CLIENT:

PROJECT:

CIVIL ENGINEERING BULK SERVICES
INVESTIGATION AND REPORT:
PROPOSED TOWNSHIP CHURCHILL
(NEAR KURUMAN)
(JOE MOROLONG LOCAL MUNICIPALITY)

SERVICES PROVIDERS:

BARZANI HOLDINGS
CIVIL ENGINEERING BULK SERVICES
INVESTIGATION AND REPORT:
PROPOSED TOWNSHIP CHURCHILL
(NEAR KURUMAN)
(JOE MOROLONG LOCAL MUNICIPALITY)

MAY 2020

| | | |
|---|---|---|
| Technical Report Prepared by | : | B D Bensley |
| Date | : | May 2020 |
| On behalf of | : | G3T Consult |
| For | : | Maxim Planning Solutions |
| Attention | : | Mr K Raubenheimer |

# CIVIL ENGINEERING BULK SERVICES INVESTIGATION AND REPORT: PROPOSED TOWNSHIP CHURCHILL (NEAR KURUMAN) (JOE MOROLONG LOCAL MUNICIPALITY)

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# 1. DEVELOPER AND SERVICE PROVIDERS DETAILS

## 1.1 Developers Details:

THE MANAGING DIRECTOR
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## 2. BACKGROUND

Churchill is a rural settlement in South Africa, and the home for the Joe Morolong Local Municipality (formerly Moshaweng Local Municipality), the largest municipality in the John Taolo Gaetsewe District of Northern Cape province. Its previous name (Moshaweng) means "place of sand". Two other rural settlements namely Esperanza and Lotlhakane is also located in the Joe Morolong Muncipal are and together they form the greater Churchill.

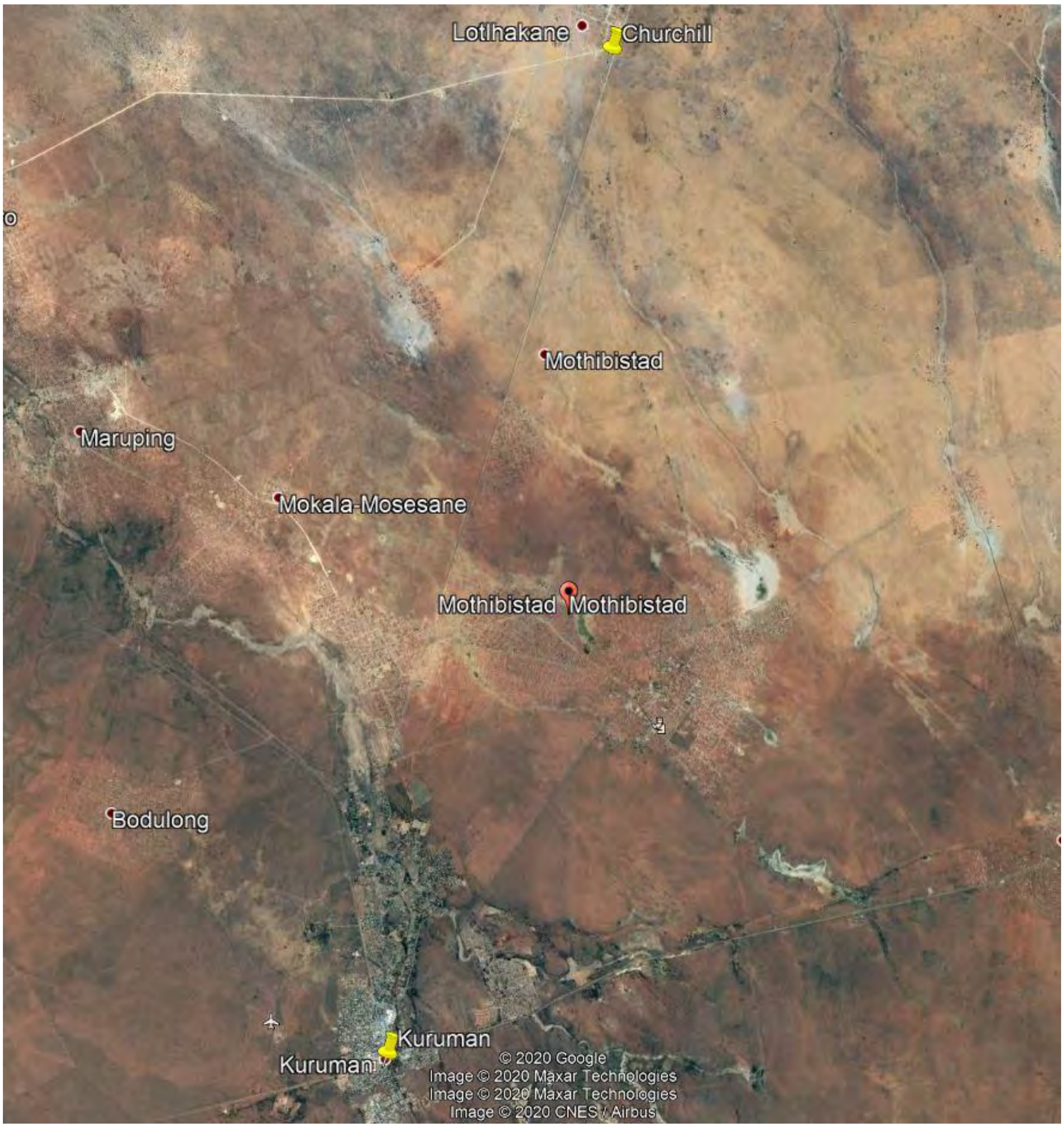


Figure 1: Town Location

Churchill lies in the Kalahari Desert region (see Fig 1 above). It's a rural/informal settlement area that lies strategically to the east of the R31 between Kuruman and Hotazel, and thirty-four minutes' drive away from Kuruman, to which it is connected by road. In between Kuruman and Churchill you can also find the well know Mothibistad. Kuruman is the closest town to Churchill that can provide income and economical enhancement for the rural settlement surrounding area.

Kuruman is a town with just over 13,000 inhabitants in the Northern Cape province of South Africa. It is known for its scenic beauty and the Eye of Kuruman, a geological feature that brings water from deep underground. It was at first a mission station of the London Missionary Society founded by Robert Moffat in 1821. The Kuruman River, which is dry except for flash floods after heavy rain, is named after the town. Kuruman is regarded as the "Oasis of the Kalahari". It is set out on the Ghaap Plateau and receives its water source from a spring called "The Eye" which rises in a cave in the semi desert "thornveld" area in the Kalahari region. Kuruman is the main town in the area and the spring gives about 20 to 30 million litres of water daily to approximately 10 000 inhabitants. It is also known as "Die Oog" or "Gasegonyane" in the Kalahari region.

Kuruman is situated on the main route between Gauteng and Namibia/Cape Town via Upington. The route is growing in popularity because of its beautiful nature and various tourist attractions. Mining and agriculture (cattle and game) support Kuruman's thriving economy. Minerals mined in Kuruman include Manganese, Iron Ore, Tiger's eye and Crocidolite. The richest deposits of Crocidolite in the world are found in the Kuruman district.

Mothibistad is a town situated 9 kilometres northeast of Kuruman in the Northern Cape province of South Africa. Before 1994 it was in the Bophuthatswana bantustan, and from 1994 until a border change in 2006 it was in North West province. It falls within the Ga-Segonyana Local Municipality and the John Taolo Gaetsewe District Municipality.

## 3. SITE DESCRIPTION


Figure 2: Proposed Development of 3500 Residential Erven

### 3.1 LOCATION

The proposed development site is on a portion of the remaining extent of the farm Churchill 211-HM and portion of the remaining extent of portion 2 of the farm Nyra 213-HM, surrounding the existing rural settlements namely Esperanza and Lotlhakane, northeast of the town of Kuruman, approximately 250.2453 hectares in size.

The site is accessible from the MR948 provincial road, towards the North West and Northern Cape border line (See Fig 2 above).

## 3.2 TOPOGRAPHY

The site is located towards the north eastern side of Kuruman.


Figure 3: Site Elevation

The proposed site has a gradual slope from the west towards the north east of approximately 24.3m over a distance of 4.85kms, 1275 to 1286 meters s above sea level. The site indicates an average slope of 0.7% to 0.8% across the entire site.

Figure 3 above depicts the gradient of the proposed site.

## 3.3 CLIMATE

### **3.3.1** Rainfall

The region is characterized by summer rainfall with thunderstorms, with annual rainfall figures of 550 mm (Vryburg) recorded at the closest weather station to the site. Winters are dry with frost common.

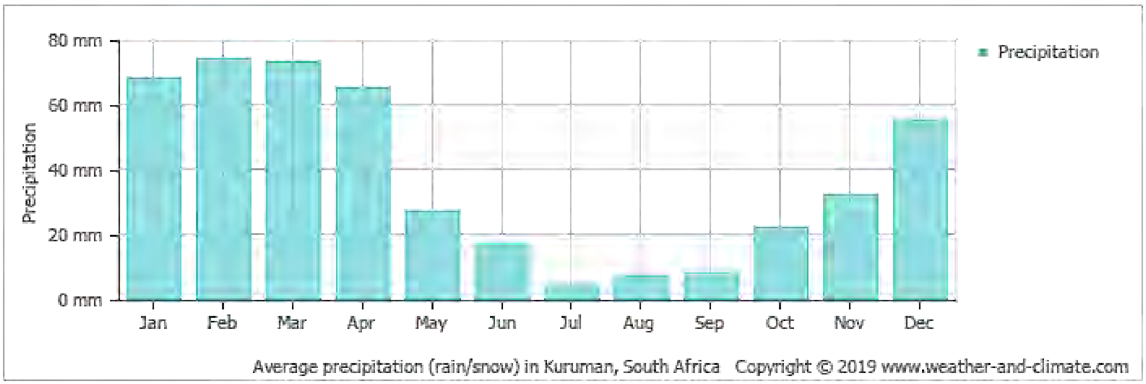


Figure 4: Precipitation

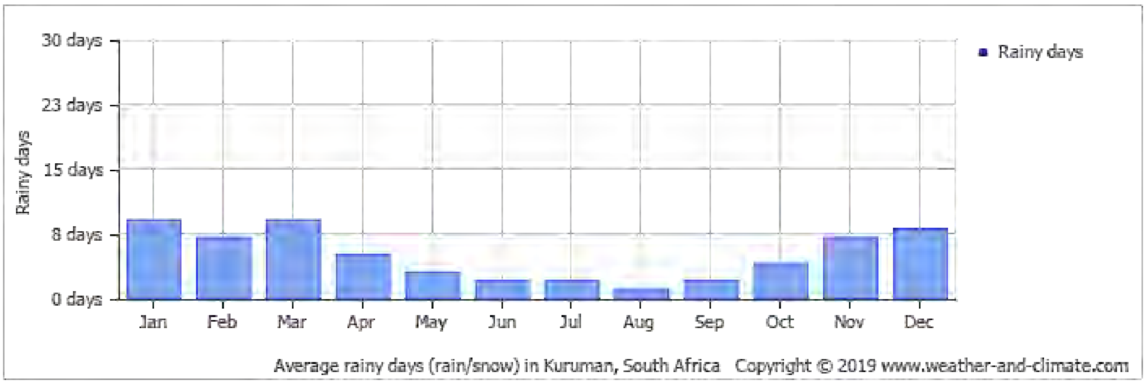


Figure 5: Rain Days

### 3.3.2 Temperature

The warmest months are normally December and January and the coldest months are June and July.

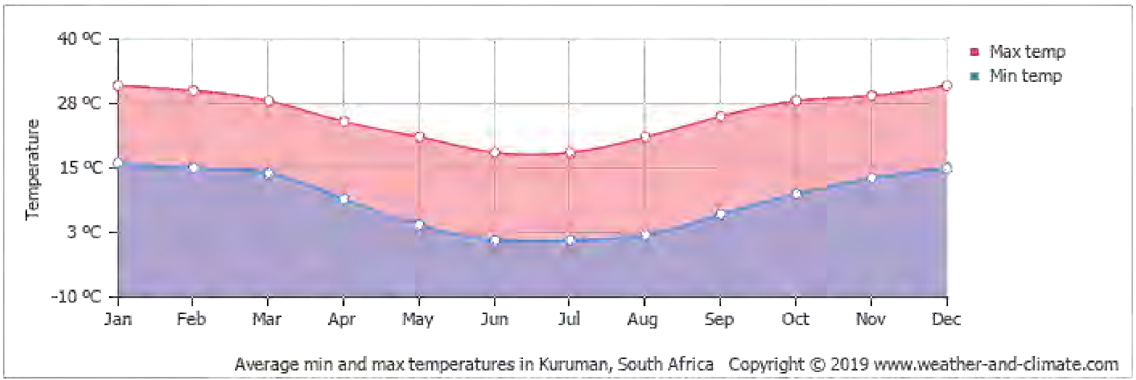


Figure 6: Temperatures

## 3.4 VEGETATION

The indigenous vegetation of the area is mainly classified as the Kuruman thornvelds which consists of closed shrub layer and well-developed open tree stratum mainly made of Acacia Erioloba (Mucina and Rutherford, 2006).

The site is extensively covered by tall grass, shrubs and trees in places. Vegetation cover comprises grass, formal gardens, shrubs and trees in places. The area is also known as the "Oasis of the Kalahari", typically characterized by semi desert thornveld veld type.

## 3.5 GEOLOGY

A detailed feasibility level dolomite stability investigation report for Churchill, in the jurisdiction of Joe Morolong local municipality, northern cape, was done by the Council of Geosciences & Geohazards.

According to the geological map, and investigations the profile of the site generally consists of aeolian deposits, calcrete or calcified (pedogenic) deposits, weathered dolomite and hard rock dolomite. Other rocks types and most noticeably dolerite was intersected in some boreholes and calcified pan dunes of Gordonia Formation. The area also hosts surface limestone of tertiary age.

This zone is largely characterised by a medium inherent hazard of a medium (2-5m diameter) sinkhole and subsidence (with sub areas of medium inherent hazard of large [5-15m diameter] sinkhole and subsidence) in a non-dewatering scenario. The inherent hazard for any size sinkhole and subsidence is low with respect to a dewatering scenario.The overburden which is non-dolomitic consists of aeolian deposits and pedogenic calcrete which is in a form of hardpan and calcified nodules in places. This zone occupies all gravity zones i.e. highs, lows and gradients. Neither wad nor low density material was recorded in the boreholes drilled. The groundwater level rests within the solid dolomite bedrock.

The geohydrological report classifies the area as a D3 Designation. Restrictions are placed on the types of residential development that may be considered on IHC: 3/4 land. Full title residential development (RN2-3) on stands of 300m² or greater is recommended or 10 − 25 dwelling houses per hectare and a population of ≤ 60 people per hectare is recommended. Any form of commercial, retail and/or light industrial development is permissible with appropriate stringent precautionary measures. Footprint investigations are required for each commercial development.

The municipality exclusively relies on groundwater resources for domestic, agricultural and business water supply. According the Department of Water Affairs' (DWA) National Groundwater Archive (NGA), there are 4 groundwater monitoring boreholes in close proximity of the site. They fall under Lower Vaal Water Management Areas and D41L drainage region. Recorded water rest levels ranged between 2.5m and 58.7m with a general average of 10m.

In general, alternating lows and highs are present in the study area, indicating possible features (bedrock) that are shallower at 0.163mGals and those that are deeper than the surrounding area at 0.404mGal. Gravity low patches are found in the south eastern and south western of the site, while gravity gradients and highs area are predominant and occur in different places across the site. Percussion drilling results confirmed the anticipated variation in the depth to bedrock and weathering profiles with relatively deep bedrock and thicker overburden profile being prevalent in gravity lows and much shallower or surface outcrops in gravity highs.

Development Recommendations can be outlined as follows:

- It is recommended that the municipality sets up at least two groundwater monitoring boreholes distributed across the current study area to establish trends. Any future developments must be investigated in accordance with SANS 1936-2 (2012).

- A high density development, i.e. 150m² stands or developed as group housing such as a block of flats, has a greater probability of inducing a sinkhole than a commercial development on the same property because of the higher density of wet services and greater chance of an undetected leak. Therefore, new development should take into cognizance the allowable land use densities as per SANS 1936-1 (2012) permissible land use Tables.

- Based on the feasibility study, the entire site is suitable for most planned low-cost housing development.

- Any signs of ground instabilities or subsidence should be reported immediately to the municipality and remediated in accordance with SANS 1936-4 (2012).

*Source: Compiled from a feasibility level dolomite stability investigation report for Churchill, in the jurisdiction of joe morolong local municipality, northern cape.*

### **3.5.1** Drainage

The site is located on a shallow slope towards the northeast. Larger areas within the higher lying catchment area can lead to flash floods during heavy rainfalls and indicated by the 1:100-year flood line.

The majority of the site is a flat surface base with minimum natural drainage. Towards the northwest side and northeast side of the site respectively, there are seasonal streams that drain naturally in a north western direction through the site.

On the western side of the site a slight ridge/hill is formed naturally that drains towards the north.

The ingress of surface water can have dire implications for dolomite stability and strict drainage measures must be implemented. It is important that prospective developers of the township are made aware of the importance of the recommended precautionary measures as stipulated in SANS 1936-3 (2012) and these include:

- All pipes and channels must be watertight, with all wet services being tested for leakage on installation,

- Piping material should be appropriate to local subsurface conditions,

- No accumulation or ponding of surface water should occur adjacent to foundations both during and after construction,

- Storm water should be effectively captured and led away from all structures preferably by means of lined, surface canals.

## 3.6 DEMOGRAPHIC OVERVIEW

As indicated in Table 1, the population of the John Taolo Gaetsewe District Municipality (JTGDM) increased by from 191 539 in 2001 to 224 799 in 2011, which represents an increase of ~ 17.4%. The population of the Joe Morolong Local Municipality (JMM) decreased from 97 945 in 2001 to 89 530 in 2011 (~ -0.9%) over the same period. The decrease in the population in the JMM was linked to a stabilisation in the 15-64 age group. This is linked to the non-growth in the mining sector and the influx of workers to the area over this ten-year period. The size of the JTGDM decreased from 4 to 3.5, while the household size in the JMM decreased from 4.3 to 3.7.

Table 3-1: Overview of key demographic indicators for the JTGDM and GLM

| ASPECT | JTGDM | | JMM | |
|---|---|---|---|---|
| | 2001 | 2011 | 2001 | 2011 |
| Population | 191 539 | 224 799 | 97 945 | 89 461 |
| % Population <15 years | 38.1 | 34.0 | 41.9 | 39.4 |
| % Population 15-64 | 57.1 | 61.2 | 54.2 | 54.2 |
| % Population 65+ | 4.8 | 4.8 | 5.6 | 6.4 |
| Households | 44 218 | 61 331 | 21 749 | 23 707 |
| Household size (average) | 4.0 | 3.5 | 4.3 | 3.7 |
| Formal Dwellings % | 70.2% | 76.6% | 64.8% | 72.5% |
| Dependency ratio per 100 (15-64) | 75.1 | 63.3 | 90.4 | 84.6 |
| Unemployment rate (official) - % of economically active population | 42.5% | 29.7% | 49% | 38.6% |
| Youth unemployment rate (official) - % of economically active population 15-34 | 53.3% | 37.2% | 59.8% | 49.5% |
| No schooling - % of population 20+ | 25.7% | 14.6% | 31.6% | 22.8% |
| Higher Education - % of population 20+ | 3.3% | 4.1% | 3.3% | 4.1% |
| Matric - % of population 20+ | 14.2% | 20.5% | 8.3% | 13.4% |

*Source: Compiled from StatsSA Census 2011 Municipal Fact Sheet*

The majority of the population in the JMM in 2011 was Black African (96.4%), followed by Coloureds (2%), Whites (1.2%), Indian/Asian (0.3%) and Other (0.2%) (Census 2011).

The dominant language spoken is Setswana (90.1%), followed by Afrikaans (3.6%), English (1.9%), IsiNdebele (1%) and IsiZulu (0.9%).

The dependency ratio in both the JTGDM and JMM decreased from 75.1 to 63.3 and 90.4 to 84.6 respectively. The decrease represents a positive socio-economic improvement by indicating that there are a decreasing number of people dependent the economically active 15-64 age group. The age dependency ratio is the ratio of dependents, people younger than 15 or older than 64, to the working, age population, those ages 15-64. However, the dependency ratio for the JTGDM remains higher than the ratio for the Northern Cape as whole, which was 55.7 in 2011.

In terms of percentage of formal dwellings, the number of formal dwellings in the JTGDM increased from 70.2% in 2001 to 76.6% in 2011. The number of formal houses in the JMM increased from 64.8% to 72.5% for the same period. This represents a positive socio- economic movement for the JMM but however still reflects the challenges faced by the JMM associated with the influx of workers and job seekers to the area. This figure also indicates that there is likely to be a housing backlog in JMM.

### 3.6.1 Employment

The official unemployment rate in both the JTGDM and JMM decreased for the ten-year period between 2001 and 2011. In the JTGDM the rate fell from 42.5% to 29.7%, a decrease of 12.8%. In the JMM the unemployment rate decreased from 49% to 38.6%, a decrease of 10.4%. Youth unemployment in both the JTGDM and JMM also dropped over the same period. Youth unemployment in the JMM area decreased from 59.8% to 49.5%. There are 12 740 people that are economically active (employed or unemployed but looking for work), and of these 38.6% are unemployed in JMM. Of the 6 323 economically active youth (15 – 34 years) in the JMM area, 49.5% are unemployed.

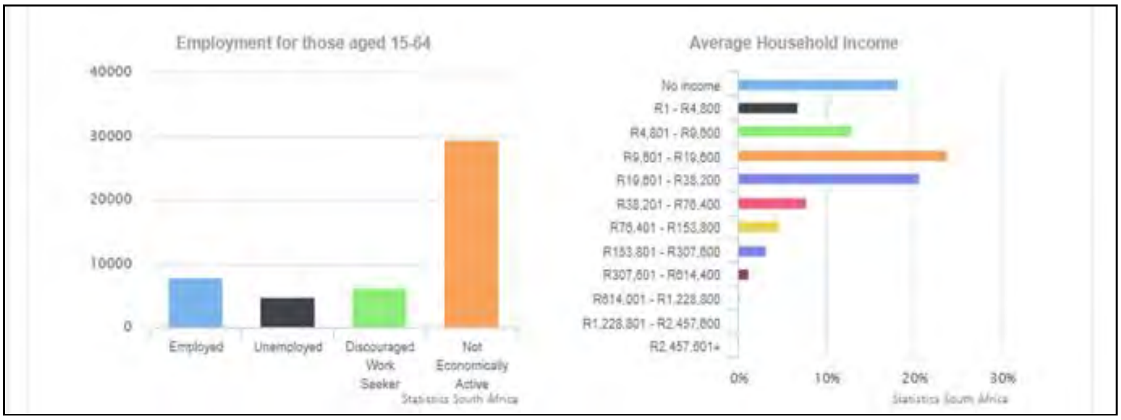


Figure 7: Employment Statistics

### 3.6.2 Key Economic Drivers in The Municipality

Mining and Agriculture are the largest contributing factors in terms of the economy in the Municipality.

| Table 3-2: Employment: Industry (Municipal Demarcation Board) | |
|---|---|
| Sector | Number of jobs created |
| Agriculture related work | 720 |

| Table 3-2: Employment: Industry (Municipal Demarcation Board) | |
|---|---|
| Sector | Number of jobs created |
| Manufacturing | 144 |
| Mining, Quarrying | 471 |
| Electricity, gas, water | 116 |
| Construction | 283 |
| Wholesale, Retail | 432 |
| Transport | 122 |
| Business services | 100 |
| Community services | 1 693 |
| Undetermined | 87 171 |

### **3.6.3** Household income

Based on the data from the 2011 Census, 18.3 % of the population of the JMM have no formal income, 6.8% earn between 1 and R 4 800, 13% earn between R 4 801 and R 9 600 per annum, 23.9% between R 9 601 and 19 600 per annum, 20.6% between R 19 601 and R 38 200 per annum, 7.8% between R 38 201 and R 76 400 per annum and 4.8% between R 76 401 and R 153 800 per annum (Census 2011). The poverty gap indicator produced by the World Bank Development Research Group measures poverty using information from household per capita income/consumption. This indicator illustrates the average shortfall of the total population from the poverty line. This measurement is used to reflect the intensity of poverty, which is based on living on less than R3 200 per month for an average sized household. This figure is likely to be linked to the influx of job seekers to the area and the inability of all of them to secure work. This is also likely to result in an increasing number of individuals and households who are likely to be dependent on social grants. The low-income levels also result in reduced spending in the local economy and less tax and rates revenue for the district and local municipality.

