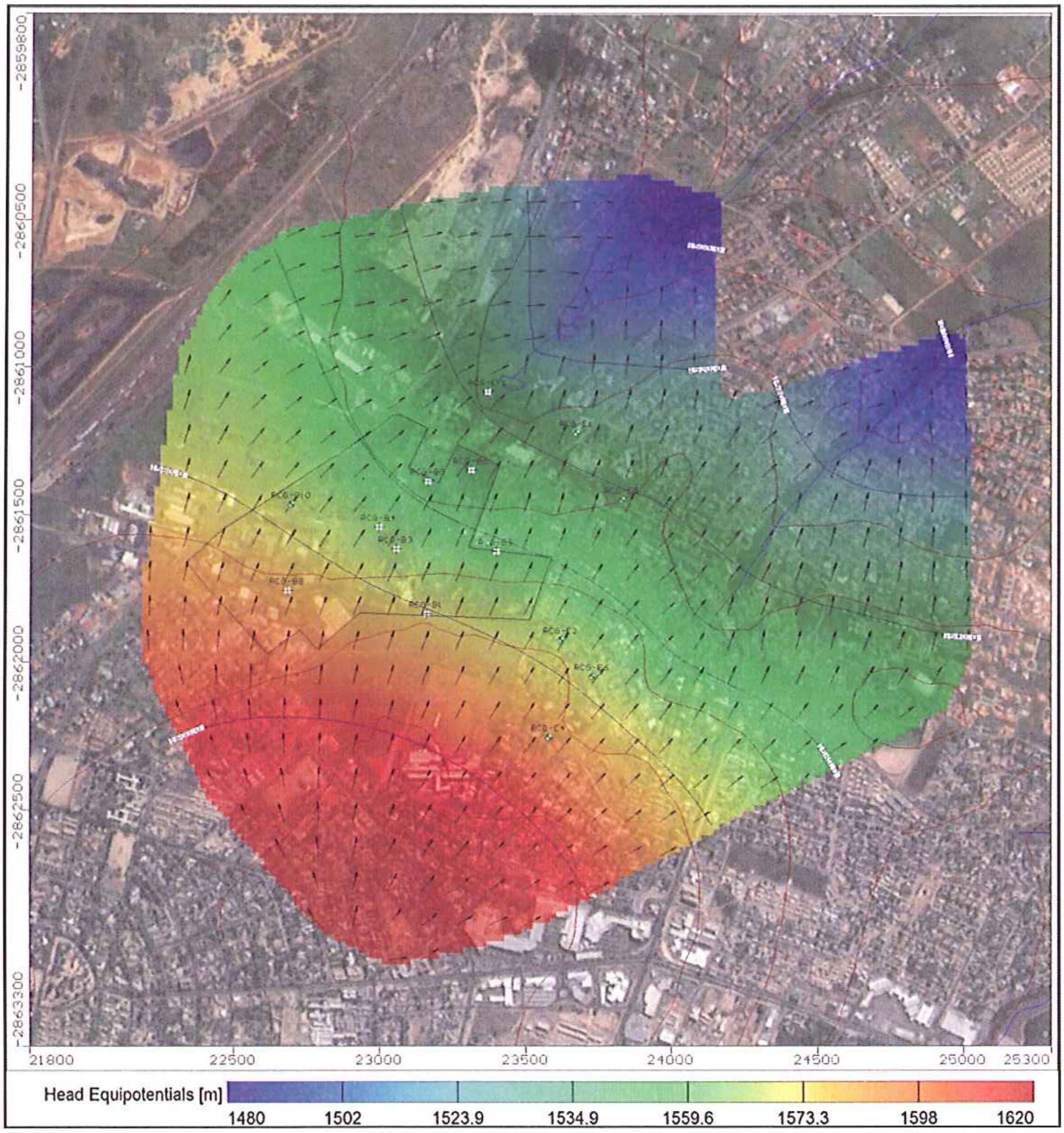
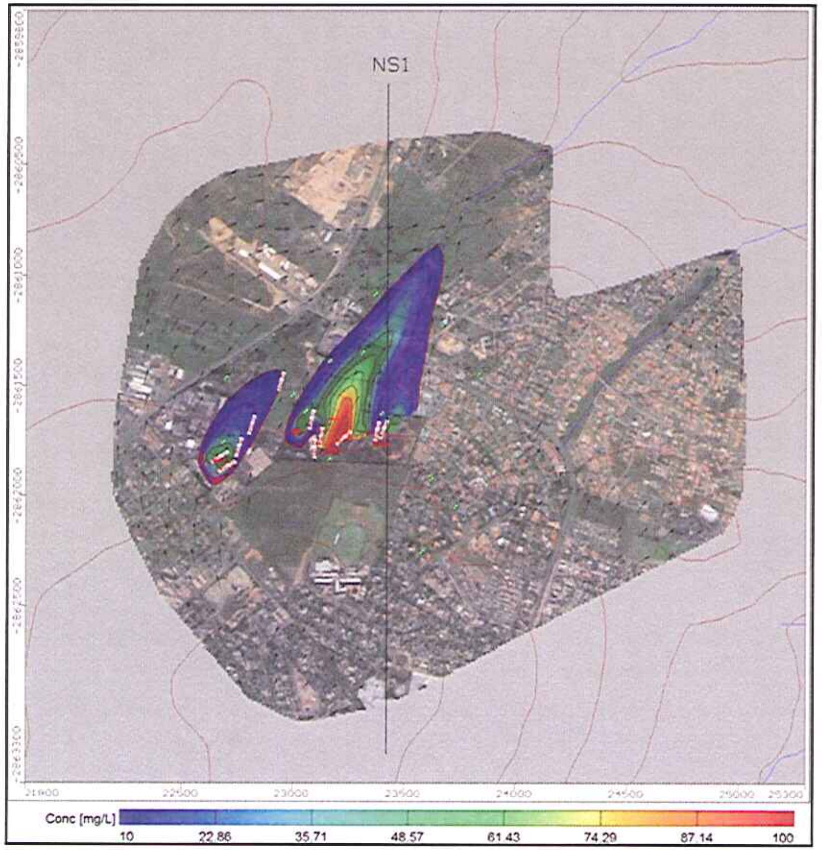
