CHAPUDI COAL PROJECT

GROUNDWATER FLOW
IMPACT ASSESSMENT REPORT

DECEMBER 2013

WSM LESHIKA CONSULTING (PTY) LTD

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GROUNDWATER FLOW IMPACT ASSESSMENT REPORT

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Job WH13077 – Chapudi Coal Project

COMPILED BY

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LIST OF ACRONYMS

C	Celsius
CoAL	Coal of Africa Limited
DMR	Department of Mineral Resources
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
GRA II	Groundwater Resources Assessment Study II
GRIP	Groundwater Resources Information Project
GSP	Greater Soutpansberg Projects
Ha	Hectare or 10 000 m^2
LMB	Limpopo Mobile Belt
Ma	Million years ago
Mbgl	metres below ground level
mamsl	metres above mean sea level
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MIA	Mining infrastructure area
MODFLOW	Numerical groundwater modeling programme
MPRDA	Mineral and Petroleum Resources Development Act (Act 28 of 2002)
MRA	Mining right application
Mtpa	Million tonnes per annum
NGDB	National Groundwater Data Base
NOMR	New Order Mining Right
RLT	Railway Load-out Terminal
RoM	Run of Mine
RMF	Regional Maximum Flood
RoM	Run of Mine
TIN	Triangular Irregular Network
WR2005	Water Resources 2005 study
WQT	Water Quality Threshold

UNITS OF MEASUREMENT

1 Ml = 1 000 Kl = 1 000 m^3 = 1 000 000 l

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1. INTRODUCTION

An application for a New Order Mining Right (NOMRs) in terms of Section 22 of the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) for the Chapudi Coal Project has been lodged by Coal of Africa Limited (CoAL) to the Department of Mineral Resources (DMR). The Chapudi Project forms part of a set of proposed mining projects collectively known as the Greater Soutpansberg Project (GSP) situated to the north of the Soutpansberg in the Limpopo Province. Similar applications for NOMR's have already been submitted by CoAL and/or subsidiary companies held by them in the Greater Soutpansberg area. The locality of the project relative to some of the main towns in the Limpopo Province is indicated in Figure 1.