### **3.6.4** Education

The education levels at both the district and local municipal level also improved, with the percentage of the population over 20 years of age with no schooling in the JTGDM decreasing from 25.7% to 14.6%.

| Table 3-3: Education Level (Census 2011) | |
|---|---|
| Education Level | Number |
| No schooling | 10 204 |
| Some primary school | 11 887 |

| Table 3-3: Education Level (Census 2011) | |
|---|---|
| Education Level | Number |
| Completed primary school | 2 324 |
| Some Secondary school | 12 384 |
| Grade 12 | 5 986 |
| Higher education | 1 823 |

### 3.6.5 Municipal services

As indicated in Table 2, the municipal service levels in the JTGDM and JMM all improved over the period 2001 to 2011. This represents a socio-economic improvement. However, the service levels in the JTGDM are significantly lower than both the national and provincial averages. The national averages for each of the relevant indicators are 57% (access to flush toilet), 62% (weekly waste removal), 46.3% (piped water inside dwelling) and 84.7% for electricity. The figures for the JMM are all lower than the national and provincial averages.

| Table 3-4: Overview of access to basic services in the JTGDM and JMM | | | | |
|---|---|---|---|---|
| Municipal Services | JTGDM | | JM | |
| | 2001 | 2011 | 2001 | 2011 |
| % households with access to flush toilet | 21.5 | 26.2 | 7.2 | 6 |
| % households with weekly municipal refuse removal | 23.1 | 26.0 | 5.8 | 6.1 |
| % households with piped water inside dwelling | 16.8 | 22.7 | 6.1 | 9.1 |
| % households which uses electricity for lighting | 39.0 | 81.8 | 39 | 81.8 |

*Source: Compiled from StatsSA Census 2011 Municipal Fact Sheet*

### 3.6.6 Population Figures

The Joe Morolong Local Municipality was established in 2000 and serves 15 wards, most of which are rural. Although unemployment is high, the municipality has great potential for developers, especially those interested in ecotourism and conservation. The municipal area is approximately 5 813 $km^2$ in size. The municipality strives to deliver basic services to its community by ensuring that there is water, sanitation and electricity.

Among the 15 wards in the Joe Morolong Municipal area rural settlements like Churchill, Esperanza, Lotlhakane, to name a few, and a large farming area forms part of the municipality. Churchill is a small rural settlement within the municipality and is also the administrative centre of the Joe Morolong Local Municipality.

Kuruman and Mothibistad are the largest established towns in the near vicinity of the rural settlements and situated in the Ga-Segonyana Municipal area.

| Table 3-5: Beneficiaries 2011 | | |
|---|---|---|
| Joe Morolong Local Municipality | | |
| Places | Population | Households |
| Avon | 263 | 89 |
| Baily Brith | 110 | 25 |
| Bareki | 150 | 32 |
| Battlemound | 353 | 90 |
| Bendell | 1820 | 511 |
| Blackrock | 403 | 151 |
| Bojalapotsane | 108 | 52 |
| Bosra | 462 | 139 |
| Bothetheletsa | 1064 | 260 |
| Bothithong | 3172 | 869 |
| Cassel | 3895 | 1033 |
| Clyde | 392 | 98 |
| Cottenend | 147 | 45 |
| Deorham | 964 | 249 |
| Dewar | 550 | 164 |
| Dikolobeng | 67 | 25 |
| Dinopeng | 3115 | 767 |
| Dithakong | 1691 | 389 |
| Ditshilabeleng | 553 | 148 |
| Ditshipeng | 1057 | 260 |
| Elston | 157 | 60 |
| Esperanza | 383 | 103 |
| Everton | 21 | 12 |
| Ga-Diboye | 574 | 156 |
| Ga-Lotlhare | 795 | 186 |

| Table 3-5: Beneficiaries 2011 | | |
|---|---|---|
| Joe Morolong Local Municipality | | |
| Places | Population | Households |
| Ga-Mabe | 968 | 204 |
| Ga-Madudu | 3598 | 874 |
| Ga-Makgatle | 476 | 105 |
| Ga-Masepa | 840 | 209 |
| Ga-Moheele | 139 | 37 |
| Ga-Mokomela | 79 | 28 |
| Ga-Morona | 612 | 161 |
| Ga-Moseki | 756 | 158 |
| Ga-Mothibi | 291 | 84 |
| Ga-Pitiela | 941 | 206 |
| Ga-sehunelo | 116 | 46 |
| Ga-Sese | 1148 | 259 |
| Gadisane | 560 | 130 |
| Gahuhuwe | 609 | 106 |
| Ganap | 569 | 143 |
| Ganghae | 120 | 38 |
| Gapopo | 66 | 18 |
| Garamatale | 54 | 22 |
| Garaphoane | 137 | 50 |
| Gatshekedi | 183 | 46 |
| Good Hope | 247 | 48 |
| Heiso | 1182 | 247 |
| Hertzog | 601 | 157 |
| Heuningvlei | 2656 | 698 |
| Hotazel | 1756 | 598 |
| Kakoje | 135 | 50 |
| Kamden | 1616 | 423 |

| Table 3-5: Beneficiaries 2011 | | |
|---|---|---|
| Joe Morolong Local Municipality | | |
| Places | Population | Households |
| Kangkuru | 264 | 76 |
| Kelokilwe | 329 | 79 |
| Kganong | 265 | 61 |
| Kganwane | 2297 | 517 |
| Kgomohute | 231 | 73 |
| Kikahela | 323 | 87 |
| Klaarkom | 476 | 127 |
| Klein Tsamaros | 205 | 44 |
| Laxey | 1590 | 413 |
| Lebonkeng | 310 | 64 |
| Letlhakajaneng | 1065 | 204 |
| Logaganeng | 520 | 132 |
| Logobate | 547 | 106 |
| Longhirst | 216 | 62 |
| Lotlhakane | 881 | 203 |
| Madibeng | 1531 | 381 |
| Madingwane | 831 | 197 |
| Magobing | 493 | 121 |
| Magojaneng | 742 | 182 |
| Magwagwe | 740 | 159 |
| Mahukubung | 393 | 92 |
| Maipeng | 1061 | 252 |
| Majankeng | 244 | 65 |
| Makadibeng | 155 | 52 |
| Makalaneng | 5358 | 1267 |
| Maketlele | 217 | 65 |
| Manyeding | 1583 | 415 |

| Table 3-5: Beneficiaries 2011 | | |
|---|---|---|
| Joe Morolong Local Municipality | | |
| Places | Population | Households |
| Maphiniki | 657 | 176 |
| March | 321 | 65 |
| Masankong | 299 | 71 |
| Masilebatsena | 707 | 147 |
| Maswehatshe | 265 | 70 |
| Mathanthanyaneng | 149 | 41 |
| Matshaneng | 478 | 102 |
| Mecwatsaneng | 339 | 104 |
| Metsemantsi | 381 | 140 |
| Minto | 157 | 51 |
| Mmatoro | 105 | 33 |
| Moalogane | 162 | 62 |
| Mogobing | 132 | 34 |
| Molomo-wa-Petsana | 279 | 76 |
| Moshaweng NU | 8228 | 2971 |
| Mothong | 86 | 22 |
| Nchwaning | 4 | 3 |
| Ncwaneng | 224 | 57 |
| Neira | 341 | 80 |
| Niks | 139 | 30 |
| Nkajaneng | 172 | 67 |
| Ntswelengwe | 1598 | 355 |
| Padstow | 908 | 242 |
| Pennyn | 435 | 129 |
| Perth | 832 | 244 |
| Phomolong | 592 | 204 |
| Ramatele | 21 | 13 |

| Table 3-5: Beneficiaries 2011 | | |
|---|---|---|
| Joe Morolong Local Municipality | | |
| Places | Population | Households |
| Rowel | 58 | 15 |
| Segwaneng | 554 | 127 |
| Smauswane | 461 | 142 |
| Tlapeng | 162 | 41 |
| Tsaelengwe | 450 | 83 |
| Tsamaros | 405 | 100 |
| Tsilwana | 198 | 53 |
| Tsineng | 2042 | 628 |
| Tsineng-Kop | 33 | 13 |
| Tsoe | 777 | 194 |
| Washington | 722 | 168 |
| Total | 89461 | 23707 |

*Source: Compiled from StatsSA Census 2011*

Joe Morolong Municipality has decreased from 97945 people in 2001 to 89461 people in 2011 (Census 2011) at an average growth rate of -0.9% per annum.

However, Churchill village also serve as one of the nodal points with potential for human settlement, and as a result of this, the Municipality has proposed a Mixed Land Use Development for 3500 (houses Low Income, Middle Income and High Income). This development will have a positive impact towards the economy of Churchill village and Joe Morolong Municipality as a whole.

| Table 3-6: Anticipated Population by 2020 | | |
|---|---|---|
| Suburb Benefiting | Total Benefiting Population | Total No. Of Households Benefiting |
| Churchill | 24500 | 3500 |
| Total | 24500 | 3500 |

## 4. TERMS OF REFERENCE

G3T Consult CC was appointed by Maxim Planning Solutions on the 02 December 2019 for the compilation of Bulk Civil and Electrical Services investigations and Reports for the development of 3500 residential erven in Churchill village in the Joe Morolong Local Municipality.

The proposed development will consist of the following:

| | |
|---|---|
| • Residential (Minimum 300m²) | 2500 Erven |
| • Residential (Minimum 400m²) | 500 Erven |
| • Residential (Minimum 450m²) | 500 Erven |
| • Business | 5 Erven |
| • Institutional Zone I (Crèche) | 5 Erven |
| • Institutional Zone II (Church) | 5 Erven |
| • Institutional Zone I (Primary School) | 1 Stand |
| • Institutional Zone I (Secondary School) | 1 Stand |
| • Open Space Zone I (Parks) | 12 Stands |
| • Open Space Zone II (Sports field) | 1 Stand |
| • Community Facilities | 2 Stands |

# 5. INFORMATION

## 5.1 Information Obtained:

### **5.1.1** Town planning Zoning

The detailed layout plan was received from Maxim Planning Solutions (Accredited Town and Regional Planners) (Annexure A*)*

### **5.1.2** Flood line information

The 1:100 flood line has been determined and is depicted on the Layout received from Maxim Planning Solutions.

### **5.1.3** Geological Investigation

An extensive Geological investigation was received from Maxim for the towns of Hotazel and Blackrock in close proximity to the proposed development.

The Geology and Rock Mass Quality of the Cenozoic Kalahari Group,

Nchwaning Mine Northern Cape was compiled by R.A. Puchner in December 2002.

### **5.1.4** Geohydrological Investigation

We also received a feasibility level dolomite stability investigation report for Churchill, in the jurisdiction of Joe Morolong Local Municipality, Northern Cape conducted by the Council of Geoscience in October 2017.

### 5.1.5 Cadastral and Topographic survey

A Cadastral and Topographical survey was obtained from Azur Aerial Photography.

### 5.1.6 Dolomitic Area

The geohydrological report as mentioned in 5.1.4 classifies the area as a *D3 Designation* and it is therefore important that all the requirements as discussed in SABS 1936-3:2012 is thoroughly adhered to and kept in mind when the feasibility and designs are finalised.

Below are extracts form the abovementioned document. The items listed below are equally important as the items mentioned in SABS 1936-3:2012 but not listed below:

*(3.3)* - *Bulk pipeline* - conveyance pipeline that has a nominal diameter of 300 mm or more

*(4.3.1)* - Bulk pipelines shall be located at least the following distances from the nearest residential, institutional or commercial property boundary, excluding buildings associated with the pipeline:

b) dolomite area designation D3: 25m.

Where this is not practically achievable, the bulk service shall be laid in a duct or culvert that will intercept any leakage in a manner that is readily observable, or an appropriate rational solution shall be provided by a competent person (engineer).

*(4.3.2)* - Dams, reservoirs, liquid-retaining structures, stormwater retention or attenuation ponds and sewer-retaining ponds shall be located at least the following distances from the nearest residential, institutional, industrial or commercial building site boundary, excluding buildings associated with such liquid-retaining facility:

b) dolomite area designation D3: 20m for commercial and industrial developments and 30m in other instances.

*(6.4)* - Additional precautionary measures in dolomite area designation D3 sites

Wet engineering services in dolomite area designation D3 sites shall comply with the following requirements, in addition to those established in 6.1 and 6.2 (SABS 1936-3:2012):

a) The preferred pipe type for all wet engineering services, and the sleeve systems for such services, on dolomite area designation D3 sites are polyethylene (PE) pipes and fittings that comply with the material manufacturing requirements of the relevant of parts 1, 2, 3 and 5 of SANS 4427, with a material designation of PE 100 and that are supplied in straight lengths of 12 m, or rolls of 50 m or 100 m with joints made by means of butt-fusion or electrofusion fittings.

b) Structured wall polyethylene (PE) pipes or steel-reinforced spirally wound PE drainage and sewer pipes shall be made from PE 100 material in accordance with SANS 4427-1. Steel-reinforced spirally wound PE pipes shall comply with SANS 674. Specified ring stiffness shall be tested in accordance with ISO 9969.

c) Manholes and inspection chambers should preferably be manufactured from structured or solid wall polyethylene (PE) or steel reinforced spirally wound pipes that comply with the requirements of SANS 4427-1 or SANS 674, as appropriate, with a material designation of PE 100 (or higher), with inlets and outlets that can be joined to compatible pipe systems by means of butt-fusion or electro-fusion fittings.

d) The nominal pressure rating of plastic pipes shall be one pipe designation or class higher than that which complies with the design requirements for a dolomite area designation D2 site.

e) Wet and dry engineering services pipes (medium pressure pipe types) shall be subjected to hydraulic pipeline testing, after installation, in accordance with SANS 2001-DP2 for the selected pipe type, irrespective of application. The test pressure applied over any section of pipeline, taking any differences in elevation along the pipeline into account, shall be such that the pressure at any point along the section is not less than 1,25 × the designated working pressure or 0,4MPa, whichever is the greater, and not more than 1,5 × the designated working pressure at these points. The field test pressure shall not exceed the appropriate values given in table 6.

NOTE Increasing the nominal pressure rating increases the safety factor and the design life of the pipe and reduces the risk of rupture due to localized stresses or damage.

f) Wet engineering services shall not be placed beneath the footprint of a building or structure.

g) The water supply to a building shall be via a single water supply connection unless otherwise approved by the competent person (engineer). This also applies to other pressurized liquid-bearing services.

h) Water supply for domestic use and firefighting inside the building can be combined, provided that there is a distinct, and clearly marked split above ground (mounted on the outside of building) of the two systems. The point of split shall include a shut-off valve for the domestic supply, but no shut-off valve on the fire-fighting supply side.

i) Within 15m of any building other than a dwelling house, the water supply and other pressurized liquid-bearing service connections shall be placed

1) in a flexible, watertight sleeve if underground.

2) above ground; or

3) in watertight (zero leakage) open ducts.

j) Distribution of water within a building or structure should preferably make use of above-ground piping mounted on walls, in the roof or in above-floor-level service shafts. Service shafts shall be watertight (zero leakage) at ground floor level, have drainage ports that drain visibly into the stormwater system, and shall be supplied with easy access inspection hatches.

k) Sewers and drains shall comply with the following minimum requirements:

1) within 15m of the footprint of a building, buried pipelines shall not be provided with joints other than specified butt-welded joints; and

2) suitable prefabricated small diameter (< 1,0m) watertight manholes shall be used in place of rodding and cleaning eyes.

l) Stormwater drainage systems shall comply with the following requirements:

NOTE The use of the word "should" in this sub clause indicates best practice to be applied where practical.

1) roadways with a gradient flatter than 1:80 should be surfaced or be sealed.

2) no piped storm water systems should be permitted within 15m of a building or structure, other than those serving the building or structure in question.

3) natural ponds and watercourses located within 10m of any structure and within 30m of a building should either be rendered impervious or diverted so that their location is not within these distances of the structure or building.

4) lined surface canals should be located at least 15m from buildings.

5) open culverts with grated covering material should be used to traverse any trafficked area within 15m of buildings or structures.

6) all stormwater from downpipes and gutters from buildings and structures shall discharge into impervious lined channels which, in turn, should discharge the water at least 15m away from such buildings and structures onto areas that permit free surface drainage.

7) pipelines shall be pressure-tested during construction using the pressure test procedures prescribed in SANS 2001-DP2.

8) manholes shall be tested for water tightness (zero leakage) using the test procedure in SANS 2001-CC1.

9) impervious paved areas or apron slabs shall be provided within 3 m (or greater if deemed appropriate by the competent person (engineer))of structures and buildings, runoff from which shall drain into lined stormwater channels feeding into the a designed stormwater system or shall be spread as sheet flow away from the buildings or structures; and

10) all areas shall be graded to slopes that permit free drainage of water away from structures and buildings.

m) The area immediately below above-ground installed wet engineering services shall be free draining to ensure drainage away from buildings and structures in the event of a burst or leaking pipe.

n) All sleeves or ducts shall be laid to grades that will facilitate drainage away from buildings and structures into designated watertight inspection chambers.

o) Engineered masonry and concrete manholes shall be designed as water-retaining structures and tested for watertightness (zero leakage) using the test procedure in SANS 2001-CC1.

p) Gas pipelines within 15 m of buildings shall be provided with welded joints.

q) Fuel reticulations shall, as far as is practicable, be above ground.

Table 5-1: (Table 6 —Maximum field test pressures (SABS 1936-3:2012))

| 1 | 2 | 3 |
|---|---|---|
| Type of pipe | Applicable materials standard | Maximum field pressure at any point in the pipeline |
| Steel | SANS 62-1, SANS 62-2, SANS 719, SANS 815-1 or SANS 815-2 | 50 % of the hydraulic test pressure |
| Ductile iron | SANS 50545 | Allowable site test pressure (PEA) |
| Reinforced concrete | SANS 676 | 75 % of the hydraulic test pressure |
| Prestressed concrete | SANS 975 | 75 % of the hydraulic test pressure |
| Polyethylene | SANS 4427-2 and SANS 4427-3 | 100 % of the hydrostatic pressure |
| Steel mesh reinforced polyethylene | SANS 370 | 1,6 times the nominal pressure |
| Polypropylene | SANS 15874-2 and SANS 15874-3 | 75 % of the hydrostatic pressure |
| PVC-U | SANS 966-1 | 75 % of the hydrostatic pressure |

| Table 5-1: (Table 6 —Maximum field test pressures (SABS 1936-3:2012)) | | |
|---|---|---|
| 1 | 2 | 3 |
| Type of pipe | Applicable materials standard | Maximum field pressure at any point in the pipeline |
| PVC-M | SANS 966-2 or SANS 1283 | 75 % of the hydrostatic pressure |

# 6. SEWER

## 6.1 Technical Design Parameters and Standards

The services will be designed to accommodate all requirements for developments of this nature. The internal services will be according to accepted engineering specifications and principles as well as acceptable environmental requirements and specifications.

Drawings indicating the proposed preliminary water, sewer, access roads and parking layouts are included in this report. The layout of the water, sewer, roads and storm water infrastructure will be finalised during the preliminary engineering and detail design phases of the project.

The design criteria and specifications as contained in this report are based on the following:

- Guidelines for the Provision of Engineering Services and Amenities in Residential Township Development, 1994 as amended (a.k.a. the "Blue Book").
- Guidelines for Human Settlement Planning and Designs as published by the CSIR and will also refer to the local municipality's guidelines and standards (a.k.a. the "Red Book").
- South African Local Government Association (SALGA) Planning and Design Guidelines Part II (K-Sanitation)

## 6.2 Existing Municipal Sewer Infrastructure

According to the Department of Water and Sanitation (DWS) dry sanitation is commonly used in Joe Morolong Local Municipality due to the vast expanses of the municipality. Therefore, there is no formal bulk sewer infrastructure in the proximity of the proposed development.

Following discussions with Joe Morolong Local Municipality and the idea of developing Churchill as a nodal point, waterborne sanitation will be provided.

## 6.3 Proposed Design Criteria:

A waterborne gravitational sewerage system is recommended to convey sewer effluent from all the areas of the proposed development to common low points. In order to keep excavations as shallow as possible a Pumpstation will have to be built. The Pumpstation will lift the sewage a second gravity network which will further convey the sewage to the proposed oxidation ponds.

Due to the dolomitic classification (D3) of the area it is essential that all requirements of SABS 1936-3:2012 is adhered to. An extract of selected items that needs to be considered as stipulated in SABS 1936-3:2012 is listed below.

- *(4.5.1)* - Sanitation systems on dolomite land other than land designated as D1 shall not incorporate evapo-transpirative beds, soakaways or french drains. Conservancy tanks linked to a low flush system that complies with the requirements of SANS 10400-P may be used where municipal water-borne sewerage connections are not available.
- *(4.5.3)* - Pit toilets shall not be provided on sites designated as D3 dolomite land.

Table 6-1: (Table 1 — Design objectives and performance requirements (SABS 1936-3: 2012))

| 1 | 2 | 3 |
|---|---|---|
| Service | Service Design objective or user requirements | Performance requirements |
| Sewer mains | The sewer mains shall convey sewage from the water-borne sanitation system to the bulk sewer infrastructure in a manner acceptable to the local authority. | The sewer mains shall, with an appropriate degree<br>of reliability and within established parameters,<br>a) withstand all the loads and pressures to which they are likely to be subjected;<br>b) be capable of receiving sewage from the water- borne sanitation system, carrying the design hydraulic load, and discharging into the local authority's bulk sewer infrastructure;<br>c) be watertight;<br>d) prevent rainwater from entering the system; and<br>e) be accessible to clean, monitor and maintain. |

Table 6-2: (Table 5 — Preferred pipe types for use on sites designated as D2 or D3 dolomite land (SABS 1936-3:2012))

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Application | Pipe type and material classification | Minimum pressure rating or ring stiffness | Applicable standards | Pipe joint requirements | Additional requirements and comments |
| Sewers (see 6.2.3.5 SABS 1936-3:2012) | | | | | |
| All diameters | High density polyethylene (HDPE): PE 100 | PN 10 SDR 17 [a, b] | SANS 4427 | Butt-fusion, electro-fusion or hot gas extrusion welds, in accordance with SANS 10268-1. | Pipes shall be supplied in minimum lengths of 12 m. |
| | Polypropylene (PP): PPH 100 | PN 10 SDR 17 [a, b] | SANS 8773 | Butt-fusion, flanges or electro-welded sockets,<br>in accordance with SANS 10268-1 [e.] | Pipes shall be supplied in minimum lengths<br>of 12 m. |
| | Unplasticized poly (vinyl chloride) (PVC-U) | Class 34 [a, b] | SANS 791 | Mechanical devices consisting of sealing rings or grooves (or both) and clamps.<br>Use stainless steel only for metal fittings. | Pipes supplied in 6 m or 9 m lengths. |

[a] The minimum pressure rating shall be as stated or in accordance with design requirements, whichever is higher. The design of the pipe shall make allowance for the design pressure and potential loss of support as required in 6.2.1.1.

[b] On sites designated as D3 dolomite land, the nominal pressure rating shall be one pipe designation or class higher than that which complies with the above requirement (see 6.4(d) SANS 1936-3:2012).

[c] On residential land, the pressure rating shall not be lower than PN 16 as the applicable pipe sizes are prone to damage by gardening activities.

[d] Small diameter HDPE pipes shall preferably be joined by electro-fusion instead of butt-fusion.

[e] Welding of polypropylene pipes can be problematic. Careful inspection and testing shall be undertaken to confirm integrity of welds.

- *(6.2.3)* - Sewers and gravity drainage systems
- *(6.2.3.1)* - All manholes shall be watertight and shall be tested for water tightness (zero leakage) during construction.
- *(6.2.3.2)* - Sewers and gravity drainage systems, inclusive of pipes, sleeves or conduits shall be subjected to hydraulic pipeline testing, after installation, in accordance with SANS 2001-DP2 for the selected pipe type, irrespective of application.
- *(6.2.3.3)* - Connections from multiple adjoining toilets or washbasins shall made above ground and shall feed into a single downpipe draining into the subsurface system.
- *(6.2.3.4)* - Toilet pans shall be provided with an external flexible connection at the junction point to the subsurface sewer system.
- *(6.2.3.5)* - The type, size and pressure rating of the pipe to be used shall be specified by the competent person (geo-professional or engineer). The preferred pipe types and other requirements for subsurface sewers and gravity drainage systems are given in table 5.

| Table 6-3: Sewer Gravitational Network Design Criteria | | |
|---|---|---|
| Parameter | Element | Guideline |
| 1. Design Effluent Generation | Residential (300m²) | 0.480 kℓ/erf/day |
| | Residential (400m²) | 0.560 kℓ/erf/day |
| | Residential (450m²) | 0.60 kℓ/unit/day |
| | Business (FSR=0.4) | 0.52 kℓ/100m²/day |
| | Institutional (Church) (FSR=0.4) | 0.48 kℓ/100m²/day |
| | Educational (Crèche) (FSR=0.4) | 0.39 kℓ/100m²/day |
| | Educational (Primary School) (FSR=0.4) | 0.39 kℓ/100m²/day |
| | Educational (Secondary School) (FSR=0.4) | 0.39 kℓ/100m²/day |
| | Open Space (Sports field) | n.a |
| | Institutional (Community Facility) (FSR=0.4) | 0.48 kℓ/100m²/day |
| | Open Space (Parks) | n.a |
| 2. Sewer gradients | Maximum (all diameters) | 1:60 |
| | Minimum 110mm Ø | 1:120 |
| | Minimum 160mm Ø | 1:200 |
| 3. Flow Velocity | Minimum (all diameters) | 0.7 m/s |

| Table 6-3: Sewer Gravitational Network Design Criteria | | |
|---|---|---|
| Parameter | Element | Guideline |
| | Maximum (all diameters) | 1.2 m/s |
| 4. Dry weather Peak Factor (PF) | Design Peak | 1.8 |
| 5. Wet weather Peak | Design Peak | 15% additional to Dry Weather Peak Flow |
| 6. Pipe Location | All Areas | Road reserve – 1.5 m from roads edge |
| 7. Pipe Materials | All pipe diameters | uPVC Class 34 |
| 8. Pipe Size | Minimum diameter | 160mm Ø |
| 9. Cover to Pipes | Minimum: Road reserves<br>Other Areas | 1,000 mm<br>800 mm |

The proposed gravitational system will consist of a network ranging from 160 mm Ø to 250mmØ HDPe PE100 PN10 pipes designed and installed in accordance to the standards and specifications as outlined by *Guidelines for Human Settlement Planning and Designs*.