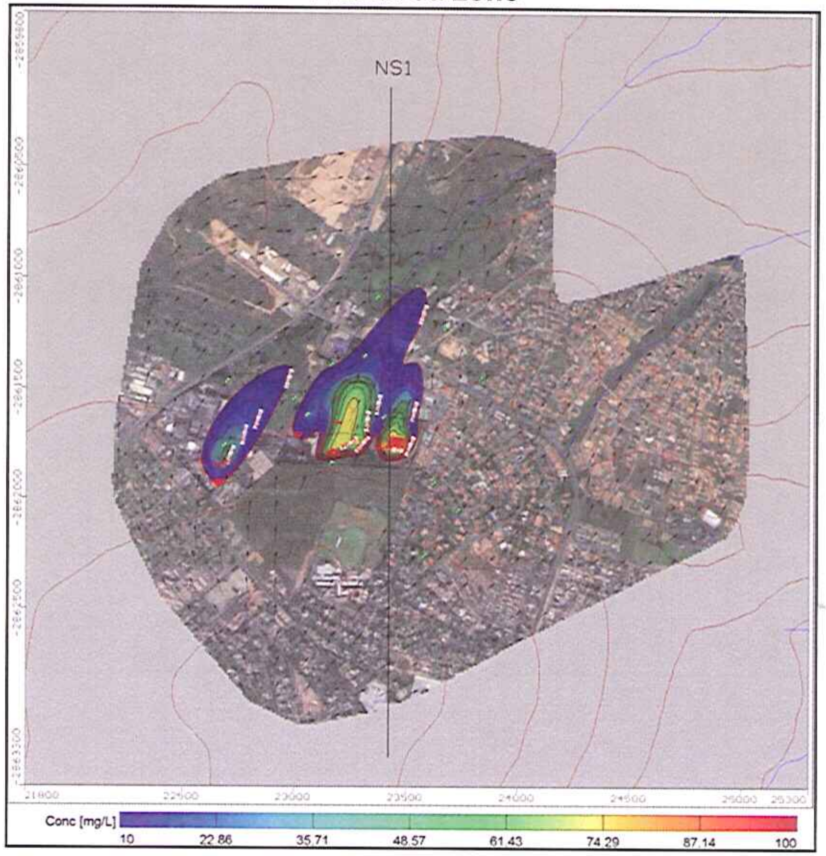