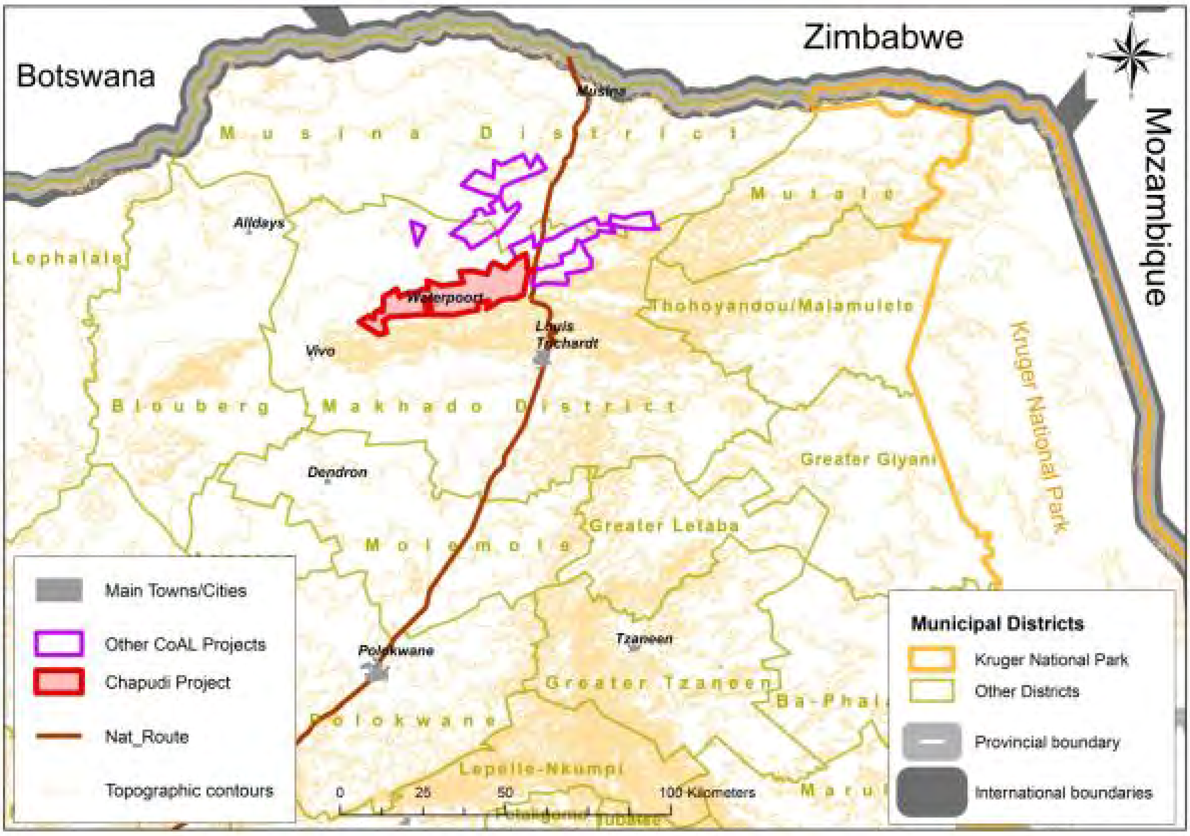

FIGURE 1: COAL GREATER SOUTPANSBERG PROJECTS IN THE LIMPOPO PROVINCE

As evident from the locality map, the various projects are close to each other, permitting rationalisation of infrastructure. The objective is to have a consolidated project with economically minable blocks which are contiguous.

WSM Leshika Consulting was appointed to conduct the groundwater flow study for the Environmental Impact Assessment (EIA) for the proposed Chapudi Colliery Project. See Appendix A for WSM Leshika's statement of independency, the details of the project team and their curriculum vitae

The EIA report describes the current groundwater status and the potential impact on the groundwater flow, of the Chapudi Colliery Project. The other surrounding CoAL Projects were taken into account and cumulative impacts evaluated.

2. PROJECT DESCRIPTION

The Chapudi and Chapudi West Sections cover an area of 4 321 ha, and the Wildebeesthoek Section covers approximately 3 254 ha, for mining and infrastructure development.

The mining and infrastructure layouts are shown in Figure 2. This Figure demonstrates the total extent of mining and is not a moment in time. The pits will be backfilled concurrent to mining and it is anticipated that no more than 600 ha will be open at any one time.

The Chapudi Project has the potential to produce good quality semi soft coking coal and a domestic thermal coal product. Measured and indicated resources are approximately 1 3874 million tonnes mineable in situ.