The proposed network will be positioned in such a way as to maintain, as far as possible, the most efficient and cost-effective network for the conveyance of sewer effluent.

Precast concrete manhole chambers will be installed throughout the proposed network in the following positions:

- Intersections of two or more sewer mains.
- Change in flow direction of sewer mains.
- Change in longitudinal gradient of sewer mains
- On sections of sewer main not exceeding 80m apart

All precast concrete manhole chambers will be installed according to specifications regarding material and construction as outlined by SANS 1200 LD: Sewers Section 3.5 and 5.6 respectively.

## 6.4 Development's Total Effluent Generation

For the purpose of bulk services planning it was necessary to divide the entire development into 2 separate contributing areas.

Figure 8 shows the sewer contributing areas. Area 1 drains towards the proposed sewer lifting station. Area 2 will gravitate towards the proposed outfall. The Peak Design Flow will be based on figures and peak factors as obtained from *Guidelines for Human Settlement Planning and Designs.*

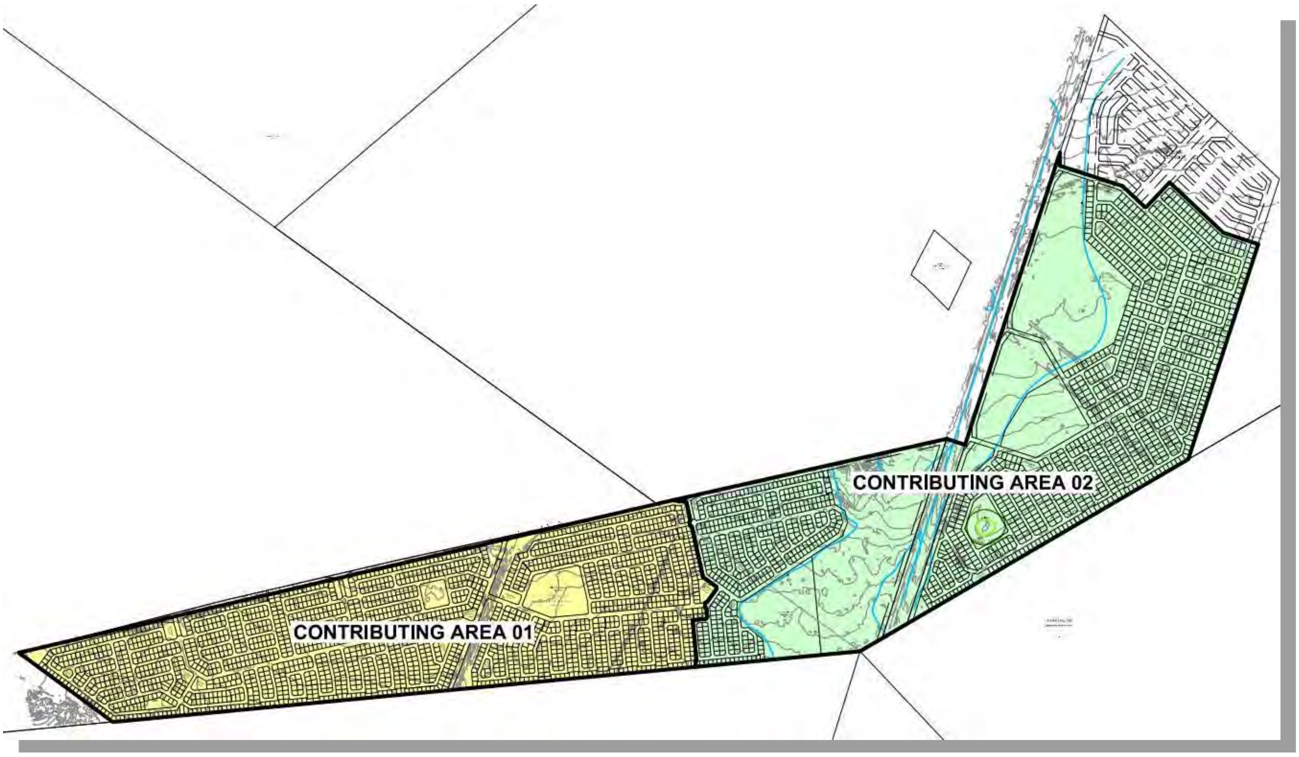


Figure 8: Contributing Areas

<u>Effluent Generation Tables</u>

| Table 6-4: Average Dry Weather Flow (Contributing Area 1) | | | | |
|---|---|---|---|---|
| Description | Capacity | Area (ha) | Unit factor (no of units) | $m^3/day$ |
| Residential (300m²) | 0.480 kℓ/erf/day | - | 483 | 231.84 |
| Residential (400m²) | 0.560 kℓ/erf/day | - | 500 | 280 |
| Residential (450m²) | 0.60 kℓ/unit/day | - | 500 | 300 |
| Business (FSR=0.4) | 0.52 kℓ/100m²/day | 0.7459 | Sum (3) | 38.79 |
| Institutional (Church) (FSR=0.4) | 0.48 kℓ/100m²/day | 0.2702 | Sum (2) | 12.97 |
| Educational (Crèche) (FSR=0.4) | 0.39 kℓ/100m²/day | 0.4086 | Sum (3) | 15.94 |
| Educational (Primary School) (FSR=0.4) | 0.39 kℓ/100m²/day | 0 | 0 | 0 |
| Educational (Secondary School) (FSR=0.4) | 0.39 kℓ/100m²/day | 5.1516 | 1 | 200.92 |
| Open Space (Sports field) | n.a | 6.8769 | 0 | 0 |

| Table 6-4: Average Dry Weather Flow (Contributing Area 1) | | | | |
|---|---|---|---|---|
| Description | Capacity | Area (ha) | Unit factor (no of units) | $m^3$/day |
| Institutional (Community Facility) (FSR=0.4) | 0.48 kℓ/100m²/day | 0 | 0 | 0 |
| Open Space (Parks) | n.a | 49.4856 | 0 | 0 |
| TOTAL | | | | 1080.46 |

| Table 6-5: Average Dry Weather Flow (Contributing Area 2) | | | | |
|---|---|---|---|---|
| Description | Capacity | Area (ha) | Unit factor (no of units) | $m^3$/day |
| Residential (300m²) | 0.480 kℓ/erf/day | - | 2017 | 968.16 |
| Residential (400m²) | 0.560 kℓ/erf/day | - | 0 | 0 |
| Residential (450m²) | 0.60 kℓ/unit/day | - | 0 | 0 |
| Business (FSR=0.4) | 0.52 kℓ/100m²/day | 0.5127 | Sum (2) | 26.66 |
| Institutional (Church) (FSR=0.4) | 0.48 kℓ/100m²/day | 0.3905 | Sum (3) | 15.23 |
| Educational (Crèche) (FSR=0.4) | 0.39 kℓ/100m²/day | 0.2657 | Sum (2) | 10.36 |
| Educational (Primary School) (FSR=0.4) | 0.39 kℓ/100m²/day | 3.1746 | 1 | 123.81 |
| Educational (Secondary School) (FSR=0.4) | 0.39 kℓ/100m²/day | 0 | 0 | 0 |
| Open Space (Sports field) | n.a | 0 | 0 | 0 |
| Institutional (Community Facility) (FSR=0.4) | 0.48 kℓ/100m²/day | 0.5481 | Sum (2) | 26.31 |
| Open Space (Parks) | n.a | 8.5516 | 0 | 0 |
| TOTAL | | | | 1170.53 |

### **6.4.1** Average Dry Weather Flow (ADWF):

The total Average Dry Weather Flow (ADWF) for the 2 Contributing areas as depicted in the tables above amount to 2250.99$m^3$/day.

**6.4.2** Peak Dry Weather Flow (PDWF):

The residential erven served is 3500. With reference to Figure 6 below and based on a population of 17 500 (5 persons per erf) the peak factor will be 1.8.

The total peak dry weather flow for the proposed development is as follows:

- PWWF = (ADWF) 2250.99 x 1.8 = 4009.5 $m^3$/day.

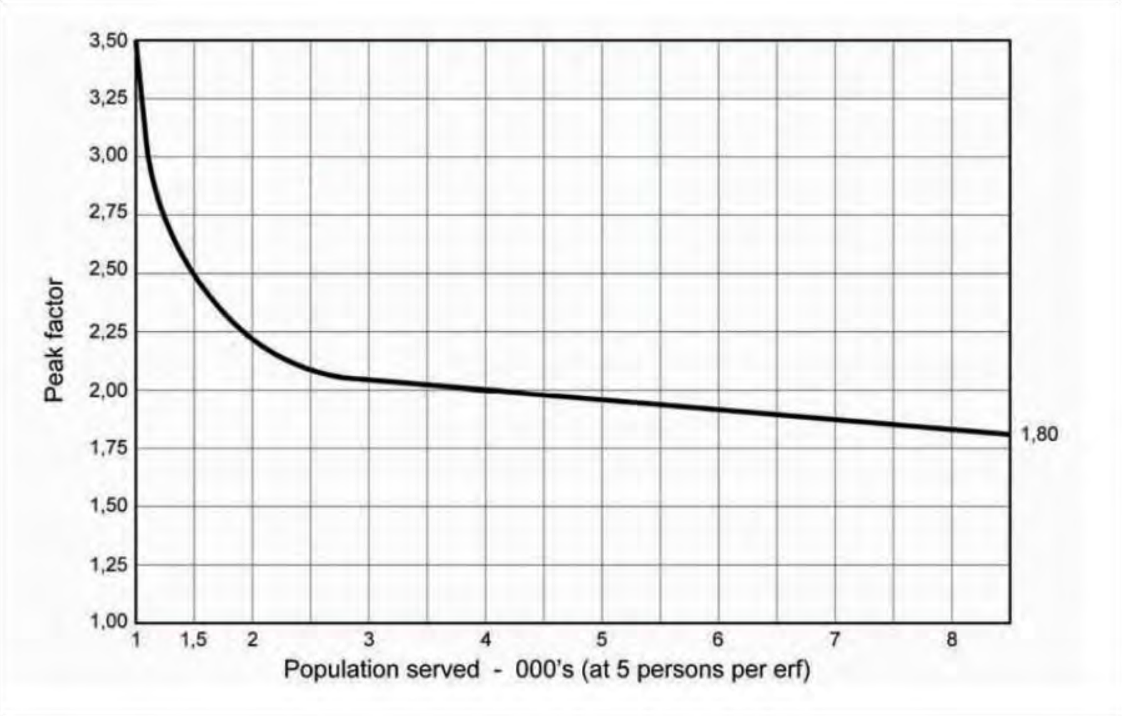


Figure 9 Peak Factors

**6.4.3** Peak Wet Weather Flow (PWWF):

Considering storm water infiltration rate of 15% the peak wet weather flow amounts to the following:

- (PDWF) 4009.5 x 1.15 = 4610.925 $m^3$/day ≈ 53.367 **ℓ/s**

**6.4.4** Instantaneous Peak Pumping:

A pumping factor of 25% has been added for the pump delivery rate, compounded as follows:

- 53.367 x 1.25 = 66.71**ℓ/s** ≈ 67**ℓ/s**

6.5 Proposed Bulk Sewer Infrastructure:

The proposed bulk infrastructure will consist of the following components, namely:

- Bulk Sewer Lines

- Bulk Electrical Connection
- Bulk Sewer Pump station
- Construction of a new proposed oxidation pond system.

## 6.6 Wastewater Treatment Works

The proposed system shall consist of two anaerobic ponds followed by five aerobic ponds. The effect of the anaerobic ponds is to reduce significantly the load to the primary pond.

In order to size the proposed Anaerobic-Aerobic pond system one needs to consider it two parts, namely:

- The Anaerobic ponds.

and

- The Aerobic ponds.

These two components will be evaluated separately, with a final judgement as to the total maximum capacity for the WTW as a hole to be set at the lowest resultant capacity.

The following also needs to be taken in account when constructing the Anaerobic-Aerobic Pond system

- Freeboard of at least 0.5m in order to accommodate 1:50 year flood.
- Side slopes of ponds to be at least 1:3
- Pond Liners to conform to a Category B landfill site
- Stormwater to not infiltrate the system via piping.
- Provision of 0.1m$^2$ of drying bed space per contributing person

### 6.6.1 Anaerobic Ponds

There are a number of minimum standards that govern the design capacities of an anaerobic pond, such as loading rates; retention times; and depth of ponds. These standards are as follows:

- Loading Rates:
  - 8 persons/m$^3$/day
  - or, 0.4 kg BOD/m$^3$/day
  - or, 0.85 kg COD/m$^3$/day
- Retention Time:
  - No Less than 12 hours of PDWF

- Depth:
  - o Minimum = 3m, maximum = 4m

Furthermore, the applicable typical characteristics of domestic sewage are defined as follows:

- Biological Oxygen Demand (BOD) = 350 to 400mg/ℓ
- Chemical Oxygen Demand (COD) = 700 to 850mg/ℓ

Taking the aforementioned criteria into consideration, the maximum capacity of the anaerobic ponds may be determined using the following assumptions:

- Depth of pond = 3 m
- Retention time = 12 hours
- BOD of sewerage = 400mg/ℓ
- COD of sewerage= 800mg/ℓ

For the following:

- Capacity in accordance to loading rates:
  - o Persons/day = 17500 persons @8 persons/$m^3$/day = 2187.5$m^3$/day
  - o BOD:
    - ▪ Total BOD = (2250.99 $m^3$) x (0.4 kg/$m^3$/day) = 900.396kg /day
    - ▪ Thus, assuming sewage strength of 400mg/ℓ

      Anaerobic pond volume = (Total BOD in mg)/400mg/ℓ

      = (900′396′000mg)/400mg/ℓ

      = 2250.99kℓ
  - o COD:
    - ▪ Total COD = (2250.99 $m^3$) x (0.85 kg/$m^3$/day) = 1913.34 kg/day
    - ▪ Thus, assuming sewage strength of 800mg/ℓ

      Anaerobic pond volume = (Total COD in mg)/800mg/ℓ

      = (1913′340′000mg)/800mg/ℓ

      = 2391.67kℓ
- Capacity in accordance to retention time:

  Volume = 12 hours PWWF

= 1.8*2250.99/24*12

= 3608.1kℓ

From the above calculations, the capacity of the Anaerobic ponds should be the greatest value of the before mentioned, thus 3608.1kℓ and must be between 3 and 4 m deep.

### 6.6.2 Aerobic Ponds

There are a number of minimum standards that govern the design capacities of aerobic ponds, such as loading rates; retention times; and depth of ponds. These standards are as follows:

- Loading Rates:
  - or, 135 kg BOD/ha/day
- Retention Time:
  - No Less than 40 days of ADWF
- Depth:
  - Minimum = 1.2 m, maximum = 1.5 m

Taking the aforementioned criteria into consideration, the size of the aerobic ponds may be determined using the following assumptions:

- Depth of pond = 1.2 m
- Retention time = 40 days
- BOD of sewerage = 400mg/ℓ

For the following:

- Capacity in accordance to loading rates:
  - BOD:

    Total Area = (2250.99*0.4)/135 kg/ha/day

    = 6.7ha
- Capacity in accordance to retention time:

  Total Volume of ponds = (2250.99) * 40 days

  = 90 039.6kℓ

From the above, the combined area of all the Aerobic dams exposed to sunlight should be 6.7 ha, the combined volume of the dams should be 90.1mℓ and the depth of the dams should be between 1.2m and 1.5m.

## 6.7 Sewer Cost Estimate:

### 6.7.1 Bulk Sewer Pump station

The proposed Bulk Sewer Pump Station will be designed to accommodate and inflow of 12.5ℓ/s. the Pump Station will be approximately 7.0m deep and be equipped with a dry sump installed sewer pump set complete.

The pumps will be complete with IE3 high efficiency motor, supplied as a unit. The pump should be able to pump 20 ℓ/s @ a head of 50 m. Minimum pump efficiency of 77.3% and minimum pump + motor efficiency of 67.9%.

The Pump station will also be fitted with a vertical pump station screen. The Pumping Stations Screen is connected directly to the sewer pipe by means of a flanged joint. The wastewater enters the screen through the optimized inflow chamber with integrated bottom step. As the water streams through the perforated plate into the pump sump, the screenings are retained. An auger, with a brush attached on its flights, rotates within the screen basket and cleans the screen. As the screenings are elevated by the auger, they are dewatered to a degree of up to 40 %. The compacted screenings are discharged into a container or skip.


Figure 10: Vertical Screen

Pumping Stations Screen units offer outstanding advantages, namely:

- Automatic screening, lifting and compaction in a single compact unit

- Optimal solids retention by means of two-dimensional screening (perforated plate)
- Prevent clogging and stressing in pump stations and manholes
- Integrated bottom step to prevent deposits in the incoming sewer
- Easy to install into existing structures
- Availability of completely submerging the screen.

**6.7.2** Proposed Rising Main:

The rising main will comprise of 160mm HDPe Class PN12 pipe to be constructed from the abovementioned pump station to an new manhole gravitating towards the proposed Wastewater Treatment Works (WTW) approximately 660m east of the proposed pump station.

**6.7.3** Main Outfall Sewer Pipeline

The main sewer outfall pipeline will comprise of 250mm HDPe Class PN12 pipe to be constructed from the abovementioned rising main to the existing Wastewater Treatment Works (WTW) approximately 5 500m north of the proposed development.

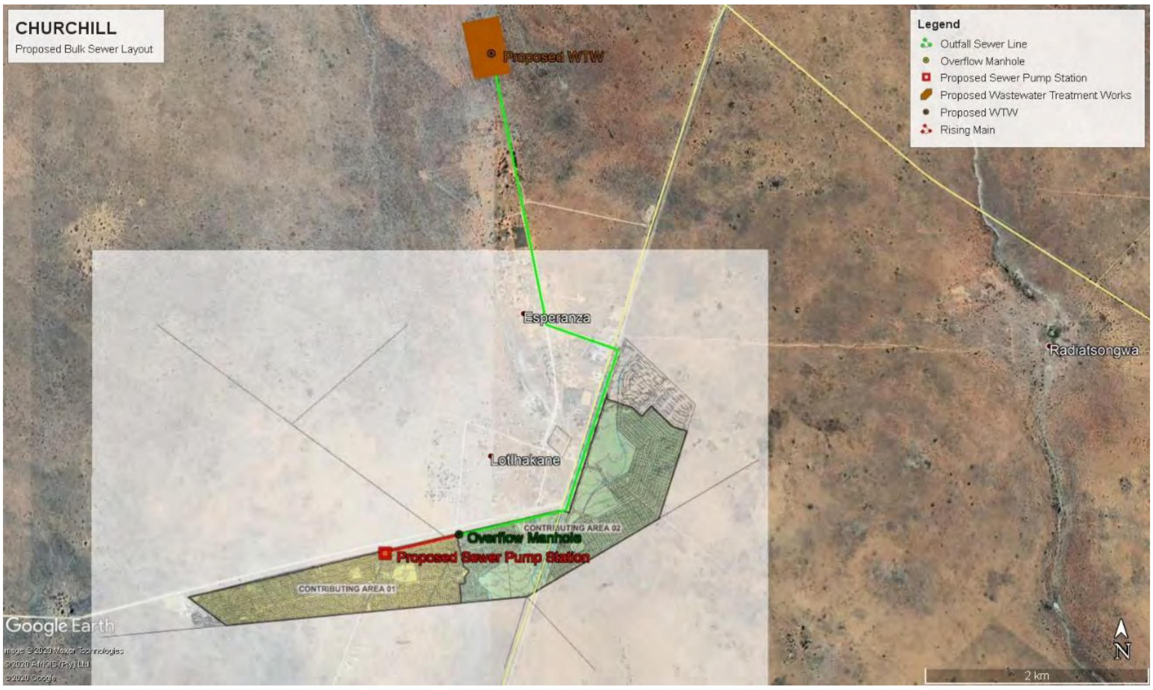


Figure 11: Schematic bulk sewer infrastructure layout

**6.7.4** Wastewater Treatment Works:

Due to the stringent design standards of the Department of Water and Sanitation (DWS) the proposed oxidation ponds will be equivalent to the design of a *"Class B Landfill Site"* as requested by DWS.

The design criteria are as follows:

6.7.4.1 ***Anaerobic Ponds:***

- 100mm 25MPa/19mm Concrete lining with REF 193 Mesh reinforcing.
- In-Situ Material is to be imported G5 material compacted to 98% Mod. AASHTO Density in layers of 150mm.

6.7.4.2 ***Facultative Pond:***

- **1.5mm "Vitaline"** or Similar Approved Flexible HDPe Membrane installed by specialist.
- 1 x Thermal Lock Geosynthetic Clay Liner (GCL), needle punched reinforced composite which combines two durable geotextile outer layers with a uniform core of natural sodium Bentonite clay.
- In-Situ Material is to be imported G5 material compacted to 98% Mod. AASHTO Density in layers of 150mm.

6.7.4.3 ***Maturation Ponds:***

- **1.5mm "Vitaline"** or Similar Approved Flexible HDPe Membrane installed by specialist.
- 1 x Thermal Lock Geosynthetic Clay Liner (GCL), needle punched reinforced composite which combines two durable geotextile outer layers with a uniform core of natural sodium Bentonite clay.
- In-Situ Material is to be imported G5 material compacted to 98% Mod. AASHTO Density in layers of 150mm.

### **6.7.5** Summary of Sewer Costs:

| Table 6-6: Estimated Cost for Bulk Sewer Infrastructure | | |
|---|---|---|
| Item | Description | Amount |
| A | Bulk Sewer Pump Station | R 20,500,000.00 |
| B | 160mmØ Rising Main (660m) | R 1,750,000.00 |
| C | 250mmØ Outfall Sewer Line (5 500m) | R 6,600,000.00 |
| D | Wastewater Treatment Works | |
| 1 | Site Preparation | R 1,967,280.00 |
| 2 | Anaerobic Ponds | R 6,427,244.36 |
| 3 | Facultation and Maturation Ponds | R 25,342,427.37 |
| 4 | Dry Beds | R 4,441,050.00 |
| Sub Total | | R 65,278,001.73 |

| Table 6-6: Estimated Cost for Bulk Sewer Infrastructure | | |
|---|---|---|
| Item | Description | Amount |
| Contingencies (10%) | | R 6,527,800.17 |
| Sub Total | | R 71,805,801.90 |
| Professional Fees | | R 11,750,040.31 |
| Sub Total | | R 83,555,842.21 |
| VAT (15%) | | R 12,533,376.33 |
| Total | | R 96,089,218.55 |

# 7. WATER

## 7.1 TECHNICAL DESIGN PARAMETERS AND STANDARDS

The services will be designed to accommodate all requirements for developments of this nature. The internal services will be according to accepted engineering specifications and principles as well as acceptable environmental requirements and specifications.

Drawings indicating the proposed preliminary water, sewer, access roads and parking layouts are included in this report. The layout of the water, sewer, roads and storm water infrastructure will be finalised during the preliminary engineering and detail design phases of the project.

The design criteria and specifications as contained in this report are based on the following:

- Guidelines for the Provision of Engineering Services and Amenities in Residential Township Development, 1994 as amended (a.k.a. the "Blue Book").
- Guidelines for Human Settlement Planning and Designs as published by the CSIR and will also refer to the local municipality's guidelines and standards (a.k.a. the "Red Book").

Due to the dolomitic classification (D3) of the area it is essential that all requirements of SABS 1936-3:2012 is adhered to. An extract of selected items that needs to be considered as stipulated in SABS 1936-3:2012 is listed below.

*(4.6)* - De-watering and groundwater recharging

*(4.6.1)* - Before abstracting groundwater on dolomite land, the person or entity undertaking such abstraction shall obtain a water use licence from the relevant national authority (see foreword) in accordance with the relevant national legislation (see foreword). The application for such licence shall

clearly state that the ground from which the water is to be abstracted is dolomite land.