Figure 3-11: Simulated steady state model - elevations & flow directions (JMA, 2012)

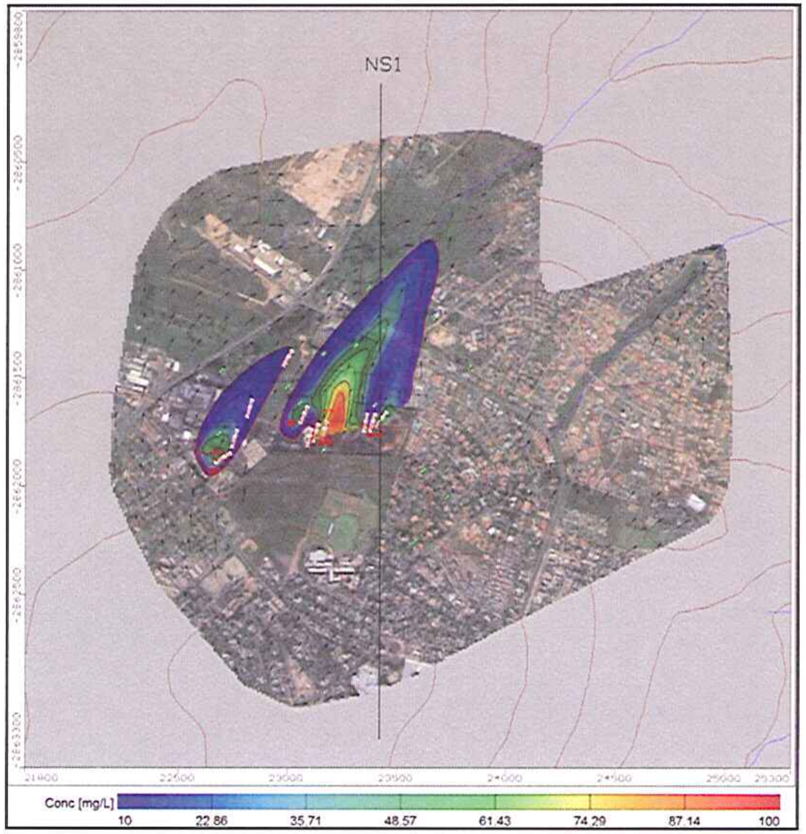
Shallow weathered zone

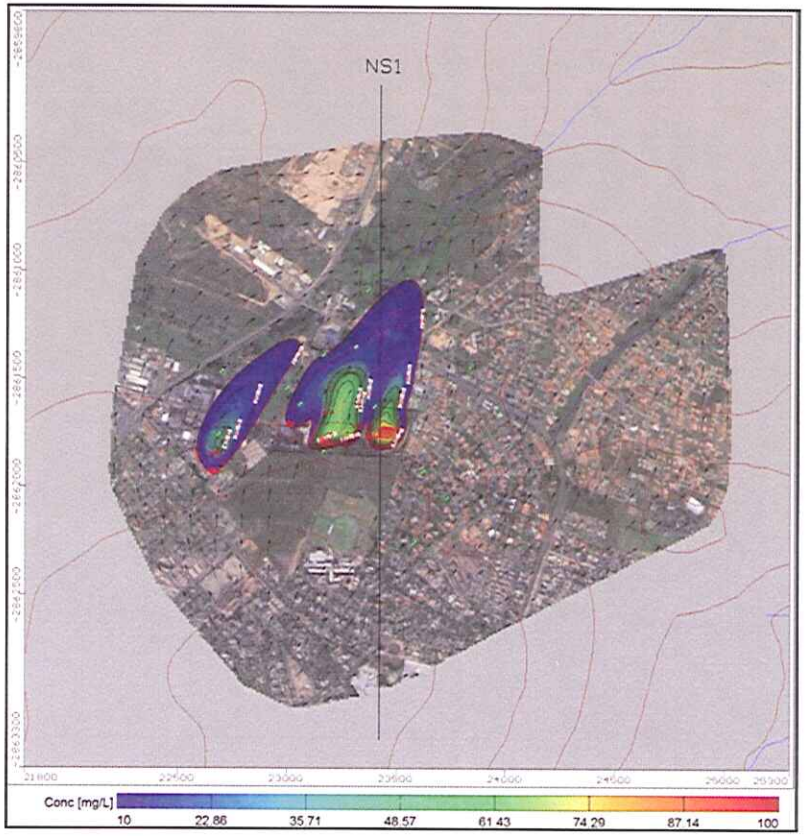


Fractured zone