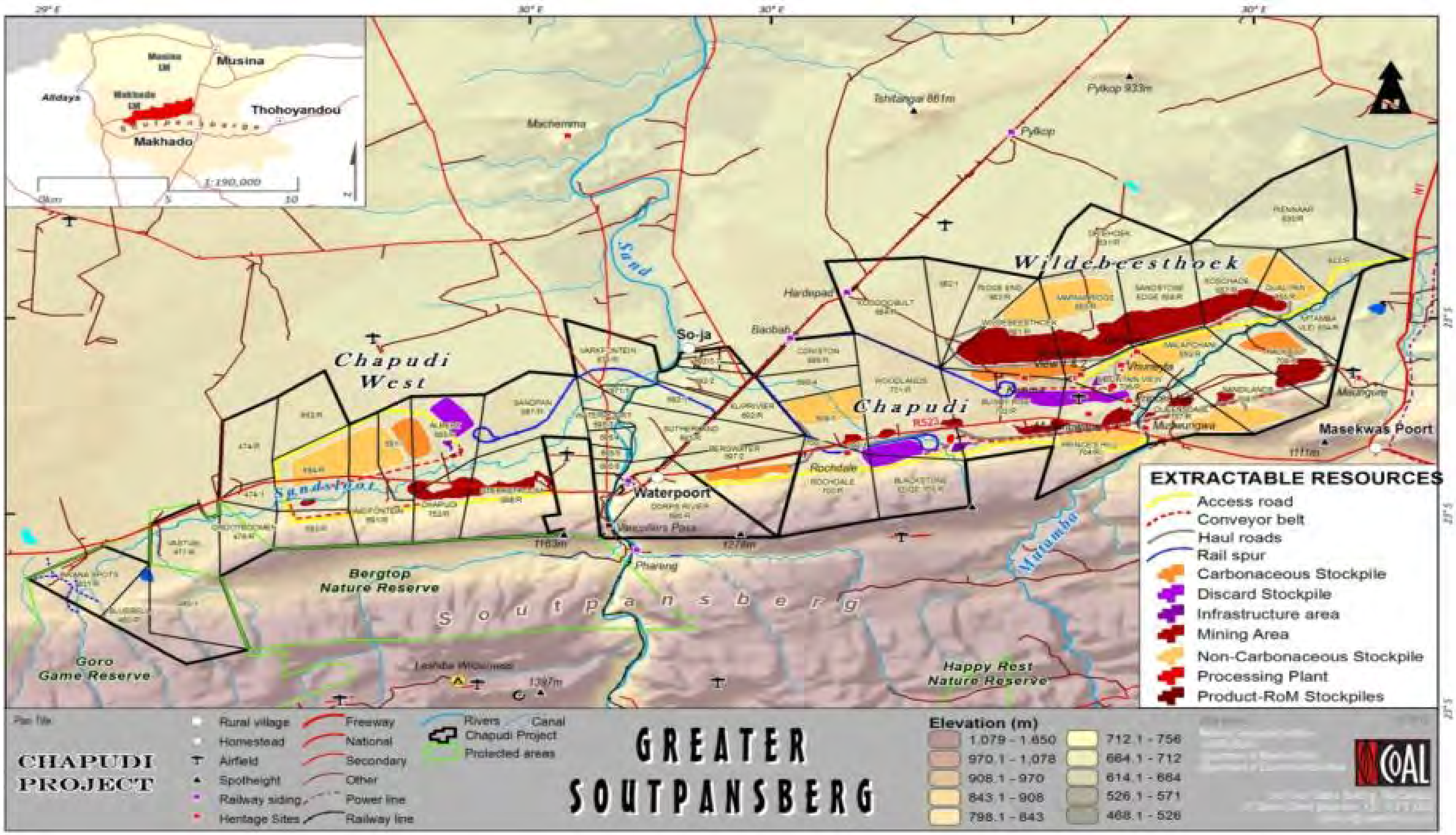

FIGURE 2: PROPOSED MINING LAYOUT WITH PITS AND DUMP MATERIAL

The current planning is that construction and mining will commence at the Wildebeesthoek Section first where the coking coal yields are the highest. It is expected that mining operations at the Chapudi Sections will only commence much later (in terms of current data towards 2033) by which time the Transnet infrastructure will be have been enhanced to cope with the greater annual production of coal from the Project.

The Wildebeesthoek Section will be mined at 12.5 Mtpa, whilst the Chapudi and Chapudi West Sections combined will be mined at 12.5 Mtpa and the life of mine (LOM) is expected to exceed 30 years.

From the date of granting of the mining right (anticipated to be in 2015) further prospecting, feasibility studies and final design studies will be undertaken. Construction will only commence in 2018.

The Chapudi Project is planned as open pit operations where the extraction of coal is a total extraction mining method using conventional truck and shovel. The mining process involves stripping, drilling, blasting, loading and hauling of overburden to the waste dumped and run of mine (ROM) stockpile or processing plant area.

Infrastructure to support the mining activities has been laid out and engineered to best suit the topography and mining pit layouts, but can be influenced by the environmental impact assessments and stakeholder engagement process.

Each of the Wildebeesthoek, Chapudi and Chapudi West Sections will require a dedicated coal beneficiation plant. The total ROM capacity for the Wildebeesthoek beneficiation plant is 12.5 Mtpa with the Chapudi Section supplying 8 Mtpa to a large beneficiation plant and the Chapudi West Section supplying 4.5 Mtpa to a smaller beneficiation plant.

The mine infrastructure areas (MIA) comprise all the facilities, roads, services and systems required for the mine to operate optimally. The individual mining sections will be provided with workshops and other necessary infrastructure required for the mining operation.

The centrally located infrastructure will comprise a coal beneficiation plant, personnel support structures, vehicle support structures, water management structures and management and monitoring systems.

Buildings will include management offices, production offices, change house, medical and fire fighting facility, shift changing facility, security and access control, training centre, control room and contractors accommodation camp (during construction only).