*(4.6.2)* - Where abstraction or recharging of ground water could result in changes of more than 6 m in the original groundwater level, the person or entity undertaking such abstraction or recharging shall notify the relevant national authorities (see foreword).

Table 7-1: (Table 1 — Design objectives and performance requirements (SABS 1936-3: 2012))

| 1 | 2 | 3 |
|---|---|---|
| Service | Service Design objective or user requirements | Performance requirements |
| Water Supply | The water supply system shall convey safe drinking water to a point within each stand, be compatible with the sanitation system that is provided, and shall serve the fire-fighting needs of the community in a manner acceptable to the local authority. | The water supply system shall, with an appropriate degree of reliability and within established parameters,<br>a) withstand all the loads and pressures to which it is likely to be subjected.<br>b) be capable of supplying water to stands.<br>c) be watertight; and<br>d) be easy to operate and maintain.<br>e) be designed to allow efficient leakage testing of bulk supply lines at all sections on the supply network, such as at large buildings or building complexes and groups of residential properties |

| Table 7-2: (Table 5 — Preferred pipe types for use on sites designated as D2 or D3 dolomite land (SABS 1936-3:2012)) | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| Application | Pipe type and material classification | Minimum pressure rating or ring stiffness | Applicable standards | Pipe joint requirements | Additional requirements and comments |
| Water Supply (see 6.2.2.10 SABS 1936-3:2012) | | | | | |
| Bulk supply:<br>OD > 300 mm | Steel pipes | In accordance with design requirements | SANS 719 or SANS 1835 | Continuous butt, sleeve or socket welds.<br>Mechanical jointing devices (including flanges) shall be used only in manholes.<br>Screwed joints shall not be used. | Pipes shall be protected against corrosion by means of galvanizing or coatings and, where required, by cathodic protection. |
| | High density polyethylene (HDPE): PE 100 | PN 8 [a, b] | SANS 4427 | Butt welded, in accordance with SANS 10268-1.<br>Mechanical jointing devices (including flanges) shall be used only in manholes. | Number of joints shall be kept to a minimum |
| OD 75 mm to 300 mm | High density polyethylene (HDPE): PE 100 | PN 12.5 [a, b] | SANS 4427 | Butt welded, in accordance with SANS 10268-1.<br>Mechanical jointing devices (including flanges) shall be used only in manholes. | Number of joints shall be kept to a minimum<br>75 mm and 90 mm diameter pipes should preferably be supplied in 100 m rolls. 110 mm diameter pipes should be supplied in 50 m rolls. |
| | Modified poly(vinyl chloride) (PVC-M) | Class 12 [a, b] | SANS 966-2 | Mechanical devices consisting of sealing rings or grooves (or both) and clamps.<br>Use stainless steel only for metal fittings. | Pipes supplied in 6 m or 9 m lengths. |

| Table 7-2: (Table 5 — Preferred pipe types for use on sites designated as D2 or D3 dolomite land (SABS 1936-3:2012)) | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| Application | Pipe type and material classification | Minimum pressure rating or ring stiffness | Applicable standards | Pipe joint requirements | Additional requirements and comments |
| Water Supply (see 6.2.2.10 SABS 1936-3:2012) | | | | | |
| | Modified poly(vinyl chloride) (PVC-M) | Class 16 [a, b] | SANS 1283 | Pressed on SG iron victaulic shoulders. | Pipes supplied in 6 m or 9 m lengths. |
| OD < 75 mm | High density polyethylene (HDPE): PE 100 | PN 12.5 [a, b] | SANS 4427 | Electro-fusion or butt-fusion [d]<br>Mechanical jointing devices (including flanges and compression fittings) shall be used only in manholes. | Number of joints shall be kept to a minimum.<br>Pipes supplied in 100 m rolls |
| [a] The minimum pressure rating shall be as stated or in accordance with design requirements, whichever is higher. The design of the pipe shall make allowance for the design pressure and potential loss of support as required in 6.2.1.1.<br>[b] On sites designated as D3 dolomite land, the nominal pressure rating shall be one pipe designation or class higher than that which complies with the above requirement (see 6.4(d) SANS 1936-3:2012).<br>[c] On residential land, the pressure rating shall not be lower than PN 16 as the applicable pipe sizes are prone to damage by gardening activities.<br>[d] Small diameter HDPE pipes shall preferably be joined by electro-fusion instead of butt-fusion.<br>[e] Welding of polypropylene pipes can be problematic. Careful inspection and testing shall be undertaken to confirm integrity of welds. | | | | | |

## 7.2 Existing Water Infrastructure

### 7.2.1 Water Sources

#### 7.2.1.1 *Borehole Abstraction:*

Churchill is supplied with ground water abstracted from 4 boreholes situated in the vicinity of the proposed development. Refer to Figure 12: Borehole Details and Table 7-3: Borehole Results DWS below for more information on the boreholes currently being used for domestic water supply.


Figure 12: Borehole Details

| Table 7-3: Borehole Results DWS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Town/Place | Population (HH * 6) | Number | Alt. Number | Aquabase | Longitude | Lattitude | Acc | Bh Depth | SWL | Pump Depth_m | Yield l/s | Duty hrs/day | Abstraction kl/day |
| Churchill | | 13-86072 | Clinic | 2723ADE0006 | 23.47804 | -27.2789 | 1 | 86 | 4.6 | 64 | 3 | 12 | 130 |
| Churchill | | 13-87619 | | 2723ADV0142 | 23.47279 | -27.2861 | 1 | 84.3 | 8.1 | 58 | 1.2 | 12 | 52 |
| Churchill | | 13-87620 | | 2723ADV0143 | 23.47231 | -27.2862 | 1 | 84.3 | 9.8 | 64 | 0.5 | 12 | 22 |
| Churchill Office | | 13-87436 | Office | 2723ADV0011 | 23.48233 | -27.2722 | 1 | 80 | 3.8 | 54 | 1.5 | 12 | 65 |
| Total | 1020 | | | | | | | | | | 6.2 | | 269 |

## 7.3 Water Supply Design Criteria:

The overall objective is to supply reliable potable water to all areas and communities in the municipal area with formal and metered house connections. Table 7-4 below depicts the Water Supply Design Criteria which will be the basis of Bulk Services Report.

Table 7-4: Water Supply Design Criteria

| Parameter | Element | Guideline |
|---|---|---|
| Design Consumptions | Residential (300m²) | 600 ℓ/erf/day |
| | Residential (400m²) | 700 ℓ/erf/day |
| | Residential (450m²) | 750 ℓ/ erf/day |
| | Business (FSR=0.4) | 0.65 kℓ/100m²/day |
| | Institutional (Church) (FSR=0.4) | 0.60 kℓ/100m²/day |
| | Educational (Crèche) (FSR=0.4) | 0.60 kℓ/100m²/day |
| | Educational (Primary School) (FSR=0.4) | 0.60 kℓ/100m²/day |
| | Educational (Secondary School) (FSR=0.4) | 0.60 kℓ/100m²/day |
| | Open Space (Sports field) | 12 kℓ/ha/day |
| | Institutional (Community Facility) (FSR=0.4) | 0.60 kℓ/100m²/day |
| | Open Space (Parks) | 12 kℓ/ha/day |
| Pressure | Maximum (Static) | 9.0 bar |
| | Minimum Reticulation Mains | 1.0 bar |
| | Minimum Trunk Mains | 2.5 bar |
| Flow Velocity | Ø ≤ 150mm<br>Ø ≥ 200mm | 1.0m/s – 3.5m/s<br>1.5m/s – 2.5m/s |
| Fire Flow | Flow: Low Risk-Group 2/3 | 15 ℓ/s/hydrant @ 7m Residual Head |
| | Design Fire Flow | 900-350 ℓ/min |
| | Maximum number of hydrants discharging simultaneously | 1 |
| | Duration of design fire flow (h) | 2 |
| Peak Factor | Summer Peak | 1.5 x AADD |

| Table 7-4: Water Supply Design Criteria | | |
|---|---|---|
| **Parameter** | **Element** | **Guideline** |
| | Daily Peak<br><br>Instantaneous Peak | 2.4 x AADD<br><br>3.6 x AADD |
| Pipe Location | Pipe Location | Pipe Location |
| Pipe Materials | 63mm ø and smaller<br><br>75mm ø to 315mm ø | HDPE PE100 PN10<br><br>HDPE PE100 PN10 |
| Pipe Size | Network pipes | 75mm min HDPE PE 100 PN10 |
| Cover to Pipes | Water connections<br><br>Minimum: Roads<br><br>Other Areas<br><br>Maximum: All Areas | Min 25mm/unit.<br><br>1m<br><br>1m<br><br>1,5m |
| Valves | Type | RS valves up to 350mm ø |

### **7.3.1** Peak Factors

The peak factors utilised are based on domestic supply for developing area with an unrestricted flow system. The Summer, Daily and Instantaneous Peak Factors are listed in Table 7-4

### **7.3.2** Fire Suppression

| Table 7-5: Design fire flow | | |
|---|---|---|
| FIRE-RISK CATEGORY | MINIMUM DESIGN FIRE FLOW(l/min) | MAXIMUM NUMBER OF HYDRANTS DISCHARGING SIMULTANEOUSLY |
| High-risk | 12000 | All hydrants within a radius of 270 m of the fire |
| Moderate-risk | 6000 | |
| Low-risk – Group 1 | 900 | 1 |
| Low-risk – Group 2 | 500 | 1 |
| Low-risk – Group 3 | 350 | |
| Low-risk – Group 4 | N/A | N/A |

#### 7.3.2.1 *Fire Risk Category*

Note: Low risk

This development is considered a low-risk group 1 to 3 as the development is primarily a residential area and the gross floor area of the dwelling houses will be 55m² and above. To be conservative Group 1's criteria will be used.

| Table 7-6: Duration of fire flow | |
|---|---|
| FIRE-RISK CATEGORY | DURATION OF DESIGN FIRE FLOW(h) |
| High-risk | 6 |
| Moderate-risk | 4 |
| Low-risk – Group 1 | 2 |
| Low-risk – Group 2 | 1 |
| Low-risk – Group 3 | 1 |
| Low-risk – Group 4 | N/A |

#### 7.3.2.2 *Trenching and Pipelines*

Trenching is to be done in accordance with SABS 1200. In addition to this all topsoil along the route will be removed to 150 mm deep – maintained and replaced as the final compacted layer. Regular compaction tests to be done to ensure adequate soil compaction in pipeline trenches. In trenches of slopes over 25% grades — bio textiles and reseeding can be used to rehabilitate and protect the compacted topsoil.

### 7.3.3 Development's Total Water Demand

The Sustained Peak Demand will be based on figures and peak factors as obtained from *Guidelines for Human Settlement Planning and Designs.*

The total annual average daily demand (AADD) for the proposed development is **3,698.36kℓ/day**.

The total peak summer demand is **5,547.54kℓ/day**

The total daily peak demand is **8,876.06kℓ/day**

The total instantaneous peak is **13,314.096kℓ/**day

| Table 7-7: Water Demand Table | | | | |
|---|---|---|---|---|
| Description | Unit factor(no of units) | Area in Hectares | Capacity | $m^3$/day |
| Residential (300m²) | 2500 | - | 600 ℓ/erf/day | 1500 |
| Residential (400m²) | 500 | - | 700 ℓ/erf/day | 350 |
| Residential (450m²) | 500 | - | 750 ℓ/ erf/day | 375 |
| Business (FSR=0.4) | Sum (5) | 1.2586 | 0.65 kℓ/100m²/day | 81.81 |
| Institutional (Church) (FSR=0.4) | Sum (5) | 0.6607 | 0.60 kℓ/100m²/day | 39.64 |
| Educational (Crèche) (FSR=0.4) | Sum (5) | 0.6743 | 0.60 kℓ/100m²/day | 40.46 |
| Educational (Primary School) (FSR=0.4) | 1 | 3.1746 | 0.60 kℓ/100m²/day | 190.48 |
| Educational (Secondary School) (FSR=0.4) | 1 | 5.1516 | 0.60 kℓ/100m²/day | 309.10 |
| Open Space (Sports field) | 1 | 6.8769 | 12 kℓ/ha/day | 82.53 |
| Institutional (Community Facility) (FSR=0.4) | Sum (2) | 0.5481 | 0.60 kℓ/100m²/day | 32.89 |
| Open Space (Parks) | Sum (12) | 58.0372 | 12 kℓ/ha/day | 696.45 |
| | | | TOTAL | 3698.36 |

### **7.3.4** Reservoir Storage:

The sizing of the reservoir is calculated with the peak factors illustrated in the design criteria depicted in table 9 and are compounded as follows:

| Table 7-8: Reservoir Storage | | |
|---|---|---|
| Description | Amount (kℓ/day) | Accumulative Amount (kℓ/day) |
| Average Annual Daily Demand | 3 698.36 | 3 698.36 |
| Fire water | 108.00 | 2806.36 |

- Storage for 48 hours 2 x 3 698.36 = 7 612.72kℓ
- Reservoir storage required amounts = 7.7**Mℓ**

### **7.3.5** Elevated Storage:

The sizing of the elevated storage is calculated with the peak factors illustrated in the design criteria depicted in table 9 and are compounded as follows:

| Table 7-9: Elevated Storage | | |
|---|---|---|
| Description | Amount (kℓ/day) | Accumulative Amount (kℓ/day) |
| Average Annual Daily Demand | 3 698.36 | 3 698.36 |
| Anticipated Water Loss 10% | 369.84 | 4 068.2 |

- The total instantaneous peak is = **13,314.096 kℓ/day**
- Peak flow = 154.09 ℓ/s
- Elevated storage (Peak Flow x 4 hrs) = 2219.01 kℓ

  (Without backup Power)
- Elevated storage (Peak Flow x 2 hrs) = 1109.508 kℓ

  (With backup Power)

### **7.3.6** Bulk Supply: Potable Water

As mentioned in 7.2.1.1, the only bulk water supply to the area is by means of 4 boreholes. These boreholes are currently being used to provide water to the existing inhabitants of Churchill. From Table 7-3: Borehole Results DWS the permissible abstraction rate (269kℓ/day) is less than the required summer peak demand of **5,547.54kℓ/day**. Bearing in mind that the existing boreholes are used to provide domestic water to the current residents, the supply of the 4 boreholes will not suffice to accommodate the required supply of the proposed development.

It is proposed that in depth specialised study is done to explore the option of using more boreholes in the area to supply the development with the required amount of domestic water. The water quality is therefore unknown which makes the possibility of the construction of some form of water treatment infrastructure a reality. Further studies regarding this is also proposed.

However, in accordance with the attached dolomitic study, the dewatering of dolomitic area poses a risk for the formation of sink holes and as stated the water rest level has subsides from 3m in 2012 to mare than 10m in 2017.

Taking into consideration that the yield of the existing boreholes are minimal and acquiring additional water sources could pose a challenge, the alternative would be to provide a bulk water pipeline from Kuruman which could serve as a water source to other villages in the vicinity.

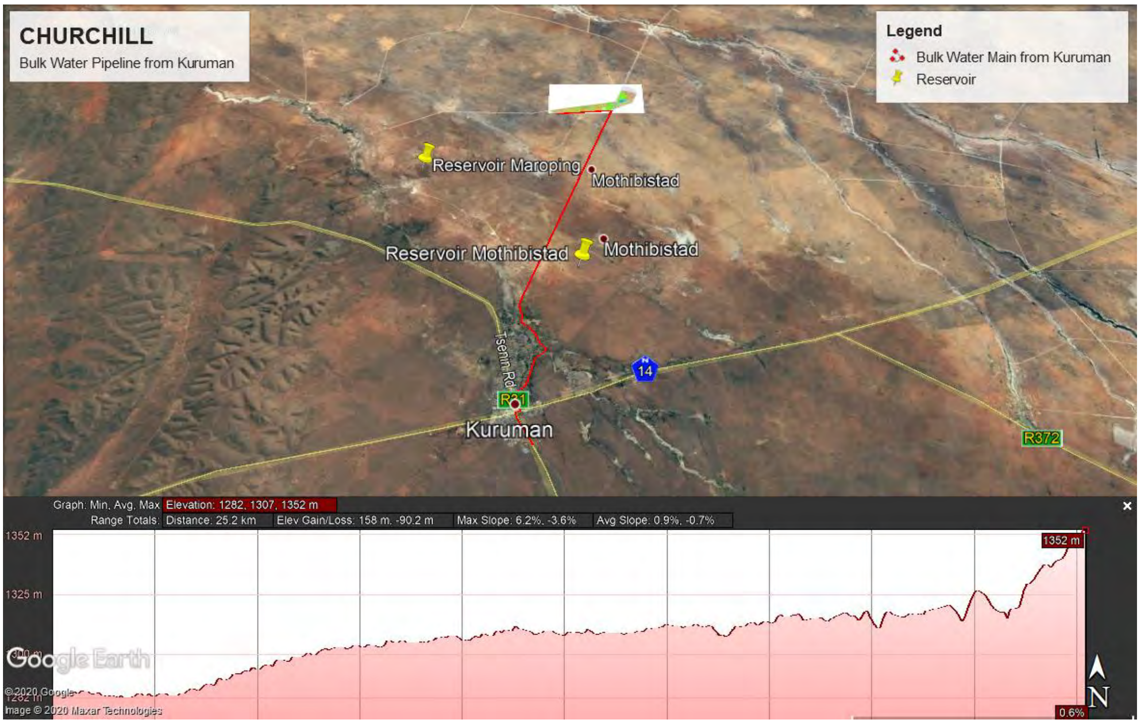


Figure 13: Bulk Water Pipeline

The proposed trunk main to serve the proposed Churchill development shall be installed from Kuruman to the proposed 7.7kℓ Reservoir approximately 25kms away. The new bulk main will be sized to provide the required demand of **5,547.54kℓ/day**.

- From the above, considering Q = V x A at maximum velocity(V) = 1.2 m/s
  - A = Q / v
  - ((Π/4) x Ø2) m2 = (0.0642m³/s)/(1.2 m/s)
  - 0.785 Ø2 = 0.0535 m

- o $Ø = \sqrt{(0.0535 \text{ m} / 0.785)}$
- o $Ø = 0.261\text{m}$

Therefore, the required internal pipe diameter is minimum 261mmØ, however, considering the elevation difference between Kuruman and the proposed site a Class PN20 should suffice. The standard pipe diameters for HDPe pipes, the most suitable diameter will be a 355 mm Ø pipe an internal diameter of 273mm.

Due to the high friction loses over a distance of 25kms, it is recommended that the proposed bulk main to the proposed development shall be a 450mmØ HDPe Class PN20 main with an internal diameter of 0.346m.

7.3.6.1 ***Proposed Storage and Distribution for 3500 Erven:***

With reference to the calculations in Section 7.3 of this report the following infrastructure is required, namely:

- 450mmØ HDPe Class PN20 Bulk Water Supply to produce **5,547.54kℓ/day**

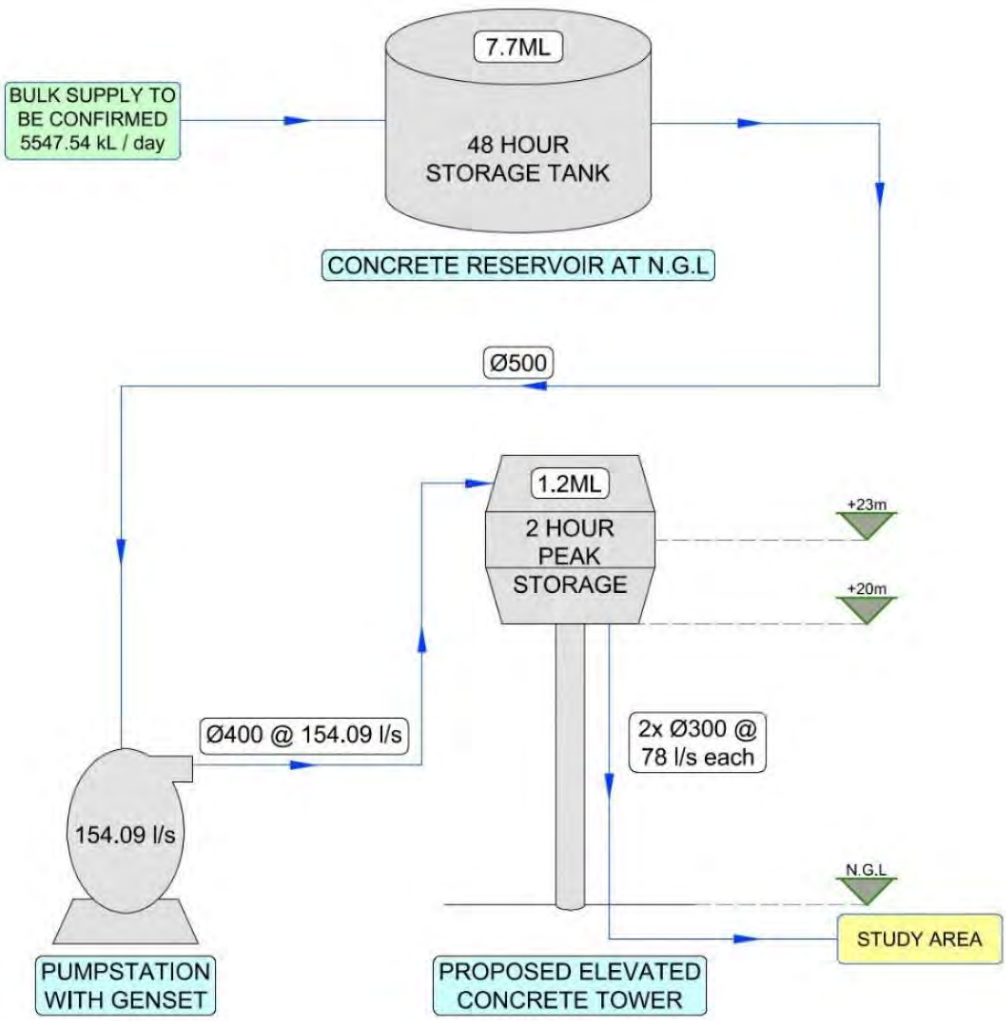


Figure 14: Schematic Layout of Bulk Water Infrastructure

- **7.7Mℓ** Concrete Reservoir (48 Hour Storage Capacity).
- **1.2Mℓ** Elevated Storage Tank (2 Hours Peak Storage Capacity), Height approximately 20m.
- Pump Station with duty and standby pumps with backup generator to produce **154.09ℓ/s** (Peak Flow). Height approximately 20m.
- Electrical Supply to the proposed Reservoir.

It is important to note that alternative water sources need to be investigated as the existing boreholes in the vicinity as depicted in Figure 10 and Table 7-3 are hopelessly insufficient.

## 7.4 Water Cost Estimate:

Table 7-10: Estimated Cost for Bulk Water Infrastructure

| Item | Description | Amount |
|---|---|---|
| A | 450mm Ø Bulk Supply Line from Kuruman (25.2kms) | R 49,118,645.00 |
| B | 7.7Mℓ Concrete Reservoir | R 17,750,000.00 |
| C | 1.2Mℓ Elevated Concrete Tower | R 15,750,000.00 |
| D | Booster pump station with Genset (154.09ℓ/s) | R 2,500,000.00 |
| E | Electrical Supply to Reservoir | Included in Electrical Report |
| Sub Total | | R 85,118,645.00 |
| Contingencies (10%) | | R 8,511,864.50 |
| Sub Total | | R 93,630,509.50 |
| Professional Fees | | R 15,321,356.10 |
| Sub Total | | R 108,951,865.60 |
| VAT (15%) | | R 16,342,779.84 |
| Total | | R 125,294,645.44 |

# 8. STORM WATER

## 8.1 Storm Water Management

The traditional design of storm water drainage systems has been to collect and convey storm water runoff as rapidly as possible to a suitable location where it can be discharged. We are also more conscious of the quality of the environment and the impact that uncontrolled increases in runoff can have on landowners.

The objective of a storm water management plan should be to manage the storm water resources of the collective watersheds to:

- Prevent flood damage.
- Preserve the natural and beneficial functions of the natural drainage system.
- Preserve and enhance storm water quality.

The collection and concentration of storm water will be kept to an absolute minimum so as not to impact negatively on any natural watercourse. The natural fall of the site is in a North-Eastern direction. The stormwater on the Western side of the road, passing through the proposed development, will be collected and conveyed via a lined channel towards the natural watercourses to the Northern side of the proposed development. The balance of the stormwater will also be conveyed via lined channel to the Northern side of the proposed development and into the natural watercourses.

## 8.2 Existing Storm Water Services

No formal storm water infrastructure exists in the study area. A natural storm water retention pond is located on the Eastern side of the main road crossing the site.

## 8.3 Proposed Storm Water Infrastructure

As stated above the natural flow of storm water is in a North Easterly direction within area earmarked for a park.

The majority of the proposed development drains towards the North and the East However, a section of the proposed development channels water directly to the North where informal housing is situated, see Figure 15.

We therefore propose a formal storm water channel be constructed to facilitate storm water drainage to the natural watercourses to the Northern side of the proposed development.