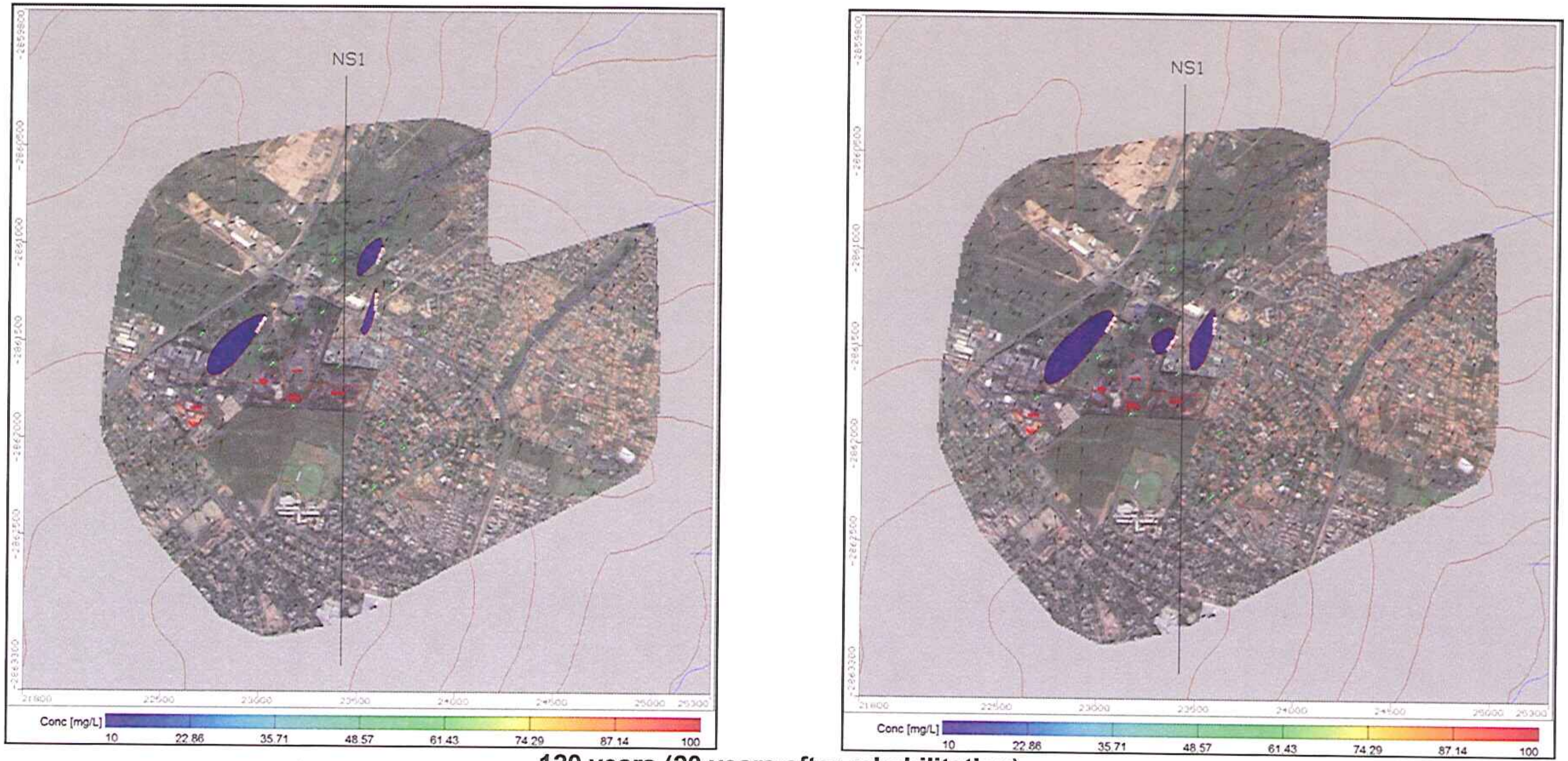


40 years


NS1
Conc [mg/L]
10
22.86
35.71
48.57
61.43
74.29
87.14
100


NS1
Conc [mg/L]
10
22.86
35.71
48.57
61.43
74.29
87.14
100

100 years



120 years (20 years after rehabilitation)