Other mine infrastructure includes:

- Access and on-site haul roads
- Topsoil stockpiles and berms
- Overburden (carbonaceous and non-carbonaceous) stockpiles for initial placement, thereafter to be disposed in-pit
- RoM coal storage area
- RoM coal processing plant (primary, secondary and tertiary crusher)
- Associated conveyors from the processing plant to the product storage areas
- Product stockpile areas
- Carbonaceous discards stockpile
- Storm water management infrastructure (i.e. clean & dirty water run-off canals and dams)
- On-site water management and reticulation systems
- Change houses and offices
- Wastewater (sewage) treatment plant
- Bulk electricity supply infrastructure
- Bulk water supply infrastructure
- Railway Siding and rail loop
- Rapid Load-out Terminal (RLT)

3. GENERAL DESCRIPTION OF THE STUDY AREA

3.1 LOCALITY

The Chapudi Project is situated in the magisterial district of Vhembe, in the Limpopo Province, approximately 20 km (direct) and 25 km (via road) north of the town of

Makhado and 32 km south of Mopane by rail in the Makhado Local Municipal areas. The town of Musina, is situated approximately 55 km to the north (Figure 3).

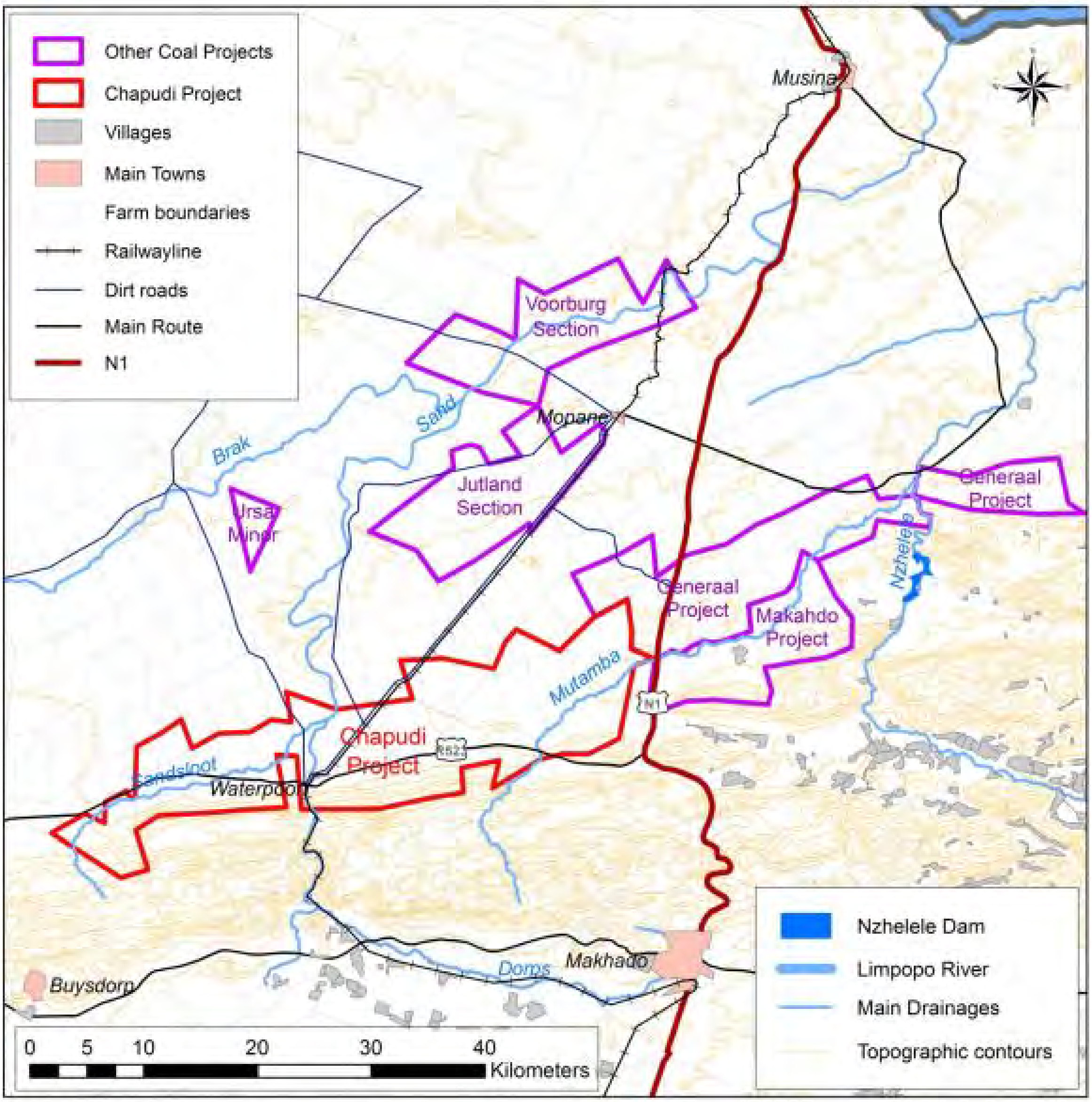

FIGURE 3: CHAPUDI PROJECT LOCALITY

The Chapudi Project, consisting of the Chapudi, Western and Wildebeesthoek Sections, is well situated with respect to major infrastructure, including rail, road and power. The Chapudi and Wildebeesthoek Sections link to the N1 road via the regional road R523 some 10 km in length travelling eastwards. The Western Section is located further west of the previous sections and is also linked by the R523 road some 24km travelling westwards. Private roads to connect mine infrastructure will need to be established.

3.2 CLIMATE

3.2.1 REGIONAL CLIMATE

The Chapudi Project area is situated in a semi-arid zone to the north of the Soutpansberg. The regional climate is strongly influenced by the east-west orientated mountain range which represents an effective barrier between the south-easterly maritime climate influences from the Indian Ocean and the continental climate influences (predominantly the Inter-Tropical Convergence Zone and the Congo Air Mass) coming from the north.