Provision has been made for a lined Trapezium Channel with a 3-meter-wide base and a 5-meter-wide opening on natural ground level with a depth of 550mm (including a 100mm freeboard). The Channel is approximately 2.6km long.

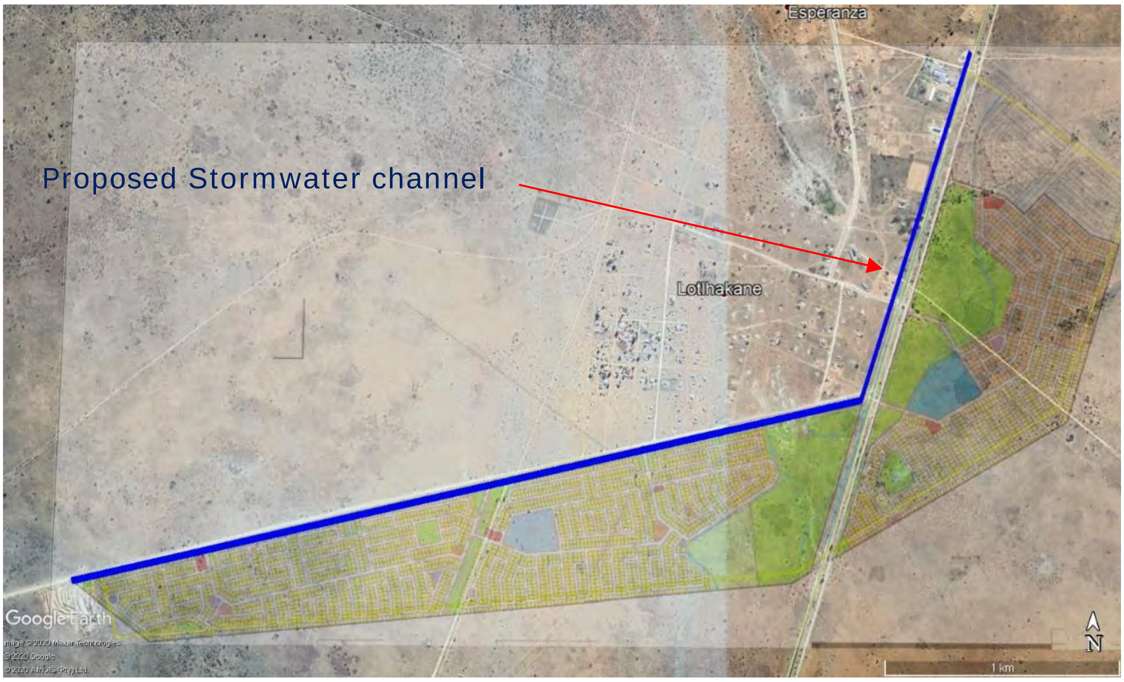


Figure 15: Proposed Storm Water Channel

## 8.4 Storm Water Design Criteria

All storm water on the roads will gravitate and flow via drifts towards the lined channel and daylight into open veld

Due to the dolomitic classification (D3) of the area it is essential that all requirements of SABS 1936-3:2012 is adhered to. An extract of selected items that needs to be considered as stipulated in SABS 1936-3:2012 is listed below.

*(4.4)* - Stormwater drainage

*(4.4.1)* - Stormwater drainage systems shall discharge into a natural watercourse unless the land upon which it is discharged is

a) not dolomite land; or

b) dolomite land categorized as dolomite area designation D1 in accordance with SANS 1936-1.

6.2.4 - Storm water drainage

6.2.4.1 - Channels and canals which are constructed to reroute water from natural drainage paths shall be lined. Any joints in such channels shall be suitably sealed to be watertight.

6.2.4.2 - Unlined storm water cut-off or diversion trenches shall be avoided as far as possible.

6.2.4.3 - All concentrated storm water entering any parcel of land shall be diverted away from any building and structures by means of concrete-lined channels. Where necessary, earth berms and contouring shall be used to enhance site drainage.

6.2.4.4 - Storm water drainage systems shall incorporate measures to ensure watertightness (zero leakage) of conveyance systems, culverts and other compartments, including the sealing of all joints, and shall be designed to minimize the effects of settlement. All manholes, junction boxes and conveyance systems shall be tested for watertightness during construction. Reinforced concrete manholes shall be designed as liquid-retaining structures.

6.2.4.5 - Storm water drainage conveyance systems shall be designed to gradients which are self-cleansing. Such systems shall have an internal diameter equal to or greater than 300 mm.

6.2.4.6 - For drainage purposes, surfaced roadways and parking areas should be constructed at a level below the surrounding buildings, developed or landscaped areas and gardens.

6.2.4.7 - All storm water from downpipes and gutters from buildings and structures shall discharge onto concrete-lined channels which, in turn, shall discharge the water at least 1,5 m away from structures onto areas permitting surface drainage away from buildings and structures. Joints between any open channel drains and buildings shall be suitably sealed.

6.2.4.8 - Small diameter storm water drainage pipes shall not be placed parallel to buildings unless they are at least 5 m (if stand size allows) from the structure. If this is not practical. a rational design shall be performed by a competent person (engineer).

6.2.4.9 - Buildings and structures without gutters shall be provided with impervious paving not less than 1,5 m wide with a minimum slope of 1:20 all around. Joints between such paving and the building or structure, as well as any joints to control shrinkage/expansion, shall be suitably sealed. The ground surface shall be shaped to fall away from the building at a minimum slope of 1:20 for a further 1 m from the edge of the slab and shall thereafter fall continuously towards the closest drainage point.

6.2.4.10 - Water shall not be permitted to accumulate against boundary walls. Suitable drainage ports shall be incorporated in boundary walls, particularly at the lowest point of the site, to permit the passage of surface runoff water. Such ports shall be provided (on both the inlet and outlet sides of the wall or fence) with a concrete slab 1,0 m wide, 100 mm thick, and extending 400 mm beyond the edges of the drainage port along the fence. The concrete slab shall have a minimum fall of 1:15 to ensure self-cleaning drainage characteristics. Any security outlet grids that are provided shall not impede the flow of water through the port.

6.2.4.11 - The type, size and pressure rating of the pipe to be used shall be specified by the competent person (engineer). The preferred pipe types and other requirements for subsurface stormwater drainage systems are given in table 5.

### 8.4.1 Cost Estimate

The estimated cost of the proposed bulk storm water infrastructure is depicted in Table 8-1 below. Please note that this estimate is based on the limited information available to us at this stage, more accurate costs will be possible once a detailed contour survey is available.

Table 8-1: Estimated Cost for Proposed Storm Water Channel

| Item | Description | Amount |
|---|---|---|
| A | Trapezium Storm Water Channel approximately 2600m in length | R 6,023,333.33 |
| Sub Total | | R 6,023,333.33 |
| Contingencies (15%) | | R 903,500.00 |
| Sub Total | | R 6,926,833.33 |
| Professional Fees | | R 1,246,830.00 |
| Sub Total | | R 8,173,663.33 |
| VAT (15%) | | R 1,226,049.50 |
| Total | | R 9,399,712.83 |

# 9. ROADS

## 9.1 Existing infrastructure

Currently there is a surfaced road running in a North-Easterly direction. All roads within the proposed development will connect to the main road through well designed intersections. It is proposed that a thorough traffic impact assessment is done by a specialist in order to design these intersections. Since there is an existing road there is no need for any new bulk road infrastructure.

# 10. SUMMARY OF COSTS

| Table 10-1: Estimated Cost for Bulk Infrastructure | | |
|---|---|---|
| Item | Description | Amount |
| A | PROPOSED BULK SEWER INFRASTRUCTURE | R 83,555,842.21 |
| B | PROPOSED BULK WATER INFRASTRUCTURE | R 108,951,865.60 |
| C | PROPOSED BULK STORM WATER INFRASTRUCTURE | R 8,173,663.33 |
| Sub Total | | R 200,681,371.15 |
| VAT (15%) | | R 30,102,205.67 |
| Total | | R 230,783,576.82 |

# 11. REFERENCES


- *Feasibility level dolomite stability investigation report for Churchill, in the jurisdiction of Joe Morolong Local Municipality, Northern Cape conducted by the Council of Geoscience in October*
- *Guidelines for the Provision of Engineering Services and Amenities in Residential Township Development, 1994 as amended (a.k.a. the "Blue Book").*
- *Guidelines for Human Settlement Planning and Designs as published by the CSIR and will also refer to the local municipality's guidelines and standards (a.k.a. the "Red Book").*
- *South African Local Government Association (SALGA) Planning and Design Guidelines Part II (K-Sanitation).*
- *Government Gazette, 5 July 2006: Electricity Regulation Act, 2006: Chapter III – Electricity Licenses and Registration*
- *Department of Energy: Bulk Infrastructure Policy Guidelines for Integrated National Electrification Programme (INEP)*
- *Department of Energy: Mixed Developer Projects Policy Guidelines for Integrated National Electrification Programme (INEP)*
- *Department of Energy: Suit of Supply Policy Guidelines for Integrated National Electrification Programme (INEP)*
- *SABS 1963-3:2012: Development of dolomite land – Part 3: Design and Construction of Buildings, Structures and Infrastructure.*

## 12. CONCLUSION

We trust this will enable you to make the necessary decisions. MVD Kalahari will gladly assist with additional information should the need arise.

___________________________

B D BENSLEY *(Pr Tech Eng)*
*MVD Kalahari*
*Consulting Engineers and Town Planners*
Level 2 B-BBEE Contributor
/bb/2985-002-QR-Bulk Civil Services Report

___________________________

G VAN TONDER *(Pr Tech Eng)*
*G3T CONSULT CC*

# Annexures

# Annexure A:
# Town Planning Layout

# DRAFT LAYOUT PLAN :

## PROPOSED TOWNSHIP CHURCHILL (3500)

### ON A PORTION OF THE REMAINING EXTENT OF THE FARM CHURCHILL 211 - HM AND A PORTION OF THE REMAINING EXTENT OF PORTION 2 OF THE FARM NYRA 213 - HM

| | |
|---|---|
| Residential : (Minimum 300m²) | 2500 Stands |
| Residential : (Minimum 400m²) | 500 Stands |
| Residential : (Minimum 450m²) | 500 Stands |
| Business : | 5 Stands |
| Church : | 5 Stands |
| Creche : | 5 Stand |
| Primary School : | 1 Stand |
| Secondary School : | 1 Stand |
| Sports Field : | 1 Stand |
| Community Facility : | 2 Stands |
| Parks : | 12 Stands |
| Total Area : 250.2453ha | |

Scale 1 : 12 000

JOE MOROLONG LOCAL MUNICIPALITY

COGHSTA
Department of Co-operative Governance, Human Settlements and Traditional Affairs of the Northern Cape

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MAXIM planning solutions
ACCREDITED TOWN AND REGIONAL PLANNERS

# Annexure B:
# Feasibility level Dolomite Stability Investigation Report

Council for Geoscience

# A FEASIBILITY LEVEL DOLOMITE STABILITY INVESTIGATION REPORT FOR CHURCHILL, IN THE JURISDICTION OF JOE MOROLONG LOCAL MUNICIPALITY, NORTHERN CAPE

**OCTOBER 2017**

**REPORT NO: 2017 – 0174**

**AUTHORS: SG CHILIZA AND M SEBESHO**



**Department:**
**Co-operative Governance, Human Settlement & Traditional Affairs**
**Northern Cape**

| Engineering Geosciences & Geohazards | | |
|---|---|---|
| CGS REPORT NUMBER:<br>2017- 0174 | Council for Geoscience | LEVEL OF CLASSIFICATION<br>Restricted |
| REVISION:<br>0 | | COPY NO. |

# A FEASIBILITY LEVEL DOLOMITE STABILITY INVESTIGATION REPORT FOR CHURCHILL, IN THE JURISDICTION OF JOE MOROLONG LOCAL MUNICIPALITY, NORTHERN CAPE

| AUTOHORISE DATE: | PROJECT NUMBER: |
|---|---|
| October 2017 | CO-2017-5810 Phase 20 |

| DOCUMENT APPROVAL | | |
|---|---|---|
| DOCUMENT OWNER: | CO-AUTHOR/CONTRIBUTOR: | REVIEWER: |
| SG Chiliza | ML Sebesho | S Diop |
| ACCEPTED BY:<br>(Acting Unit Manager) | ACCEPTED BY:<br>(Project Executive) | AUTHORISED BY:<br>(Chief Executive Officer) |
| E Kgaswane | S Tlowana | M Mabuza |

## Executive Summary

*The Council for Geoscience (CGS) was appointed by the Northern Cape Department of Co-operative Governance, Human Settlements & Traditional Affairs (CoGHSTA) to conduct feasibility level dolomite stability investigation for five (5) sites which are located within the jurisdictions of Kgatelopele, Joe Morolong and Ga-Segonyana Local Municipalities. This report presents findings of a dolomite stability investigation which was carried out in Churchill which is located within the jurisdiction of Joe Morolong Local municipality to facilitate development planning for low cost housing.*

*This dolomite stability investigation was carried out in accordance with the latest standard practice (SANS 1936-2:2012); and broadly included desk study, site-walk over, gravity survey, percussion drilling, analysis of results and report writing. A gravity map was produced and used to determine borehole positions from gravity highs, lows and gradients. A total 62 percussion boreholes for this 151 Ha site were proposed and drilled.*

*According to the 1:250 000 scale, geological map, 2722 KURUMAN, the site is predominantly underlain by aeolian sands, calcrete and calcified pan dunes of Gordonia Formation. The area also hosts surface limestone of tertiary age.*

*Recorded water rest levels ranged between 2.5 m and 58.7 m with a general average of 10 m.*

*The profile of the site generally consists of aeolian deposits, calcrete or calcified (pedogenic) deposits, weathered dolomite and hard rock dolomite. Other rocks types and most noticeably dolerite was intersected in some boreholes.*

*The stability evaluation was conducted in accordance with the widely accepted scenario supposition method which considers the factors which include blanketing layer, receptacles, mobilisation or mobilizing agents and maximum potential development space.*

*The assessment favoured the site to be zoned into one (1) Inherent Hazard Zone: Zone A, as dictated by geological conditions revealed by percussion drilling results and geohydrological data.*

***Zone A***

- *Inherent Hazard Class: 3/4 (1) // 3(1)*

*This zone is largely characterised by a medium inherent hazard of a medium (2-5 m diameter) sinkhole and subsidence (with sub areas of medium inherent hazard of large [5-15 m diameter] sinkhole and subsidence) in a non-dewatering scenario. The inherent hazard for any size sinkhole and subsidence is low with respect to a dewatering scenario.*
*The overburden which is non-dolomitic consists of aeolian deposits and pedogenic calcrete which is in a form of hardpan and calcified nodules in places. This zone occupies all gravity zones i.e. highs, lows and gradients. Neither wad nor low density material was recorded in the boreholes drilled. The groundwater level rests within the solid dolomite bedrock.*

- *Dolomitic Area Designation*

*This zone is assessed as D3 and implies that extra precautionary measures in addition to those pertaining to the prevention of concentrated ingress of water into the ground, in accordance with the relevant requirements of SANS 1936-3, are required and must be adhered to.*

- *Development Potential*

*Restrictions are placed on the types of residential development that may be considered on IHC: 3/4 land. Full title residential development (RN2-3) on stands of 300 $m^2$ or greater is recommended or 10 – 25 dwelling houses per hectare and a population of ≤ 60 people per hectare is recommended. Any form of commercial, retail and/or light industrial development is permissible (C1 to C10) with appropriate stringent precautionary measures. Footprint investigations are required for each commercial development.*

*A Competent Person must be appointed to compile a site specific* ***Dolomite Risk Management Strategy (DMRS)****. Such a plan, which is considered beyond the scope of this investigation, should define ongoing processes to manage water ingress and assign responsibilities to particular persons. General principles are provided. Groundwater Monitoring should also form part of the DRMS.*

*The drop in water rest level from 3 m in 2012 to about 10 m in 2017, shows that the compartment may have been impacted by excessive extraction. Accordingly, as an immediate precautionary measure two (2) monitoring boreholes were drilled and equipped for continuous groundwater level monitoring.*

**Table of Contents**

## LIST OF FIGURES

## LIST OF TABLES



## APPENDICES

# 1. INTRODUCTION

## 1.1 Terms of Reference

The Council for Geoscience (CGS) was appointed by the Northern Cape Department of Co-operative Governance, Human Settlements & Traditional Affairs (CoGHSTA) to conduct feasibility level dolomite stability investigation for five (5) sites which are located within the jurisdictions of Kgatelopele, Joe Morolong and Ga-Segonyana Local Municipalities. The appointment was made through a letter by then CoGHSTA head of department Mr. D Heerden, dated 16 November 2017. A service level agreement was signed on the 17 January 2017.

## 1.2 Background

This report presents findings of a dolomite stability investigation which was carried out in Churchill which is located within the jurisdiction of Joe Morolong Local municipality.
A site hand-over meeting took place on 13 January 2017 and was attended by the Joe Morolong Local Municipality official, CoGHSTA project management unit (PMU) personnel and Council for Geoscience personnel.
The overall purpose of the investigation was to determine the Inherent Hazard Class (IHC) and the Dolomite Area Designations for the area, in order to facilitate development planning for low cost housing.

The primary objectives of the investigation are to provide the following:

- The overview of the geology and groundwater conditions of the site,
- The description and discussion of subsurface profiles from ground surface to dolomite bedrock,
- The assessment of the dolomite bedrock morphology,
- The assessment of Inherent Hazard Class(es) (IHC) for sinkhole and subsidence formation,
- The determination of appropriate dolomite area designation(s),
- The establishment of allowable development type, in terms of the National Standard (SANS 1936) with due cognisance of the Inherent Hazard Class,

- The determination of precautionary measures; and
- The determination of the risk management required to achieve and sustain a tolerable hazard rating.

## 2. INFORMATION USED IN THE STUDY

Information supplied to CGS before the start of the project was a site boundary and other geological reports in the vicinity of the study area.

At the time of the investigation the following sources of information were available and consulted:

- 1:250 000 geological map: 2722 KURUMAN – Council for Geoscience
- 1:50 000 topographical map: 2723AD KURUMAN – Surveyor General
- 1:500 000 Hydrogeological Map: 2722 KIMBERLERY – Department of Water Affairs
- Google Earth® Satellite Imagery

Only one (1) dolomite stability report in the vicinity of the study area for the establishment of library was available and can be cited as follows:

- Breytenbach, I.J. (2012). A report on dolomite stability conditions at the Moshaweng Municipality near Kuruman: A report for the proposed establishment of Churchill library. SoilKraft Cc Report No: 2012/J054/UCE.

The reports met the minimum requirements of SANS 1936-1&2 (2012) and was revised once.

## 3. SITE LOCATION AND DESCRIPTION

### 3.1 Site Location and Physiography

The site is located approximately 20 km north-east of Kuruman (Figure 1); and is accessible via Seoding Road from Kuruman CBD. The village is named ***Letlhokane*** in most of available

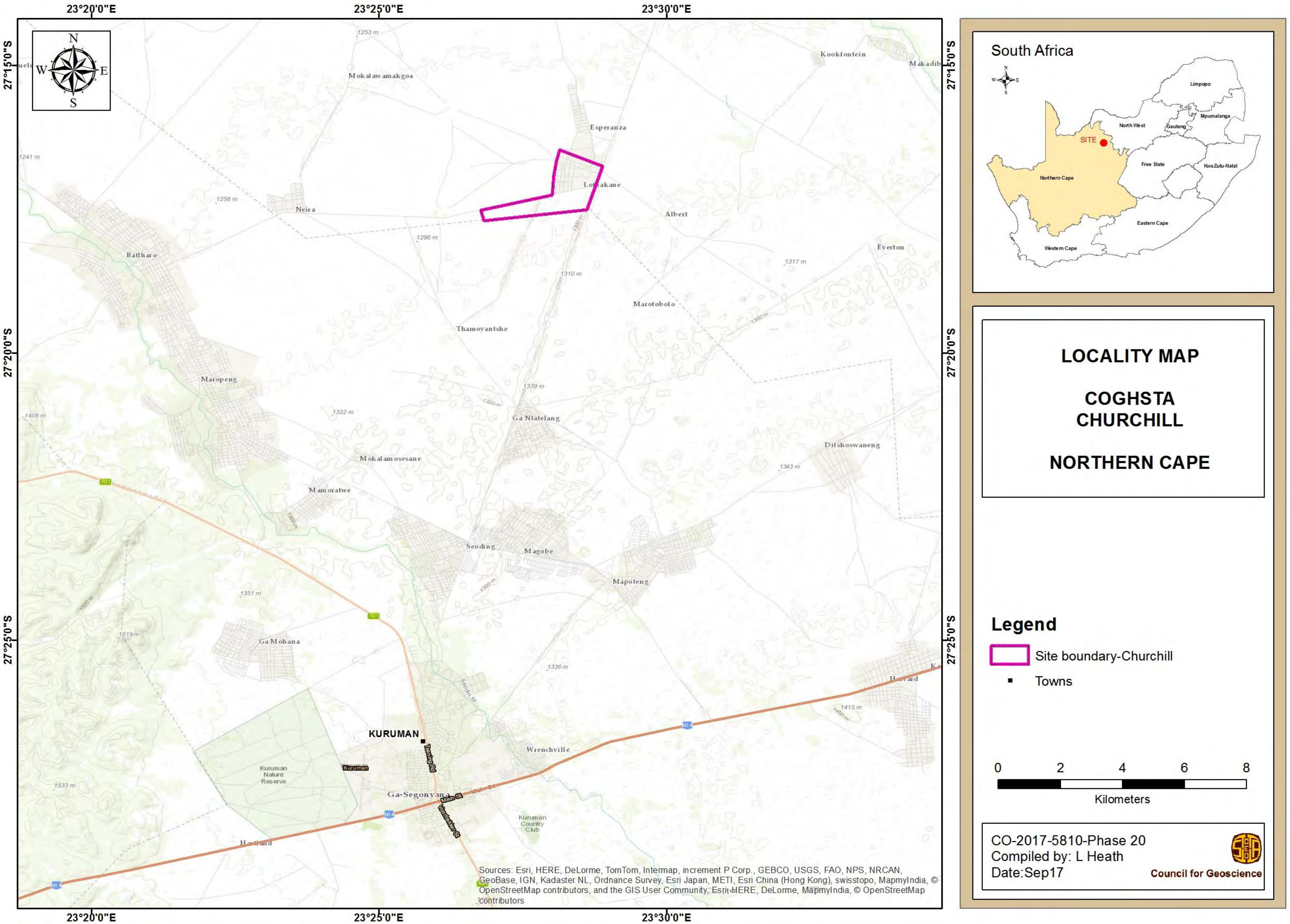


**Figure 1: Locality Map.**

maps e.g. GPS maps, topographical map and on Google Earth. The site boundary is characterised as a north facing L shape village land which is approximately 337 Ha in size.

The north eastern portion of the site is built up with schools, playing fields, small business premises and residential houses. The southern part of the site is a greenfield and is generally used for sheep and goats grazing. In places there are small borrow pits for natural gravel material (calcrete) particularly towards the main road in the eastern boundary. The layout of the stand is semi-formal with average stand sizes of about 900 $m^2$ and is equipped with a network of gravel roads.

## 3.2 Topography and Drainage

The site topography is essential flat but slightly undulating in places. The highest and lowest elevations within the site boundary are 1 287 m and 1 271 m above minimum sea level in the eastern and western boundaries respectively. The site generally slope towards south east with average slope of less than 2% (<1°). What appears to be a non-perennial and dry drainage course occurs in the eastern boundary and traverses the site from north to south. Site drainage is largely by sheet wash.

## 3.3 Climate

Frost is frequent in winter. Mean monthly maximum and minimum temperatures ranging from 35.9°C and -3.3°C for January and June, respectively (Mucina and Rutherford, 2006).

Churchill receives about 300 – 450 mm of rain per year with most of its rainfall occurring during summer and autumn with very dry winters (Mucina and Rutherford, 2006). The climatic N-value for the area is greater than 5 indicating that the environment is more arid and the predominant mode of weathering is physical weathering. According to Brink (1979), under semi-arid zones, there is a possibility of founding on rock at shallow depth.

## 3.4 Vegetation

The indigenous vegetation of the area is mainly classified as the Kuruman thornvelds which consists of closed shrub layer and well-developed open tree stratum mainly made of Acacia erioloba (Mucina and Rutherford, 2006). The site is extensively covered by tall grass, shrubs and trees in places.

Vegetation cover comprises grass, formal gardens, shrubs and trees in places.