Figure 3-12: Pollution plume development (JMA, 2012)

The recharge from the sources is stored in the aquifer over the first 100 years, up until the simulated removal and rehabilitation of the sources. After removal and rehabilitation of the sources the release in storage from the aquifer is only slightly higher than all the cumulative seepage from the sources into the aquifer over the first 100 years.

It is calculated that after 50 years, the mass of the contaminants stored in the aquifer is 4 300 (normalized percentage). This increased with only 22% to 5 242 after year 100 and explains why so little change occurs in the simulated plume after 40 – 50 years of the model run time. After 30 years from removal and rehabilitation (model year 130), the mass of the contaminants within the aquifer is simulated to decrease by 46%. After a further 70 years (model year 200) it will only decrease by a further 37 %.

3.5 Socio-economic environment

3.5.1 General

Rand Carbide is situated within the eMalahleni municipal area in the Nkangala District of the Mpumalanga Province. The eMalahleni Local Municipality represents one of six (6) local municipalities in the Nkangala District.

The eMalahleni Municipality is strategically located in provincial context and in relation to the national transport network. It is situated in close proximity to the City of Johannesburg, City of Tshwane and Ekurhuleni Metropolitan Municipality in Gauteng, and it is connected to these areas by the N4 and N12 freeways and a railway network. These freeways converge in eMalahleni Municipality, from where the N4 extends to Nelspruit, the provincial capital, and ultimately to Maputo in Mozambique. The N4 freeway and the railway line which runs parallel with and adjacent to it from Gauteng to Mozambique constitute the Maputo Corridor. The corridor forms part of a transcontinental corridor initiative, aimed at linking Walvis Bay on the west coast of Africa with Maputo on the east coast, thereby creating strategic linkages for trade and tourism between Namibia, Botswana, South Africa and Mozambique.

The southern parts of the eMalahleni Municipality form part of the precinct referred to as the Energy Mecca of South Africa, due to its rich deposits of coal reserves and power stations such as Kendal, Matla, Duvha and Ga-Nala. The southward road and rail network connect the eMalahleni area to the Richards Bay and Maputo harbours, offering export opportunities for the coal reserves.

In 2001, the total population of the eMalahleni Municipality amounted to 276 412 persons, which constituted 27% of the total Nkangala District's population (1 020 589 persons) and 9% of Mpumalanga's population (3 122 988 persons). The latest population estimate (2007) is 435 217 persons and the 2011 census results are still outstanding. The towns of eMalahleni and Middelburg (situated in the adjacent Steve Tshwete Municipality) are the highest order settlements in the Nkangala District. These towns offer the full spectrum of business and social activities and both towns have large industrial areas. They also fulfil the function of service centres to the smaller towns and settlements as well as farms in the District.

3.5.2 Spatial structure

The eMalahleni Municipality can be described as an urban and rural area, consisting of large farms, dispersed urban settlements, coal mines and power stations. eMalahleni (Witbank) is seen as the main urban centre in the municipality, with the other activity nodes/towns in the municipal area represented by:

- Ogies and Phola;
- Ga-Nala and Thubelihle;
- Rietspruit;
- Van Dyksdrift; and
- Wilge.

3.5.3 Business activities

The primary business centre in eMalahleni is the eMalahleni Central Business District (CBD), which includes offices, retail, general business and commercial uses. There are also decentralised nodes in the eMalahleni area with mainly retail uses, like the Highveld Mall, Safeways Shopping Centre and Klipfontein Shopping Centre. Shopping centres are also planned in Kwa-Guqa Extensions 9 and 15. The casino in eMalahleni (The Ridge) adjacent to the Highveld Mall offers a hotel, restaurants and entertainment centre.