The southern Sand River Basin is within a cold semi-arid zone summer rainfall area of 500 to 600 mm precipitation. The Chapudi Project is located in the hot-arid zone to the north of the Soutpansberg where the rainfall decreases to 400-500 mm. High precipitation occurs on the Soutpansberg which creates high local runoff. The area is characterized by cool, dry winters (May to August) and warm, wet summers (October to March), with April and September being transition months.

The mountains give rise to wind patterns that play an important role in determining local climates. These wind effects include wind erosion, aridification and air warming.

3.2.2 PRECIPITATION

The project area is affected by 2 quaternary catchments A71J and A80F (Figure 3), defined in the WR2005 Study (Middleton and Bailey, 2009).

The quaternary catchment A71J is located in Rainfall Zone A7C, whereas catchment A80F falls within Rainfall Zone A8A. The mean monthly precipitation values are given in Table 1 below.

Table 1: Mean monthly rainfall distribution of site rainfall (Zone A7C and A8A)

Rainfall Zone	Mean Monthly Precipitation (% Distribution)											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
A7C	7.33	15.11	16.81	19.04	16.23	12.55	5.83	2.54	1.25	1.01	0.77	2.39
A8A	6.46	11.81	15.17	20.17	18.66	13.16	5.40	2.29	1.63	1.66	1.15	2.43

(Source: Middleton, B.J. and A.K. Bailey (2009). Water Resources of South Africa, 252005 Study. WRC Rep No TT381. Pretoria)

The absolute monthly rainfall (% distribution x MAP), for the 2 affected quaternary catchments is shown in Table 2 below. The average rainfall for the 2 catchments have been determined and the maximum rainfall of 81mm occurs in January and the lowest of 1mm in August.

Table 2: Mean monthly quaternary rainfall (mm)

Quaternary Catchment	Mean Annual Precipitation (mm)	Rainfall Zone	Mean Monthly Precipitation (mm)											
			OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
A71J	396	A7C	29	59	68	81	68	47	21	8	5	3	1	10
A80F	388	A8A	25	46	59	78	72	51	21	9	6	6	4	9

The Mean Annual Precipitation is given in Figure 4 below.