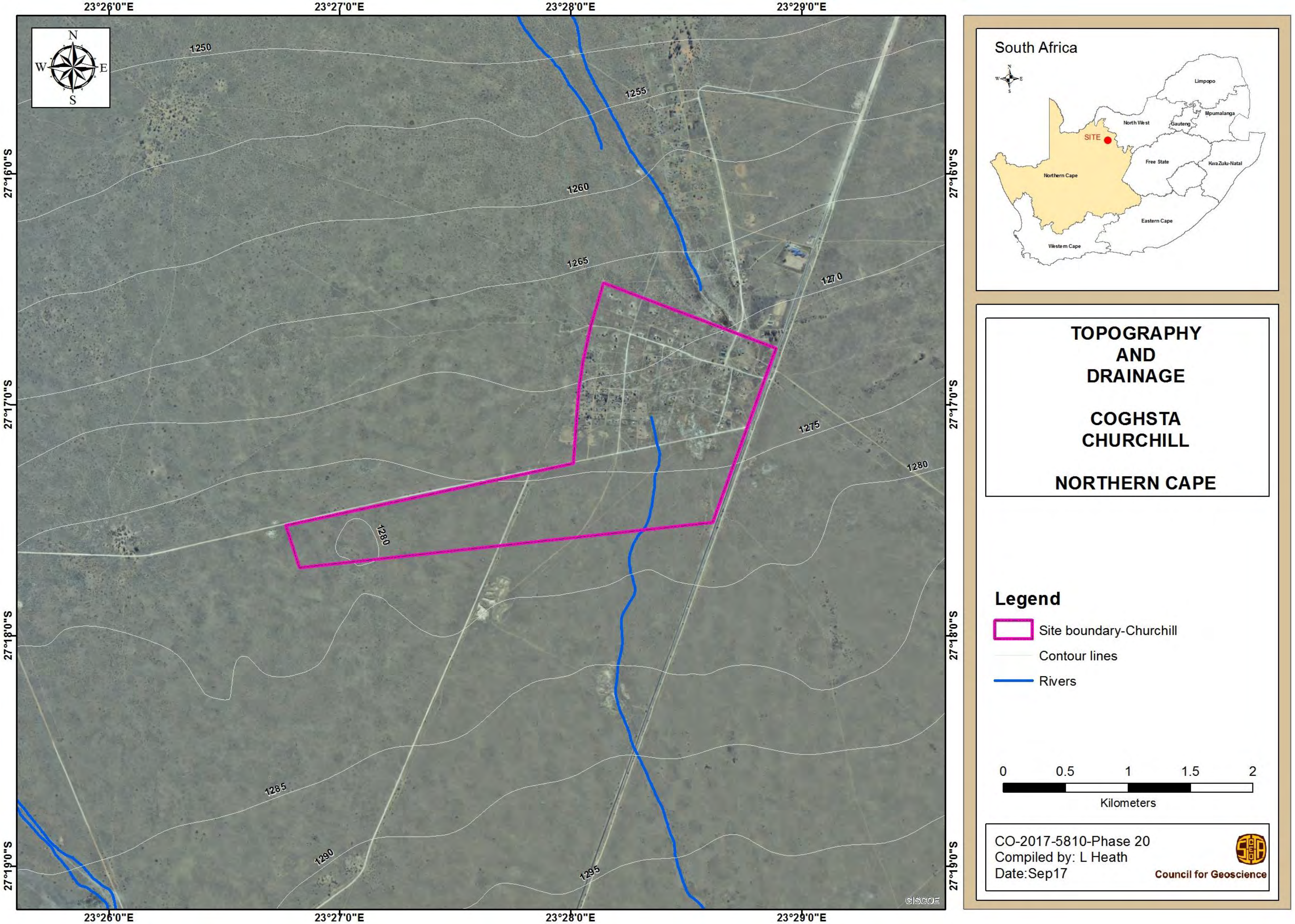


**Figure 2: Site drainage.**

# 4. INVESTIGATION PROCEDURES

This dolomite stability investigation was carried out in accordance with the latest standard practice (SANS 1936-2:2012); and broadly included desk study, site-walk over, gravity survey, percussion drilling, analysis of results and report writing.

## 4.1 Desk study

The initial step of the investigation took form the of a desk study, where all available and relevant information was collected and reviewed. Google Earth® satellite imagery was also reviewed to assess the terrain and elevation profile of the site.

## 4.2 Site Walk-Over Survey

A site walk-over survey was conducted on 13 January 2017. The site walk-over mainly revealed that access to the site was good and that no accessibility problems were anticipated for gravity surveys and percussion drilling.

## 4.3 Gravity survey

The gravity survey was conducted by the Geophysics and Remote Sensing Unit of the Council for Geoscience in accordance with SANS 1936-2: 2012 requirements for geophysical surveys in dolomitic land. The survey was conducted between 17 May and 31 June 2017 with a total of 3 974 points completed. Gravity survey involves measuring variations of the gravitational field, which aids to locate areas of greater or lesser density than the surrounding formations. The points were surveyed by means of Trimble real time GPS at 30 m spacing. A Scintrex CG-5 Autograv gravity meter no. G078 was calibrated and used to correspond with the known difference in absolute gravity between the Pretoria and Mowbray (Cape Town) stations. This is in accordance with the International Gravity Standardisation Net (IGSN′71) as described by Morelli *et al.* (1974) and the gravity formula, based on the 1967 Geodetic Reference System (Moritz, 1968). The gravity data was reduced to Bouguer anomaly and gridded to create the Bouguer Anomaly map. The Bouguer anomaly was upward continued to 500 m, The Bouguer anomaly was subtracted from the upward continued in order to separate the regional trend from the local trend. A gravity map was produced and used to determine borehole positions from gravity highs, lows and gradients. A gravity report titled “Detailed Gravity Survey at Churchill, Northern Cape Province” is presented in Appendix **1.**

## 4.2 Rotary percussion drilling

Drilling commenced on 4 August and was completed on 25 August 2017. A total 62 percussion boreholes for this 151 Ha site were proposed and drilled as per SANS 1936-2 minimum frequency of percussion boreholes in dolomitic areas. Twenty boreholes were drilled by Leruo Resources (Pty) Ltd and the rest by the Council for Geoscience drilling unit, using Super Rock 1000 and Prakla-Thor 5000 percussion rigs respectively. Rotary percussion boreholes were drilled to a minimum of at least 6 m into hard rock dolomite. Alternatively boreholes were drilled at least 60 m in gravity highs, lows anomalies as well as gradients. The two machines could hardly achieve a 3 minutes plus penetration per meter even for boreholes which were drilled in gravity highs and up to 60 m. This could be attributed to both compressor capacity of 2.4 kbar which is higher than the prescribed minimum 1.8 kbar as well as drill bit and hammer efficiency. During percussion drilling soil and rock-chip samples were recovered for every meter of advance and retained in a small labeled sample bag. The penetration rate per meter advance was recorded together with air loss, sample recovery and any other information regarding groundwater strike by the driller.

The logging of percussion borehole chips was done by a registered engineering geologist in accordance with accepted standard methodologies as per the national standard SANS 633: 2012 “*Soil profiling and rotary percussion borehole logging on dolomite land* in *Southern Africa* for *engineering purposes*”. Borehole logs were prepared using Dotplot® software. Logs of the percussion borehole are presented in Appendix 2. The setting of percussion borehole positions was determined solely on the basis of the gravity survey results, where gravity highs, lows and gradient anomalies were targeted. Borehole positions setting and their distribution are indicated in the subsequent sections of this report.

# 5. SITE GEOLOGY AND GEOHYDROLOGY

## 5.1 Regional geology

According to the 1:250 000 scale, geological map, 2722 KURUMAN, the site is predominantly underlain by aeolian sands, calcrete and calcified pan dunes of Gordonia Formation. The area also hosts surface limestone of tertiary age.

The Ghaap Group outcrops are found within 10 kilometres from the study area. According to the Ghaap Group is subdivided into four subgroups of different depositional composition, namely; Schmidstdrift (siliclastic carbonates), Campbell Rand (dolomite and siliclastic mudstone), Asbestos Hill (banded and granular Banded Iron Formation) and Koegas (submarine fans) Subgroups (Kendal *et al*, 2012). The beds tend to dip 5° in a south westerly direction.

Dolomitic rock is composed mainly of the mineral dolomite, which is a carbonate of calcium and magnesium. Groundwater that is weakly acidic through enrichment with carbon dioxide, dissolves and removes the calcium and magnesium in the form of bicarbonates as it percolates through the network of joints, fractures and faults in the rock mass. This dissolution gives rise to karst features in the form of cave systems and voids. In many parts of South Africa, the karst landscape is buried beneath younger deposits and/or weathering products of the dolomitic formation, and these materials can either collapse or be transported into voids or cave systems, resulting in catastrophic ground movement at surface.

Because of risks of sinkhole and subsidence development associated with the presence of these soluble dolomitic rocks, it is required that a dolomite stability assessment be conducted, in accordance with SANS 1936-2:2012. It is further stated that developments on such dolomitic land shall be in accordance with the Inherent Hazard Classes and the Dolomite Area Designations as determined by the geotechnical site investigations.

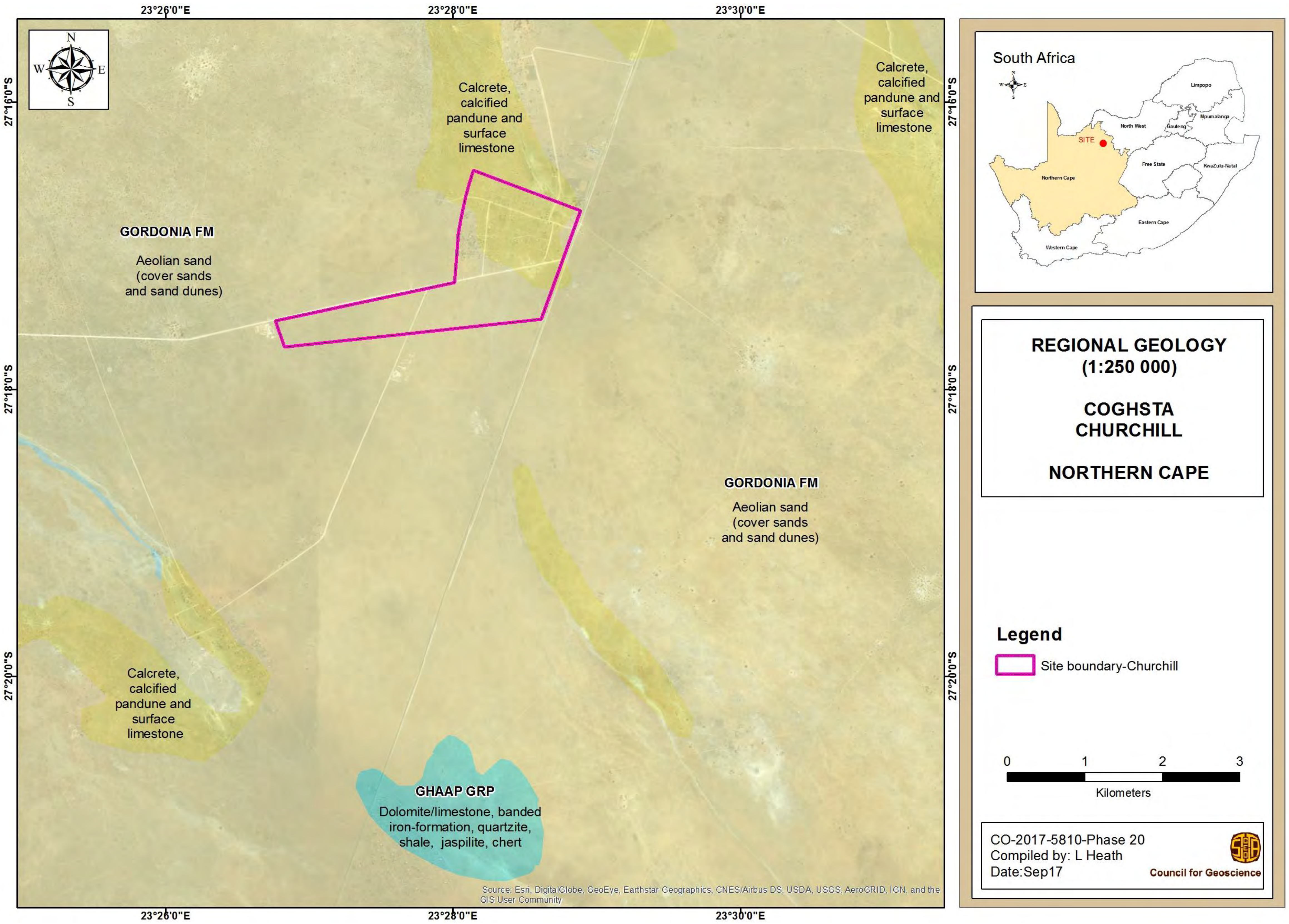


**Figure 3: Site Geology Map.**

## 5.2 Geohydrology

The groundwater scenario is a key risk assessment factor in the engineering-geological characterisation of dolomitic environments. According to a 1:500 000 hydrogeological Map 2722 KIMBERLERY, the principal groundwater occurrence system is a fractured, karstic and fissured dolomite aquifer type. The borehole yield (i.e. groundwater potential) class is >2.0 (median l/sec). The probability of such borehole for this yield class is between 50% and 60%. The municipality exclusively relies on groundwater resources for domestic, agricultural and business water supply. According the Department of Water Affairs' (DWA) National Groundwater Archive (NGA), there are 4 groundwater monitoring boreholes in close proximity of the site. They fall under Lower Vaal Water Management Areas and D41L drainage region. According to DWA records the water rest level ranges from 1.3 m to 2.51 m.

During percussion drilling of this investigation water strikes were encountered and water rest levels readings were taken using a dip meter after 24 hours as per SANS1936-1(2012). Water rest level measurements indicated that water rest levels were around 10 m in most of drilled boreholes. Recorded water rest levels varied between 2.5 m and 58.7 m in boreholes CH57 and CH55 respectively as shown in Figure 4. This shows a drawdown fluctuation of at least 8 m when comparing the current average of 10 m to that of 3 m measured by Breytenbach (2012) study, where water rest levels in all three (3) boreholes drilled were around 3 m. Breytenbach (2012) stated that, there was very little additional information of significance for this area and he deduced that the area has historically not been dewatered extensively. He added that, the last observation (monitoring) in this area was made in 2003, with observation supposed to have continued to 2007.

The drop in water rest level from 3 m in 2012 to more than 10 m in 2017, shows that the compartment may have been impacted by excessive extraction. In terms of dolomite stability for a dewatering scenario, the risk of sinkhole and subsidence to form is medium as the groundwater generally rests within the overburden which is calcrete in this case. Accordingly, as an additional precautionary measure 2 monitoring boreholes were drilled and equipped for continuous groundwater level monitoring.

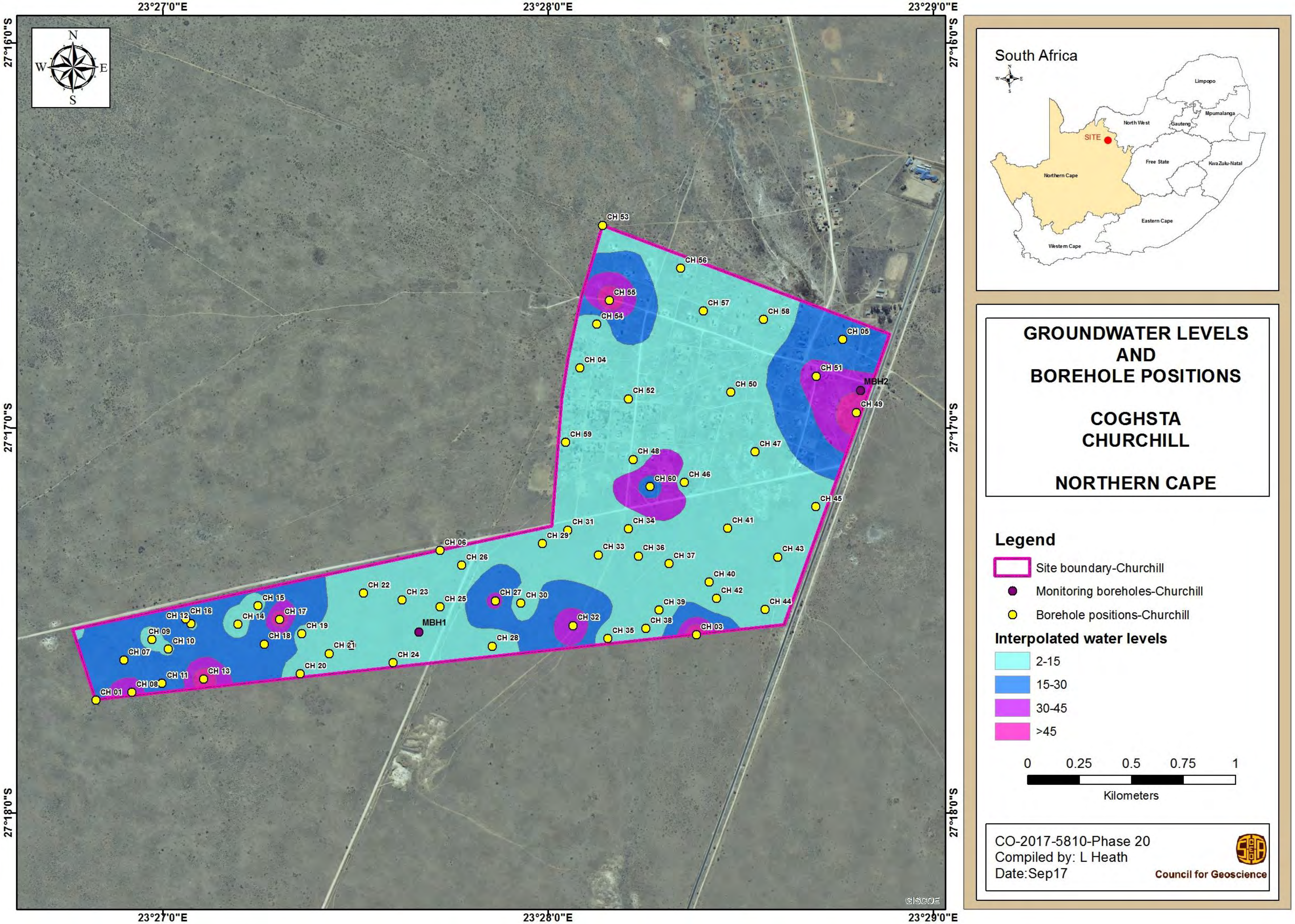


**Figure 4: Ground water level Map**

# 6. GEOPHYSICAL SURVEY RESULTS

## 6.1 Gravity

In a dolomitic environment gravity highs are usually associated with shallow dolomite bedrock or more dense material and gravity lows often represent deeply weathered intrusives, thick overburden or low density material. The residual gravity presented here is based on theoretical data as it was not re-calibrated after drilling was concluded.

A gravity report is attached as Appendix 1, but may be summarized as follows: (see also in Figure 5).

In general, alternating lows and highs are present in the study area, indicating possible features (bedrock) that are shallower at 0.163 mGals and those that are deeper than the surrounding area at 0.404 mGal. Gravity low patches are found in the south eastern and south western of the site, while gravity gradients and highs area are predominant and occur in different places across the site. Percussion drilling results confirmed the anticipated variation in the depth to bedrock and weathering profiles with relatively deep bedrock and thicker overburden profile being prevalent in gravity lows and much shallower or surface outcrops in gravity highs.

The correlation between the residual gravity pattern and drilling results was assessed as moderate to good.

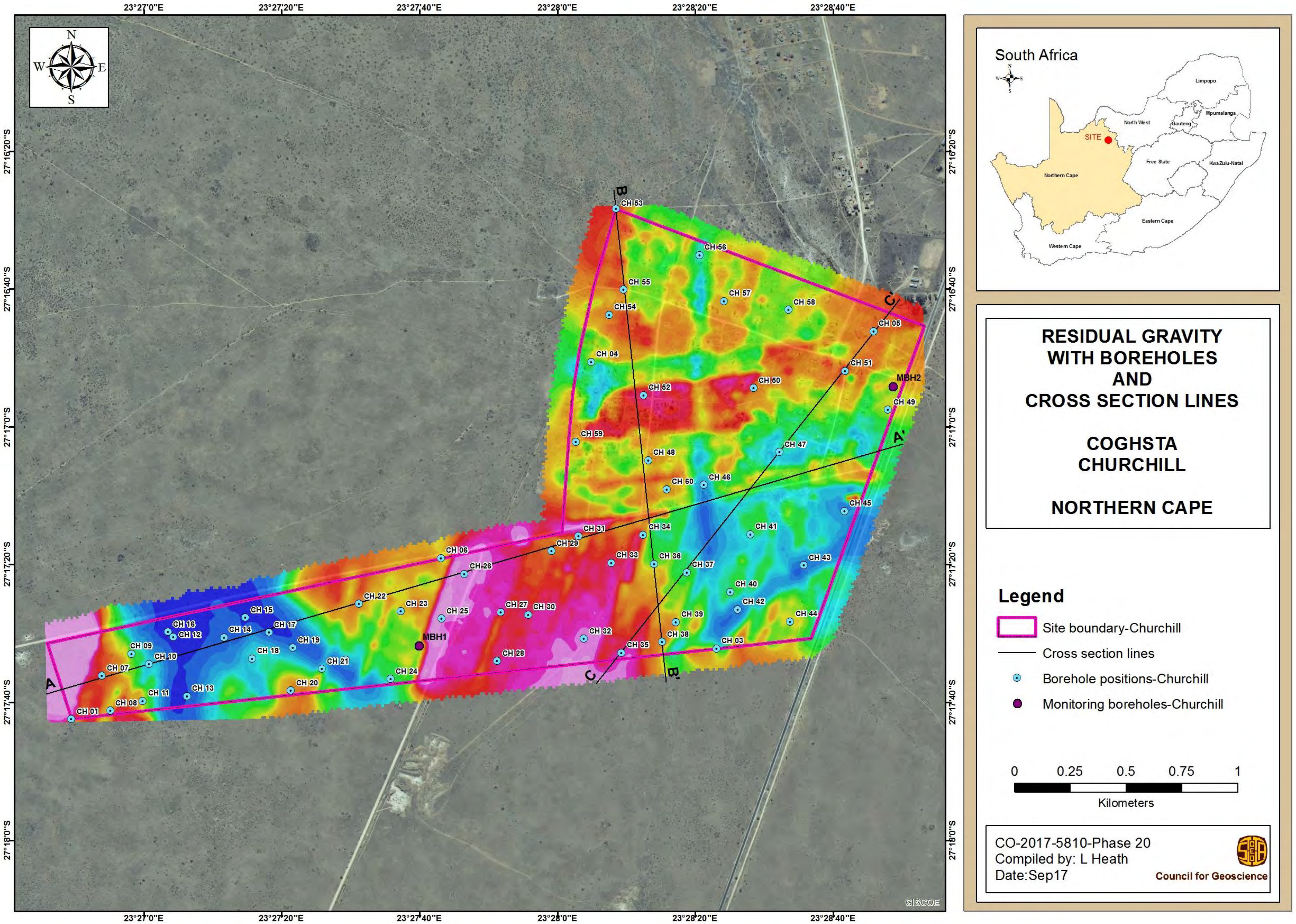


**Figure 5: Map showing residual gravity, borehole positions and cross-section lines.**

## 7. GEOLOGICAL PROFILES (SITE GEOLOGY)

Relevant information from the percussion boreholes is summarised in Table 1, and a general description of the respective geological horizons is presented in the paragraphs that follow. The profile of the site generally consists of aeolian deposits, calcrete or calcified (pedogenic) deposits, weathered dolomite and hard rock dolomite. Other rocks types and most noticeably dolerite was intersected in some boreholes as shown in Appendix 2.

It must be noted that while the process of percussion drilling is well suited for identification of the broader components of the dolomite profile and therefore assessment of the dolomite stability, detailed delineation of the subtleties within the soil profile is not possible. The geological cross sections in Figure 6, shows a subsurface model of the profile on site. They are based on the actual drilling results.

### 7.1 Aeolian Deposits

Percussion drilling results showed that this well-developed layer of transported material consists of brown, sandy silt with traces of calcified gravels in places. The horizon contains some plant roots in places. The thickness of this layer varies between 1 m and 2 m.

### 7.2 Hardpan Calcrete and Calcified (Pedogenic) Deposits

The pedogenic hardpan calcrete which is in the form of calcified gravel in certain places is well developed across the site; and occurs below the aeolian deposits.

Pedogenic hardpan calcrete generally occurs as very pale orange speckled black, moderately weathered slightly weathered, sub-rounded to sub angular, 15 mm diameter chips, calcrete. This calcrete layer was encountered in all boreholes drilled. The layer varies in thickness from 4 m up to 18 m in boreholes CH 05 and CH 55 respectively.

## 7.3 Weathered Dolomite

Moderately to highly weathered dolomite as per definition for surface characteristics (i.e. partial to complete discolouration and friable in places) was encountered only in CH 12 and CH 17. This horizon was described as light to dark grey, moderately to highly weathered, 10 mm diameter of chips, dolomite. The layer occurs between 13 m and deeper than 60 m in CH 12 and CH 17 respectively with an average thickness of 21m in gravity low areas.

## 7.4 Unweathered dolomite bedrock

As pointed out earlier, consistent penetration rates of greater than 3 minutes per meter (m/m) were not recorded. Unweathered dolomite bedrock refers to dolomite chips which showed surfaces with unchanged colour and very partial discolouration in certain places with an average penetration rate of 1.5 m/m.