3.5.4 Industrial activities

There are nine (9) major industrial areas in eMalahleni, mostly concentrated in and around eMalahleni City. This also represents the largest concentration of industrial activity in the Nkangala District. Undermining, however, poses a major constraint to the expansion of these areas, which is problematic in view of the fact that there is a need for industrial land in eMalahleni, both in terms of land for heavy industries (approximately 20 to 50 hectares) and for light industries, service industries and high-tech industries.

3.5.5 Mining

Mining occurs throughout the central and southern portions of the eMalahleni area, with large sections of the municipal area affected by shallow undermining and/or mineral rights. Many of the mines have closed down for a variety of reasons.

This has had a significant impact on the environment, resulting in sinkhole formation, subsidence, underground fires, and seepage of water and Acid Mine Drainage (AMD) from underground workings. It has also had a significant economic impact, with some of the mining towns closing down and people being retrenched.

3.5.6 Electricity

Due to the rich coal reserves in the eMalahleni Municipality, Eskom developed the Kendal, Ga-Nala, Matla, Wilge and Duvha power stations during the 1970's and 1980's to provide in future electricity needs. This has led to the establishment of towns at Ga-Nala, Thubelihle and Wilge and the growth of these townships. Wilge is no longer operational.

Kendal is the largest power station with capacity of 4 032 MW. The chimneys at the Duvha power station are the highest manmade structures in Africa. These smoke stacks are each 300 metres tall, 30 metres higher than the Hillbrow tower in Johannesburg. Coal is a limited resource and there are plans to convert to gas in future to feed the power stations.

3.5.7 Agriculture

The non-urban areas of the eMalahleni Municipality consist mainly of farms and agricultural holdings. The agricultural holdings are found on the periphery of the urban settlements. In terms of agriculture, stock farming (sheep and cattle) and maize farming occur through the area and especially along the river drainage basins.

3.5.8 Economic profile

The eMalahleni economy is dominated by electricity as the main contributor to the Gross Geographic Product (GGP) of the area. The electricity sector dominates the local economy whilst the mining activities contribute significantly. The manufacturing and community services sectors are respectively the third and fourth most important sectors in the local economy.

During 1996-1999 only the finance sector and the electricity sector recorded significant growth rates. However, 1999-2002 was a period of expansion in the local economy with the aggregate economy expanding by 2.7%.

The key sectors that drove this expansion were:
- Mining;
- Manufacturing;
- Transport; and
- Finance.

3.5.9 Economic activity

Approximately 45% of the population is economically active, which is considerably higher than the Nkangala District (34%). The highest number of unemployed people reside in Hlalanikahle (23.5%), followed by Lynnville (22.6%), Phola (22.1%) and Kwa-Guqa (20.9%). Employment of the population according to the major types of industry in the area is as follows:

- 23% in mining and quarrying;
- 13.2% in community, social and personal services;
- 13.1% in wholesale and retail trade;
- 10% in manufacturing; and
- 3.1% in agriculture, hunting, forestry and fishing combined.

From this breakdown it is clear that most people in the area are employed in the primary and secondary sectors, with very few people employed in the tertiary sector (only 5.7% as professionals and 4.1% as legislators; senior officials and managers).

The average monthly household income in the area amounted to approximately R3 721 in 2001, which was significantly higher than the averages for the District (R2 531.27) and Mpumalanga Province (R2 286.61)

3.5.10 Rand Carbide's socio-economic contribution

Jobs: Rand Carbide currently employs 292 permanent staff of which 229 is African, 3 is Coloured, 1 is Indian and 59 are White (of which one person is disabled and none are foreign nationals). This translates into 80% of the workforce being people of colour. Only 7% of the workforce is female.

Support industries: Rand Carbide currently utilises more than 400 vendors for projects ranging from air conditioning installations and maintenance to winch repairs.

Economic: Rand Carbide's products (predominantly ferrosilicon, silicon metal and electrode paste) are purchased by almost twenty (20) major industries in South Africa (including Columbus Steel and Higveld Steel) which, in turn, generates additional employment opportunities and further growth potential in both local and national GDP. Columbus Steel is considered as one of South Africa's largest stainless steel producers. Rand Carbide also exports to Europe and America.

2010 investment to reduce environmental impacts: > R1.6 million
Annual environmental monitoring: R124 612