In some boreholes, drilling was continued to 60 m after a continuous intersection of unweathered dolomite bedrock in order to prove that consistent penetration rates of greater than 3 minutes per meter (m/m) were not achievable given the efficiency of the compressors, hammer and drill bits for both machines. Unweathered dolomite bedrock is represented in the chip samples by light to dark grey, unweathered to slightly weathered, angular to sub-angular, 10 mm diameter of chips, dolomite.

## 7.6 Non-dolomitic bedrock

Another rock type which was revealed by drilling results was identified as dolerite. In boreholes CH: 18, 19, 41, 42, 43 and 58 It also occurred as minor component or interbedded with dolomite and chert in places. In boreholes CH: 34, 55, 56, and 57; was described as olive green weathering to brown, unweathered to slightly weathered, sub-angular to angular, 15 mm diameter of chips, dolerite. It is highly weathered in places. Its thickness varies from 14 m in CH 34 to 37 m in CH 56.

**Table 1: Summary of borehole logs.**

| BH No. | Collar elevation (m) | Y-Coordinate (latitude) | X – Coordinate (longitude) | Overburden material (i.e. "unconsolidated" loose soil overlying the hard rock geology and includes residual soils) | | Non dolomite bedrock | Dolomitic profile | | | Groundwater: water strike/ rest level (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Colluvium (m) | Pedogenic material | | Dolomite residuum | Weathered dolomite bedrock (m) | Hard dolomite bedrock (m) | |
| CH01 | 1279.327 | -27.2951 | 23.447095 | 0 – 1 (1) | 1– 13 (12) | | | 13 – 28 (15) | 28 – 48 (20) | 37/30 |
| CH02 | 1277.693 | -27.2927 | 23.458156 | 0 - 1 (1) | 1 – 11 (10) | | | | 11 – 60 (49) | Dry/5.0 |
| CH03 | 1277.528 | -27.2923 | 23.473095 | 0 – 1 (1) | 1 – 14 (13) | | | 14 – 21 (7) | 21 - 60 | 15/58.7 |
| CH04 | 1268.426 | -27.2807 | 23.468045 | 0 – 1 (1) | 1 – 9 (8) | | | 19 – 21 (2) | 9 – 37 (26) | 15/4.60 |
| CH05 | 1270.811 | -27.2795 | 23.479426 | 0 – 1 (1) | 1 – 5 (4) | | | | 5 – 25 (20) | Dry/24.6 |
| CH06 | 1273.924 | -27.2886 | 23.461986 | 0 – 1 (1) | 1 – 17 (16) | | | | 17 – 30 (13) | Dry/7 |
| CH07 | 1278.653 | -27.2934 | 23.448318 | 0 – 1 (1) | 1 – 14 (13) | | | | 14 – 28 (14) | Dry/24 |
| CH08 | 1278.958 | -27.2948 | 23.448654 | - | 0 – 12 (12) | | | 12 – 24 (12) | 24 – 60 (36) | Dry/43 |
| CH09 | 1278.53 | -27.2925 | 23.449516 | 0 – 1 (1) | 1 – 12 (11) | | | | 12 – 25 (13) | 22/10.4 |
| CH10 | 1279.472 | -27.2929 | 23.450226 | 0 – 1 (1) | 1 – 13 (12) | | | | 10 – 37 (27) | Dry/13.47 |
| CH11 | 1279.359 | -27.2944 | 23.449959 | 0 – 1 (1) | 1 – 13 (12) | | | | 13 – 60 (47) | Dry/12 |
| CH12 | 1279.552 | -27.2918 | 23.451207 | 0 – 1 (1) | 1 – 13 (12) | | | 13 – 60 (47) | | 22/9 |
| CH13 | 1279.941 | -27.2942 | 23.45176 | 0 – 1 (1) | 1 – 14 (13) | | | 35 – 45 (10) | 14 – 35 (21), 45 – 55 (10) | 37/ |
| CH14 | 1278.438 | -27.2918 | 23.453239 | 0 – 1 (1) | 1 – 12 (11) | | | | 12 – 60 (48) | |
| CH15 | 1277.52 | -27.291 | 23.454106 | 0 – 1 (1) | 1 – 12 (11) | | | 12 – 26 (14) | 26 – 40 (14) | Dry/9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CH16 | 1279.312 | -27.2916 | 23.450991 | 0 – 1 (1) | 1 – 11 (10) | 16 – 20 (2) | | | 11 – 24 (13) | Dry/ |
| CH17 | 1277.449 | -27.2916 | 23.455061 | 0 – 2 (2) | 2 – 16 (14) | | | 16 – 60 (44) | | 39/ |
| CH18 | 1278.163 | -27.2927 | 23.45438 | 0 – 1 (1) | 1 – 13 (12) | | | | 13 – 31 (18) | 14.28 |
| CH19 | 1277.552 | -27.2923 | 23.456014 | 0 – 1 (1) | 1 – 12 (11) | | | | 12 – 60 (48) | 9.49 |
| CH20 | 1278.371 | -27.294 | 23.455941 | 0 – 1 (1) | 1 – 13 (12) | | | | 13 – 30 (17) | 10 |
| CH21 | 1277.907 | -27.2931 | 23.457191 | 0 – 2 (2) | 2 – 15 (13) | | | | 15 – 40 (25) | 11.5 |
| CH22 | 1275.961 | -27.2905 | 23.458684 | 0 – 1 (1) | 1 – 11 (10) | | | | 11 -37 (16) | 7.8 |
| CH23 | 1276.205 | -27.2908 | 23.460359 | 0 – 1 (1) | 1 – 11 (10) | | | 11 – 35 (24) | 35 - 60 (25) | 8.09 |
| CH24 | 1277.958 | -27.2935 | 23.459959 | 0 – 3 (3) | 3 – 11 (8) | | | | 11 – 55 (44) | Dry/10.4 |
| CH25 | 1276 | -27.2911 | 23.462004 | 0 – 1 (1) | 1 – 14 (13) | | | | 14 – 25 (11) | Dry/8.75 |
| CH26 | 1275.006 | -27.2893 | 23.462935 | 0 – 1 (1) | 1 – 12 (11) | | | | 12 – 24 (12) | 8 |
| CH27 | 1276.049 | -27.2908 | 23.464388 | 0 – 2 (2) | 2 – 11 (9) | | | | 11 – 31 (20) | - |
| CH28 | 1277.129 | -27.2928 | 23.464258 | 0 – 2 (2) | 2 – 12 (10) | | | | 12 -31 (9) | 9 |
| CH29 | 1274.394 | -27.2884 | 23.466434 | 0 – 2 (2) | 2 – 10 (8) | | | | 10 – 22 (12) | 8 |
| CH30 | 1276.675 | -27.2909 | 23.465499 | 0 – 1 (1) | 1 – 13 (12) | | | | 13 – 60 (47) | Dry/8.81 |
| CH31 | 1273.81 | -27.2878 | 23.467525 | 0 – 1 (1) | 1 – 10 (9) | | | | 10 – 21 (11) | Dry/7.9 |
| CH32 | 1277.617 | -27.2919 | 23.467754 | 0 – 3 (3) | 3 – 11 (8) | | | | 11 – 43 (32) | 24/ |
| CH33 | 1274.986 | -27.2888 | 23.468854 | 0 – 1 (1) | 1 – 10 (9) | | | | 10 – 19 (9) | Dry/8.5 |
| CH34 | 1274.073 | -27.2877 | 23.470138 | 0 – 1 (1) | 1 – 9 (8) | 20 – 34 (14) | | | 9 -60 (37) | 14/8.54 |
| CH35 | 1277.624 | -27.2925 | 23.469265 | 0 – 1 (1) | 1 – 9 (8) | | | | 9 – 32 (23) | 18/9 |
| CH36 | 1275.17 | -27.2889 | 23.470578 | 0 – 1 (1) | 1– 13 (12) | | | | 9 – 30 (21) | Dry/11.8 |
| CH37 | 1275.679 | -27.2892 | 23.471902 | 0 - 3 (1) | 3 – 10 (7) | | | | 10 – 60 (50) | 8.9 |
| CH38 | 1277.44 | -27.292 | 23.470897 | 0 – 1 (1) | 1 – 8 (7) | | | | 8 – 35 (27) | 8 |
| CH39 | 1277.085 | -27.2912 | 23.471464 | 0 – 1 (1) | 1 – 11(10) | | | | 11 – 26 (15) | 7.8 |
| CH40 | 1276.015 | -27.29 | 23.473639 | 0 – 3 (3) | 3 – 9 (6) | | | | 9 – 40 (31) | 6.7 |
| CH41 | 1274.15 | -27.2877 | 23.474451 | 0 – 1 (1) | 1 – 8 (7) | | | | 8 – 43 (35) | 7.4 |
| CH42 | 1276.543 | -27.2907 | 23.473952 | 0 – 1 (1) | 1 – 13 (12) | 13 – 42 (29) | | | 13 – 42 (29) | 26/7.6 |
| CH43 | 1275.002 | -27.2889 | 23.476616 | - | 0 – 12 (12) | 12 – 43 (31) | | 12 – 43 (31) | | 7.2 |
| CH44 | 1276.419 | -27.2912 | 23.476064 | 0 – 1 (1) | 1 – 12 (11) | | | | 12 – 25 (13) | 5.8 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CH45 | 1273.222 | -27.2867 | 23.478248 | 0 – 1 (1) | 1 – 13 (12) | | | | 10 – 37 (27) | 7.6 |
| CH46 | 1272.669 | -27.2857 | 23.472574 | 0 – 1 (1) | 1 – 13 (12) | | | | 13 – 60 (47) | 13.6 |
| CH47 | 1272.232 | -27.2844 | 23.475635 | 0 – 1 (1) | 1 – 8 (7) | | | | 8 – 40 (32) | 4.6 |
| CH48 | 1271.996 | -27.2847 | 23.470344 | 0 – 1 (1) | 1 – 12 (11) | | | | 12 – 31 (19) | 8.8 |
| CH49 | 1272.294 | -27.2827 | 23.480011 | 0 – 1 (1) | 1 – 10 (9) | | | | 10 – 60 (50) | 44/ |
| CH50 | 1270.707 | -27.2818 | 23.474581 | 0 – 2 (2) | 2 – 9 (7) | | | | 9 – 43 (34) | 4.9 |
| CH51 | 1271.36 | -27.2811 | 23.478285 | 0 – 1 (1) | 1 – 10 (9) | | | | 10 – 31 (21) | - |
| CH52 | 1270.545 | -27.2821 | 23.470152 | 0 – 1 (1) | 1 – 12 (11) | | | | 12 – 37 (25) | Dry/5.4 |
| CH53 | 1263.584 | -27.2746 | 23.469039 | 0 – 1 (1) | 1 – 13 (12) | | | | 13 – 31 (18) | 5 |
| CH54 | 1267.014 | -27.2788 | 23.468771 | 0 – 1 (1) | 1 – 10 (9) | | | | 10 – 25 (15) | Dry/4.8 |
| CH55 | 1266.366 | -27.2778 | 23.469333 | 0 – 1 (1) | 1 – 19 (18) | 19 – 60 (41) | | | | 58.7 |
| CH56 | 1265.671 | -27.2764 | 23.472403 | 0 – 1 (1) | 1 – 13 (12) | 23 – 60 (37) | 13 – 23 (10) | | | Dry/5.2 |
| CH57 | 1268.02 | -27.2783 | 23.473391 | 0 – 1 (1) | 1 – 11 (10) | 32 – 39 (7) | | | 11 – 46 (35) | 38/2.4 |
| CH58 | 1268.661 | -27.2786 | 23.475991 | 0 – 1 (1) | 1 – 8 (7) | 22 – 42 (20) | | | 8 – 42 (34) | 21/2.8 |
| CH59 | 1270.823 | -27.284 | 23.467428 | 0 – 2 (2) | 2 – 13 (11) | | | | 13 – 60 (47) | 6 |
| CH60 | 1272.895 | -27.2859 | 23.471086 | 0 – 1 (1) | 1 – 14 (13) | | | | 14 – 25 (11) | - |
| MBH1 | 1276.000 | -27.29217 | 23.46109 | | 0 – 9 (9) | | | 9 – 11 (2) | 11 – 30 (19) | 17/17 |
| MBH2 | 1216.00 | -27.28173 | 23.48019 | | 0 – 6 (6) | | | | 6 – 60 (54) | 17/9 |

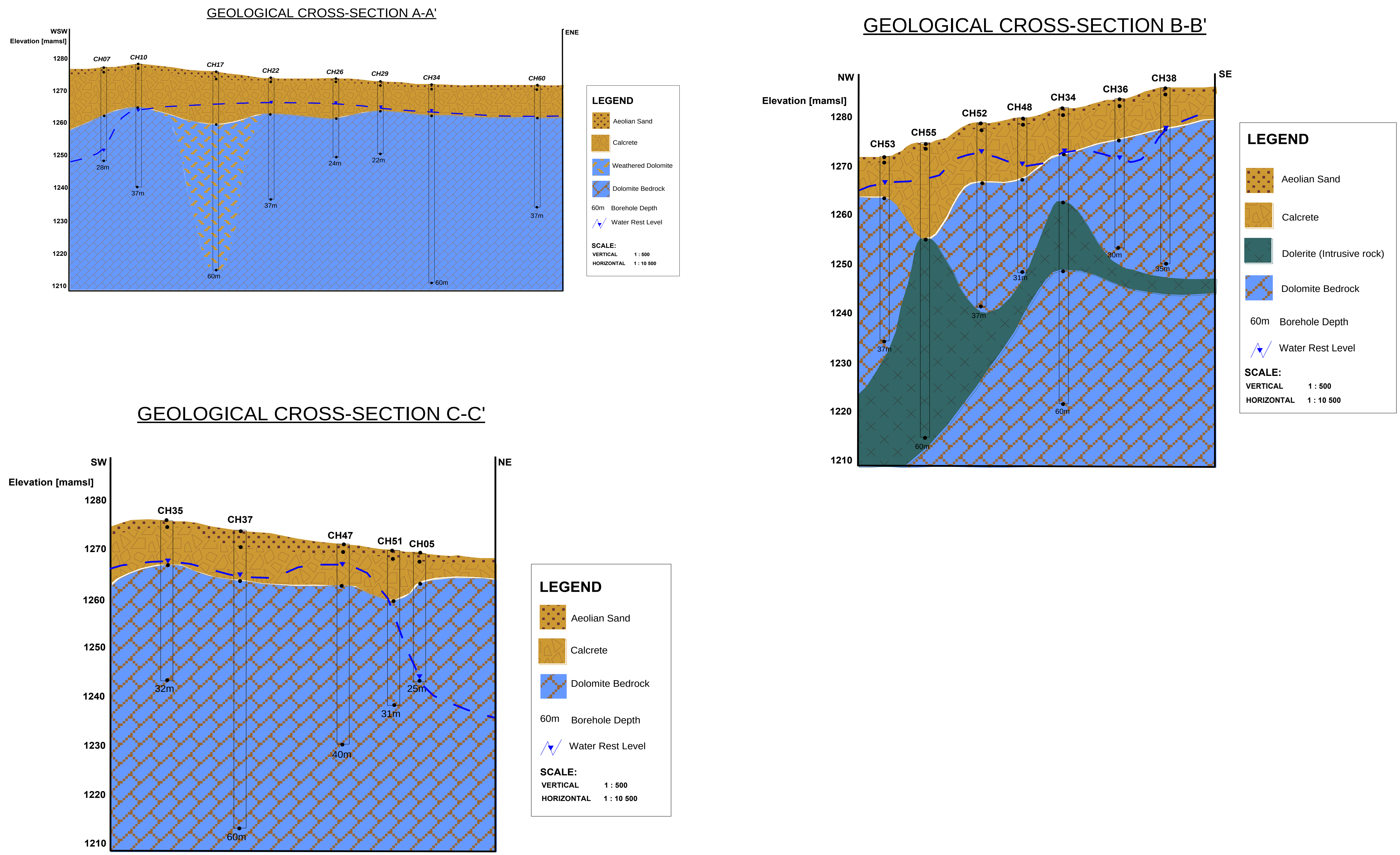




**Figure 6: Geological cross sections A - A', B - B' and C - C' showing a geological model of the study area.**

# 8. DOLOMITE STABILITY EVALUATION

## 8.1 Hazard (stability) characterisation procedure

The Inherent Hazard for sinkhole formation is a reflection of the geotechnical characteristics of the materials in the blanketing layer and depends mainly on the susceptibility (also termed mobilising potential) of materials to exploitation and mobilisation under the influence of a mobilising agency (Buttrick *et al*, 2001). The Inherent Hazard Class is defined in terms of ingress (non-dewatering scenario) and groundwater level drawdown (dewatering) reflected by two Inherent Hazard Class designations separated by a double forward slash, i.e. Inherent Hazard Class (ingress scenario) // Inherent Hazard Class (groundwater level drawdown).

The Method of Scenario of Supposition for evaluating the risk of sinkhole and subsidence formation (Buttrick and Van Schalkwyk, 1995) requires hypothesising the impact of man's future activities on the potential for sinkhole and subsidence formation, in a dolomitic karst environment in the context of either a dewatering or non-dewatering scenario. For stability evaluation purposes in a de-watering scenario, were borehole had collapsed or where they had to be backfilled immediately after drilling due to safety concerns, the groundwater rest level was assumed to be above dolomite bedrock. This would be a worst case scenario and was applied in the IHC characterization of boreholes 13, 16, 17, 27, 32, 49, 51 and 60.

Factors considered in assessing the hazard potential of the site are blanketing layer characteristics, the presence of receptacles, mobilisation potential of materials, mobilizing agents in operation and the maximum potential development space.

### 8.1.1 Nature of overburden

Dolomitic overburden comprises all the materials occurring between the ground surface and the dolomitic bedrock surface. It typically consists of residual dolomitic soils (wad and chert rubble), unweathered and weathered intrusive sills, and layers of Karoo sedimentary rock and quaternary deposits. The term blanketing layer is defined as that component of the dolomitic overburden that overlies the potential receptacles (Buttrick *et al*, 2001). It determines the susceptibility of the subsurface material to erosion by water ingress. The presence of material such as shales or intrusive, act as aquitards, to reduce the mobilisation potential and enhance the stability.

### 8.1.2 Receptacles

Receptacles may occur either as small disseminated and interconnected openings in the overburden (especially where chert rubble is present), or as substantial openings (cavities) in the bedrock. Both types of openings may be able to receive mobilised (transported) materials from overlying horizons (Buttrick *et al*, 2001). Information gathered from boreholes such as penetration rate, air loss combined with geophysical and geological information is used to formulate an impression of the degree of voids.

### 8.1.3 Mobilization and mobilizing agent

Mobilisation is defined as the movement of dolomitic overburden by subsurface erosion which is controlled by dramatic groundwater level fluctuations. Mobilising agents may include ingress water, ground vibrations, water level drawdown or any activity or process that can induce mobilisation of the material within the blanketing layer under the force of gravity. In a non-dewatering scenario the static ground water level is not an agent but a positive, mitigating factor (Buttrick *et al*, 2001).

### 8.1.4 Maximum potential development space

This is a simplified estimation of the maximum size sinkhole that can be expected to develop in a particular profile, provided that the available space is fully exploited by the mobilising agency. The available space depends on the depth below ground surface to the throat of a receptacle or disseminated receptacle and the ‘angle-of-draw’ in the various blanketing materials (Buttrick *et al*, 2001). The gravity survey results combined with borehole information influences the appraisal of this factor.

The hazard of sinkhole and subsidence formation is expressed in three broad categories, namely low, medium and high (Table 2).

Table 2: Hazard levels in terms of likelihood of events occurring.

| Hazard Characterization | Anticipated events per hectare over time |
|---|---|
| Low | 0 up to and including 0.1 events per hectare anticipated, but occurrence of events cannot be excluded. Return period is greater than 200 years. |
| Medium | Greater than 0.1 and less and equal to 1.0 events per hectare. Return period is between 200 and 20 years. |
| High | Greater than 1.0 event anticipated per hectare. Return period is less than 20 years. |

The study area is characterised in terms of potentially eight standard Inherent Hazard Classes. These classes denote the chance of a sinkhole or subsidence occurring as well as its likely size (diameter) (Table 3). The terminology used in terms of likely size of an event (sinkhole or subsidence) is defined as follows:

Table 3: Classification of sinkhole size (after Buttrick et al, 2001).

| Maximum potential development space | Maximum diameter of surface manifestation (dimension: meters) | Suggested terminology |
|---|---|---|
| Small potential development space | <2 | Small sinkhole |
| Medium potential development space | 2-5 | Medium-size sinkhole |
| Large potential development space | 5-15 | Large sinkhole |
| Very large potential development space | >15 | Very large sinkhole |

The larger the Inherent Hazard Class number, the greater the likelihood of a sinkhole or subsidence occurring and the larger its potential size should it occur (Table 4).

The meaning/definition of each Inherent Hazard Class is as follows:

Table 4: Definition of the eight standard Inherent Hazard Classes.

| Hazard Class | Characterization of Area |
|---|---|
| Class 1 | Areas characterized as reflecting a low Inherent Hazard of sinkhole and subsidence formation (all sizes) with respect to ingress of water. |
| Class 2 | Areas characterised as reflecting up to a medium Inherent Hazard of small sinkhole and subsidence formation with respect to ingress of water. |
| Class 3 | Areas characterised as reflecting up to a medium Inherent Hazard of medium sinkhole and subsidence formation with respect to ingress of water. |
| Class 4 | Areas characterised as reflecting up to a medium Inherent Hazard of large size sinkhole and subsidence formation with respect to ingress of water. |
| Class 5 | Areas characterised as reflecting up to a high Inherent Hazard of small sinkhole and subsidence (all sizes) formation with respect to ingress of water. |
| Class 6 | Areas characterised as reflecting up to a high Inherent Hazard of medium size sinkhole and subsidence formation with respect to ingress of water. |
| Class 7 | Areas characterised as reflecting up to a high Inherent Hazard of large sinkhole and subsidence formation with respect to ingress of water. |
| Class 8 | Areas characterised as reflecting up to a high Inherent Hazard of very large size sinkhole and subsidence formation with respect to ingress of water. |

Based on the outcomes of the investigation and the Inherent Hazard Class assigned, an appropriate dolomite area designation (Table 5) is determined so that appropriate precautionary measures can be communicated. On land categorised as D2 and D3, appropriate precautionary measures in accordance with SANS 1936-3: 2012 must be implemented. In proposing suitable foundations types in D3 areas, consideration should be given to the potential loss of support which could be anticipated for the designated Inherent Hazard class based on expected sinkhole size.

Table 5: Dolomite Area Designations.

| Dolomite area designation | Description |
|---|---|
| D1 | No precautionary measures are required |
| D2 | General precautionary measures, in accordance with the requirements of SANS 1936-3, that are intended to prevent the concentrated ingress of water into the ground, are required. |
| D3 | Precautionary measures in addition to those pertaining to the prevention of concentrated ingress of water into the ground, in accordance with the relevant requirements of SANS 1936-3, are required. |
| D4 | The precautionary measures required in terms of SANS 1936-3 are unlikely to result in a tolerable hazard. Site-specific precautionary measures are required. |

## 8.2 Monitoring designations

Monitoring designations which indicate monitoring activities to are also allocated in terms of SANS 1936-4:2012 (Table 6). The higher the hazard, the more frequent the monitoring activities.

Table 6: Monitoring Area Designation.

| Monitoring Area Designation | Risk Reduction Measures |
|---|---|
| A | Visual inspections of ground, structures and above-ground infrastructure (e.g. roads, storm water canals, ditches), surface runoff, obstructions to free flow, etc. Any evidence of cracking or ground settlement shall immediately be reported and investigated. |
| B | Visual inspection of storm water system for blockages, leaks, misalignment and ponding. Any evidence of blockages, leaks, misalignment and ponding shall be reported and cleared immediately. |
| C | Testing of wet services for leaks. Any leaks shall be reported and repaired immediately. |
| D | Visual inspection of dry services sleeves, ducts, manholes and facility chambers for water ingress. Any water ingress shall be reported and point of entry repaired/blocked immediately. |
| E | Monitoring of structures and ground levels. Any evidence of sustained movement shall be reported and investigated. |
| F | Monitoring of the groundwater level.<br>Evidence of lowering shall be reported to the relevant national authority.<br>On de-watered compartments, such as on the Far West Rand, monitoring of levels need only commence once de-watering has ceased and water level rise takes place. |

Table 7: Frequency designation.

| **Frequency Designation** | **Frequency of Activates** |
|---|---|
| 0 | Not required |
| Daily | Daily |
| Weekly | Weekly |
| 1 | Once a month |
| 3 | Quarterly |
| 6 | Bi-annually |
| 12 | Annually |
| 24 | Every two years |
| TBD | To Be determined |

The monitoring area designation is described in terms of the risk reduction measures and the frequency of activities, as follows: (Monitoring area designation from Table 6) Frequency designation from table 7 e.g. (A) DAILY or; (E) 24

- Zones with a D1 dolomite area designation in accordance with SANS 1936-1 require no monitoring from a dolomite risk management perspective.
- Zones with a D2 dolomite area designation are assigned a low priority and require basic monitoring and maintenance activities at long intervals.
- Zones with a D3 or D4 dolomite area designation are assigned high priority in terms of monitoring and maintenance should receive attention more frequently.

TBD should be assigned, indicating that these are yet to be determined as no data or insufficient data exist and the inherent hazard classification is undetermined.

## 8.3 Stability characterisation of the site

In order to characterise the stability of the site (scenario supposition), the available information, geophysical gravity data, borehole logs and geohydrological information gathered during the investigation were reviewed and evaluated to determine the Inherent Hazard Class(es) (IHC) for individual boreholes. The following characteristics were gathered and analysed during the assessment process. The condition, nature and occurrence of material and geological horizons are generally uniform and persistent across the site.

- *Nature of blanketing layer*

As per the definition dolomitic overburden comprises all the material occurring between the ground surface and the dolomite bedrock surface, while the blanketing layer refers to a component of a dolomitic overburden that overlies receptacles. At the site, the overburden which is non-dolomitic consists of aeolian deposits and pedogenic calcrete which is in a form of hardpan and calcified nodules in places. The overburden thickness ranges from 5 m in CH 05 to 60 meters and CH17 if considering weathered dolomite as part of the overburden. Aeolian deposit material lacks cohesion and therefore is highly susceptible to mobilisation. However, this horizon attains a maximum thickness of only 2 m across the site. The pedogenic calcrete which underlies aeolian sand is considered to have a low mobilisation potential and competent to prevent the aeolian from being eroded or mobilised.

Although weathered dolomite in CH 22 may be considered as part of the overburden, it was deemed to have a low potential to mobilise.

- *Receptacles*

Receptacles occur as interconnected openings in the dolomitic overburden (especially where chert rubble is present) or as large solution cavities in the bedrock. During drilling, air loss was minimal and no cavities were intersected across the sites hence receptacle development is unlikely.

- *Mobilization and mobilizing agent*

The mobilization potential by head ward erosion due to water ingress from leaking services of surface ponding is low. In a dewatering or lowering of the groundwater level scenario, the mobilisation potential is medium for a sinkhole or subsidence to form because the groundwater rests within the blanketing layer.

- *Maximum potential development space*

The potential development space at the site is very limited as the bedrock is generally present at shallow depths (<15 m) and is also overlain by relatively strong and competed pedogenic calcrete.

All IHC results for individual boreholes are given in Table 3. They were assigned on the basis of overburden material properties, receptacle development, mobilising potential and potential development space as outlined in Hazard (stability) characterisation procedure section 8.

**Table 8: Characterisation of sinkhole hazard formation.**

| BH No. | Thickness of overburden (m) | Receptacles | Overburden Mobilization potential | Potential maximum sinkhole size | Water rest level recorded after 24 hrs. (m) | Depth to bedrock (m) | Hazard characterization (sinkhole or/ doline formation) | IHC |
|---|---|---|---|---|---|---|---|---|
| CH 01 | 0 – 28 Aeolian sands, calcrete weathered dolomite | No air loss and medium to good sample recovery (75-100%) | Low to Medium | Large sinkhole | 30.0 | 28 -48 Unweathered dolomite | Medium | 3//3 |
| CH 02 | 0 – 11 Aeolian sands, calcrete | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 5.00 | 11 - 60 Unweathered dolomite. | Medium | 3//3 |
| CH 03 | 0 – 21 Aeolian sands, calcrete weathered dolomite | No air loss and good sample recovery (100%) | Low to medium | Large sinkhole | 58.7 | 21 -60 Unweathered dolomite. | Medium | 4//1 |
| CH 04 | 0 – 21 Aeolian sands, calcrete | No air loss and good sample recovery (90%) | Low to Medium | Medium sinkhole | 4.60 | 21- 37 Unweathered dolomite. | Medium | 3//3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CH 05 | 0 – 5 Aeolian sands, calcrete | No air loss and good sample recovery (90%) | Low to Medium | Medium sinkhole | 24.6 | 5 – 25 Unweathered dolomite. | Medium | 3//1 |
| CH 06 | 0 –17 Aeolian sands, calcrete. | No air loss and good sample recovery (100%). | Low to medium | Large sinkhole | 7.00 | 17 - 30 Unweathered dolomite. | Medium | 4//3 |
| CH 07 | 0 – 14 Aeolian sands, calcrete. | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 24.0 | 14 - 28 m Unweathered dolomite. | Medium | 3//1 |
| CH 08 | 0 – 24 Aeolian sands Calcrete Weathered dolomite. | No air loss and good sample recovery (80%). | Low to Medium | Large sinkhole | 43.0 | 24 - 60 Unweathered dolomite | Medium | 4//1 |
| CH 09 | 0 – 12 Aeolian sands, calcrete. | No air loss and good sample recovery (100%) | Low to medium | Medium sinkhole | 10.4 | 12 - 25 Unweathered dolomite. | Medium | 3//3 |
| CH 10 | 0 – 13 Aeolian sands, calcrete. | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | 13.47 | 13 - 37 Unweathered dolomite. | Medium | 3//1 |
| CH 11 | 0 – 13 Aeolian sands, calcrete. | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | 12.0 | 13 - 60 Unweathered dolomite. | Medium | 3//3 |
| CH 12 | 0 – 60 Aeolian sands, calcrete. weathered dolomite | No air loss and good sample recovery (100%) | Low to medium | Large sinkhole | 9.00 | >60 Unweathered dolomite. | Medium | 4//3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CH 13 | 0 – 45 Aeolian sands, calcrete, weathered dolomite | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | - | 45 - 55 Unweathered dolomite. | Medium | 4//3 |
| CH 14 | 0 – 12 Aeolian sands, calcrete. | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 9.1 | 12 - 60 Unweathered dolomite. | Medium | 4//3 |
| CH 15 | 0 – 26 Aeolian sands, calcrete. weathered dolomite | No air loss and good sample recovery (95%) | Low to medium | Large sinkhole | 9.00 | 26 – 40 Unweathered dolomite. | Medium | 4//3 |
| CH 16 | 0 – 11 Aeolian sands, calcrete | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | - | 11 - 31 Unweathered dolomite. | Medium | 3//3 |
| CH 17 | 0 – 60 Aeolian sands, calcrete weathered dolomite | No air loss and good sample recovery (100%) | Low to Medium | Large sinkhole | - | >60 Unweathered dolomite. | Medium | 4//3 |
| CH 18 | 1 – 13 Aeolian sands, calcrete | No air loss and good sample recovery (100%) | Low to medium | Medium sinkhole | 14.28 | 13 - 31 Unweathered dolomite | Medium | 3//1 |
| CH 19 | 0 – 12 Aeolian sands, calcrete. | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | 9.49 | 12 - 60 Unweathered dolomite. | Medium | 3//3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CH 20 | 0 – 13 Aeolian sands, calcrete. | No air loss and medium to good sample recovery (75 - 100%). | Low to Medium | Medium sinkhole | 10.0 | 13 - 30 Unweathered dolomite. | Medium | 3//3 |
| CH 21 | 0 – 15 Aeolian sands, calcrete | No air loss and good sample recovery (100%) | Low to medium | Medium sinkhole | 11.5 | 15 - 40 Unweathered dolomite. | Medium | 3//3 |
| CH 22 | 0 – 11 Aeolian sands, calcrete | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | 7.80 | 11 - 37 Unweathered dolomite. | Medium | 3//3 |
| CH 23 | 0 – 35 Aeolian sands, calcrete weathered dolomite | No air loss and good sample recovery (100%). | Low to Medium | Large sinkhole | 8.09 | 35 - 60 Unweathered dolomite. | Medium | 4//3 |
| CH 24 | 0 – 11 Aeolian sands, calcrete | No air loss and good sample recovery (90%). | Low to medium | Medium sinkhole | 10.4 | 11 - 55 Unweathered dolomite. | Medium | 3//3 |
| CH 25 | 0 – 14 Aeolian sands, calcrete | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | 8.75 | 14 - 25 Unweathered dolomite. | Medium | 3//3 |
| CH 26 | 0 – 12 Aeolian sands, calcrete | No air loss and medium to good sample recovery (75- 100%). | Low to Medium | Medium sinkhole | 8.00 | 12 - 24 Unweathered dolomite. | Medium | 3//3 |
| CH 27 | 0 – 11 Aeolian sands, calcrete | No air loss and good sample recovery (100%). | Low to medium | Medium sinkhole | - | 11 – 31 Unweathered dolomite. | Medium | 3//3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CH 28 | 0 – 12 Aeolian sands, calcrete | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | 9.00 | 12 - 31 Unweathered dolomite | Medium | 3//3 |
| CH 29 | 0 – 10 Aeolian sands, calcrete | No air loss and good sample recovery (100%). | Low to Medium | Medium sinkhole | 8.00 | 10 - 22 Unweathered dolomite. | Medium | 3//3 |
| CH 30 | 0 – 13 Aeolian sands, calcrete | No air loss and good sample recovery (100%). | Low to medium | Medium sinkhole | 8.81 | 13 - 60 Unweathered dolomite. | Medium | 3//3 |
| CH 31 | 0 – 10 Aeolian Sands Calcrete | No air loss and medium sample recovery (50%) | Low to Medium | Medium sinkhole | 7.9 | 10 – 21 Unweathered dolomite | Medium | 3//3 |
| CH 32 | 0– 11 Aeolian Sands Calcrete | No air loss and good sample recovery (90%) | Low to Medium | Medium sinkhole | - | 11 – 43 Unweathered dolomite | Medium | 3//3 |
| CH 33 | 0 – 10 Aeolian Sands Calcrete | No air loss and good sample recovery (100%) | Low to medium | Medium sinkhole | 8.5 | 10 – 19 Unweathered dolomite | Medium | 3//3 |
| CH 34 | 0 – 9 Aeolian Sands Calcrete | Slight to no air loss and good sample recovery (90%) | Medium | Medium sinkhole | 8.54 | 9 – 60 Unweathered dolomite | Medium | 3//3 |
| CH 35 | 0 – 9 Aeolian Sands Calcrete | No air loss and good sample recovery (80%) | Low to medium | Medium sinkhole | 9 | 9 - 32 Unweathered dolomite | Medium | 3//1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CH 36 | 0– 9<br>Aeolian Sands<br>Calcrete | Slight to no air loss and medium to good sample recovery (70%) | Low to medium | Medium sinkhole | 11.8 | 9 – 30<br>Unweathered dolomite | Medium | 3//1 |
| CH 37 | 0 – 10<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Low<br>Medium | Medium sinkhole | 8.9 | 10 - 60<br>Unweathered dolomite | Medium | 3//3 |
| CH 38 | 0– 8<br>Aeolian Sands<br>Calcrete | Slight to no air loss and good sample recovery (80%) | Low to medium | Medium sinkhole | 8 | 8 – 35<br>Unweathered dolomite | Low to Medium | 3//1 |
| CH 39 | 0 – 11<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (90%) | Low to Medium | Medium sinkhole | 7.8 | 11 - 26<br>Unweathered dolomite | Medium | 3//3 |
| CH 40 | 0 – 9<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 6.7 | 9 - 40<br>Unweathered dolomite | Medium | 3//3 |
| CH 41 | 0 – 8<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Low to Medium | Large sinkhole | 7.4 | 8 - 43<br>Unweathered dolomite | Medium | 3//3 |
| CH 42 | 0 – 13<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Medium (to high?) | Medium sinkhole | 7.6 | 13 – 42<br>Unweathered dolomite interlayered with dolerite | Medium | 4//3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CH 43 | 0 – 30<br>Aeolian Sands<br>Calcrete<br>Dolomite<br>residuum? | No air loss and good sample recovery (100%) | Medium (to high?) | Large sinkhole | 7.2 | 30 – 43<br>Unweathered dolomite interlayered with dolerite | Medium | 4//3 |
| CH 44 | 0 – 12<br>Aeolian Sands<br>Calcrete | Slight air loss and good sample recovery (80%) | Low to Medium | Medium sinkhole | 5.8 | 12 - 31<br>Unweathered dolomite | Medium | 3//3 |
| CH 45 | 0 – 10<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 7.6 | 10 – 60<br>Unweathered dolomite | Medium | 3//3 |
| CH 46 | 0 – 31<br>Aeolian Sands<br>Calcrete<br>weathered dolomite | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 13.6 | 31 - 60<br>Unweathered dolomite | Medium | 3//1 |
| CH 47 | 0 – 8<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 4.6 | 8 – 40<br>Unweathered dolomite | Medium | 3//3 |
| CH 48 | 0 – 12<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (90%) | Low to medium | Medium sinkhole | 8.8 | 12 - 31<br>Unweathered dolomite | Medium | 3//3 |
| CH 49 | 0 – 10<br>Aeolian Sands<br>Calcrete | Slight air loss and good sample recovery (80%) | Low to Medium | Medium sinkhole | - | 10 - 60<br>Unweathered dolomite | Medium | 3//3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CH 50 | 0 – 9<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (90%) | Low to Medium | Medium sinkhole | 4.9 | 9 - 43<br>Unweathered dolomite | Medium | 3//3 |
| CH 51 | 0 – 10<br>Aeolian Sands<br>Calcrete | Slight to no air loss and good sample recovery (80%) | Low to medium | Medium sinkhole | - | 10 – 31<br>Unweathered dolomite | Medium | 3 |
| CH 52 | 0 – 12<br>Aeolian Sands<br>Calcrete | Slight to no air loss and good sample recovery (90%) | Low to Medium | Medium sinkhole | 5.4 | 12 - 37<br>Unweathered dolomite | Medium | 3//3 |
| CH 53 | 0 – 8<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (95%) | Low to Medium | Medium sinkhole | 5 | 8 – 37<br>Unweathered dolomite | Medium | 3//3 |
| CH 54 | 0 – 10<br>Aeolian Sands<br>Calcrete | Slight to no air loss and good sample recovery (90%) | Low to medium | Medium sinkhole | 4.8 | 10 – 25<br>Unweathered dolomite | Medium | 3//3 |
| CH 55 | 0 – 23<br>Aeolian Sands<br>Calcrete<br>weathered dolerite | No air loss and good sample recovery (100%) | No Hazard | None | 58.7 | 23 - 60<br>Unweathered Dolerite | None | 1//1 |
| CH 56 | 0 – 23<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (90%) | Low to medium? | Small to medium? | 5.2 | 23 - 60<br>Unweathered Dolerite with minor dolomite | Low to medium | 4//1 |

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|---|---|---|---|---|---|---|---|---|
| CH 57 | 0 – 11<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Low to medium | Medium sinkhole | 2.4 | 11 - 46<br>Unweathered dolomite interlayered with dolerite | Medium | 3//3 |
| CH 58 | 0 – 8<br>Aeolian Sands<br>Calcrete | No air loss and good sample recovery (100%) | Low to Medium | Medium sinkhole | 2.8 | 8 - 42<br>Unweathered dolomite interlayered with dolerite | Medium | 3//3 |
| CH 59 | 0 – 13<br>Aeolian Sands<br>Calcrete | Slight air loss and good sample recovery (90%) | Low to Medium | Medium sinkhole | 6 | 13 - 60<br>Unweathered dolomite | Medium | 3//3 |
| CH 60 | 0 – 10<br>Aeolian Sands<br>Calcrete | Slight air loss and good sample recovery (80%) | Low to medium | Medium sinkhole | - | 10 - 37<br>Unweathered dolomite | Medium | 3//3 |
| MBH 01 | 0 – 11<br>Calcrete<br>Weathered dolomite | Slight air loss and good sample recovery (80%) | Low to medium | Medium sinkhole | 17 | 11 – 30<br>Unweathered dolomite | Medium | 3//1 |
| MBH 02 | 0 – 6<br>Calcrete | Slight air loss and good sample recovery (80%) | Low to medium | Medium sinkhole | 9 | 6 – 60<br>Unweathered dolomite | Medium | 3//1 |

# 9. CONCLUSIONS, PRECAUTIONARY MEASURES AND RECOMMENDATIONS

## 9.1 Summary of Dolomite Hazard

The hazard zonation is based on geophysical surveys and drilling results from 62 boreholes. An assessment of all these based on the method of scenario supposition, Buttrick *et. al.* (2001) favours the site being zoned into one (1) Inherent Hazard Zone as dictated by geological conditions revealed by the drilling results.

Based on the percussion drilling results, geohydrological data and geological information, the dolomite stability of the site is described in terms of the following zones as:

**Zone A**

- *Inherent Hazard Class: 3/4 (1) // 3(1)*

This zone is largely characterised by a medium inherent hazard of a medium (2-5 m diameter) sinkhole and subsidence (with sub areas of medium inherent hazard of large [5-15 m diameter] sinkhole and subsidence) in a non-dewatering scenario. The inherent hazard for any size sinkhole and subsidence is medium with respect to a dewatering scenario.

The non-dolomitic overburden consists of aeolian deposits and pedogenic calcrete which is in a form of hardpan and calcified nodules in places. This zone occupies all gravity zones (i.e. highs, lows and gradients). Neither wad nor low density material was recorded in the boreholes drilled. The groundwater level rests within the blanketing layer.

- *Dolomitic Area Designation*

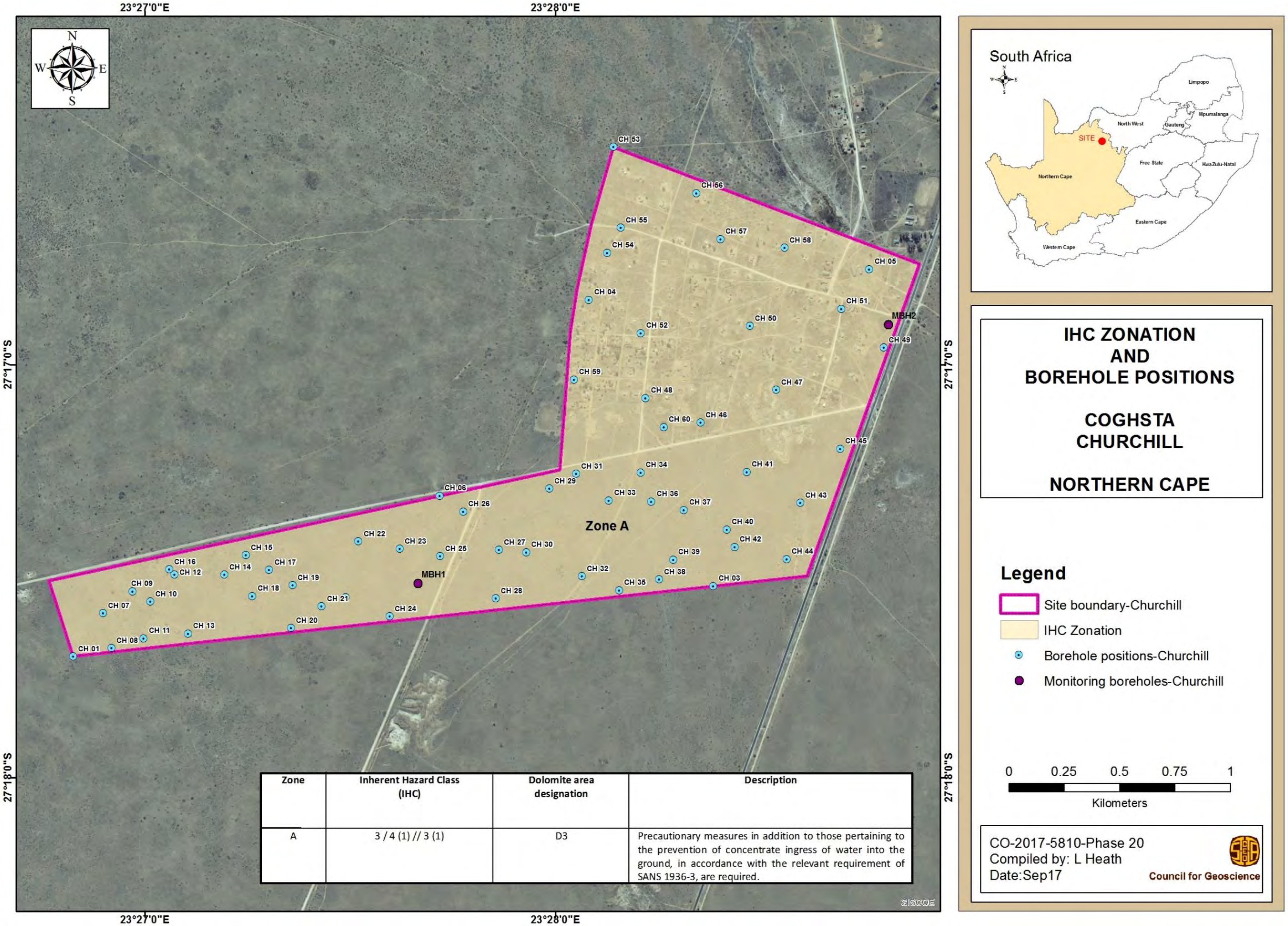
This zone is assessed as D3 and implies that extra precautionary measures in addition to those pertaining to the prevention of concentrated ingress of water into the ground, in accordance with the relevant requirements of SANS 1936-3, are required and must be adhered to.

- *Location*

The zone covers the entire site boundary area.

- *Development Potential*

Restrictions are placed on the types of residential development that may be considered on Class 3 land. Full title residential development (RN2-3) on stands of 300 $m^2$ or greater is recommended or 10 – 25 dwelling houses per hectare and a population if ≤ 60 people per hectare is recommended. Any form of commercial, retail and/or light industrial development is permissible (C1 to C10) as in SANS 1936-1(2012) Table 1 with appropriate stringent precautionary measures. Footprint investigations are required for each commercial development.




| Zone | Inherent Hazard Class (IHC) | Dolomite area designation | Description |
|---|---|---|---|
| A | 3 / 4 (1) // 3 (1) | D3 | Precautionary measures in addition to those pertaining to the prevention of concentrate ingress of water into the ground, in accordance with the relevant requirement of SANS 1936-3, are required. |

**Figure 7: Interpreted Inherent Hazard Classes (IHC) zones**

## 9.2 Drainage, Monitoring and General Precautionary Measures

### 9.2.1 Drainage

The ingress of surface water can have dire implications for dolomite stability and strict drainage measures must be implemented. It is important that prospective developers of the township are made aware of the importance of the recommended precautionary measures as stipulated in SANS 1936-3 (2012) and these include:

- All pipes and channels must be watertight, with all wet services being tested for leakage on installation,
- Piping material should be appropriate to local subsurface conditions,
- No accumulation or ponding of surface water should occur adjacent to foundations both during and after construction.
- Storm water should be effectively captured and led away from all structures preferably by means of lined, surface canals.

### 9.2.2 Monitoring

Frequent monitoring and maintenance is recommended for the whole site for the purposes of identifying the effects of concentrated ingress of water or groundwater level drawdown. The generic activities considered appropriate are as follows:

- Visual inspection of ground, structures and above ground infrastructure (e.g. roads, storm water canals, ditches).
- Visual inspection of storm water systems crossing the site for blockages.
- Testing of wet-services for leaks
- Monitoring of structures and ground levels.
- Monitoring of the groundwater level.

### 9.2.3 Precautionary measures

The prevention of sinkhole and subsidence formation is largely related to the control and or removal of the triggering mechanism i.e. the prevention of ingress water/dewatering. NHBRC and SANS 1936-3 (2012) water precautionary measures must be implemented for the site (Appendix 4). All water borne services must meet SANS 1936-3 (2012) requirements for water ingress prevention measures.

SANS 1936-1 requires the owners of the infrastructure on parcels of land categorized as dolomite area designation D2, D3 and D4 sites to implement appropriate dolomite risk management strategies in accordance with the principles and requirements of SANS 1936-4 in order to mitigate the risks associated with the development of such land. SANS 1936-1 also provides requirements for local authorities to establish implement and maintain a dolomite risk management strategy.

A Competent Person must be appointed to compile a site specific ***Dolomite Risk Management Strategy (DMRS)***. Such a plan, which is considered beyond the scope of this investigation, should define ongoing processes to manage water ingress and assign responsibilities to particular persons. General principles are attached in Appendix 5. Groundwater Monitoring should also form part of the DRMS.

## 9.3 Recommendations

- It is recommended that the municipality sets up at least two groundwater monitoring boreholes distributed across the current study area to establish trends.Any future developments must be investigated in accordance with SANS 1936-2 (2012).
- A high density development, i.e. 150 $m^2$ stands or developed as group housing such as a block of flats, has a greater probability of inducing a sinkhole than a commercial development on the same property because of the higher density of wet services and greater chance of an undetected leak. Therefore, new development should take into cognizance the allowable land use densities shown in Appendix 3 as per SANS 1936-1 (2012) permissible land use Tables.
- Based on this feasibility study, the entire site is suitable for most planned low cost housing development.
- Any signs of ground instabilities or subsidence should be reported immediately to the municipality, and remediated in accordance with SANS 1936-4 (2012).

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