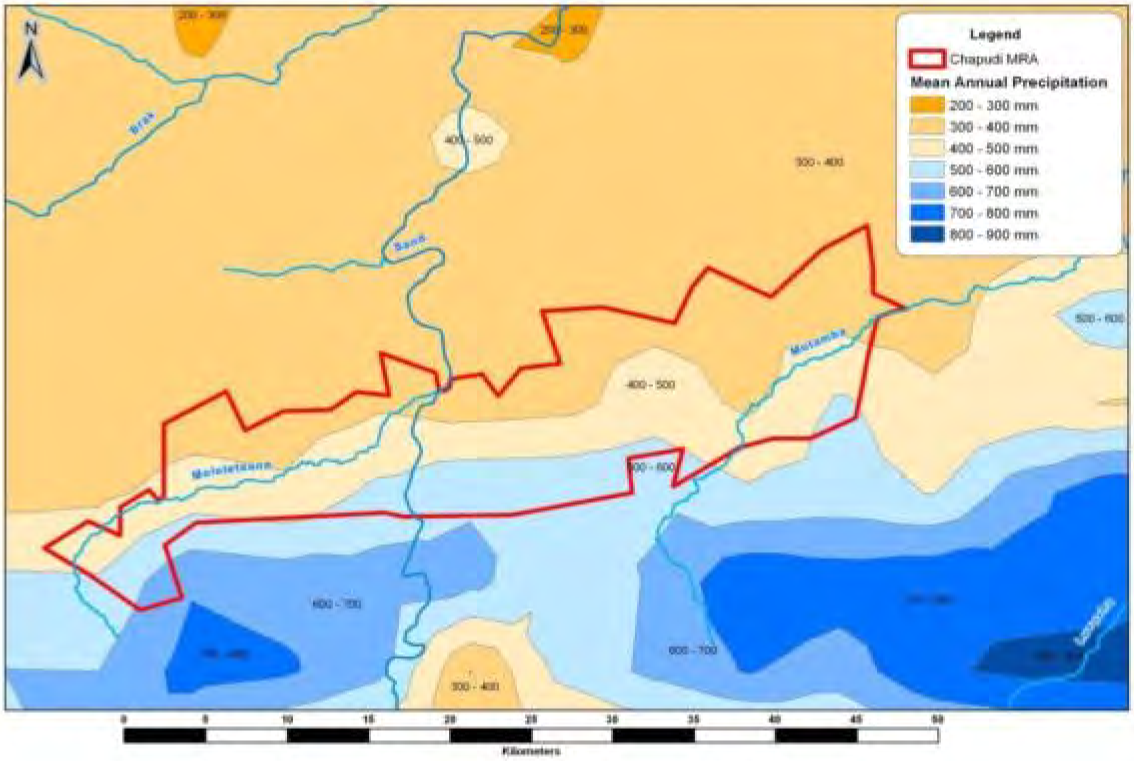

FIGURE 4: MEAN ANNUAL PRECIPITATION IN MM

A baseline study of the Chapudi site was conducted in November 2009 by SRK Consulting (Pty) Ltd. In their surface water report, Report Number 395099/SW/1, they utilised data from the Waterpoort rainfall station (0765234AW), which is located in the centre of the Chapudi Project area, to approximate a mean annual precipitation from the entire record beginning in October 1977 and ending in October 2008. The mean annual precipitation that they calculated was 389 mm per annum.

This correlates to the 396mm mean annual precipitation for rainfall zone A7C and quaternary catchment A71J.

3.2.3 TEMPERATURE

Average monthly minimum and maximum temperatures for the Tshipise weather station (No. 0766277 1) some 50 km north-east of the Chapudi Project area is shown in Table 1 below. Note that this station is the closest station with long term available climate data. Average daily maximum and minimum summer temperatures (November to February) at the weather station range between ~33°C and ~20°C, while winter temperatures (May to August) range between ~28°C and ~7°C respectively. The high average temperatures are reflected by the fact that the minimum average daily summer temperature is a high 20°C and the minimum average daily winter temperature does not dip below 7°C.

TABLE 3: TEMPERATURE DATA FOR TSHIPISE FOR THE PERIOD FROM 1994 TO 2006

Month	Temperature (° C)			
	Highest Recorded	Average Daily Maximum	Average Daily Minimum	Lowest Recorded
January	42.2	32.8	21.5	12.6
February	41.4	32.3	21.5	14.9
March	42.9	31.5	20.1	13.0
April	40.9	30.1	16.3	5.7
May	42.3	27.9	11.2	1.7
June	34.3	25.6	8.2	-0.4
July	34.1	25.0	7.3	-1.2
August	37.4	27.8	10.3	1.7
September	41.2	27.7	12.9	3.6
October	41.4	29.1	16.5	8.0
November	42.5	32.2	20.1	11.1
December	43.4	33.1	21.0	13.8
Year	43.4	29.6	15.6	-1.2

Source: Weather SA (Station No 0766277 1)

The Department of Agriculture's Agricultural Geo-referenced Information System (AGIS) hosts a wide spectrum of spatial information maps for public use. The two figures below, Figure 5 and Figure 6, indicate the maximum and minimum annual temperature for the region that was obtained from their natural resources atlas on climate.

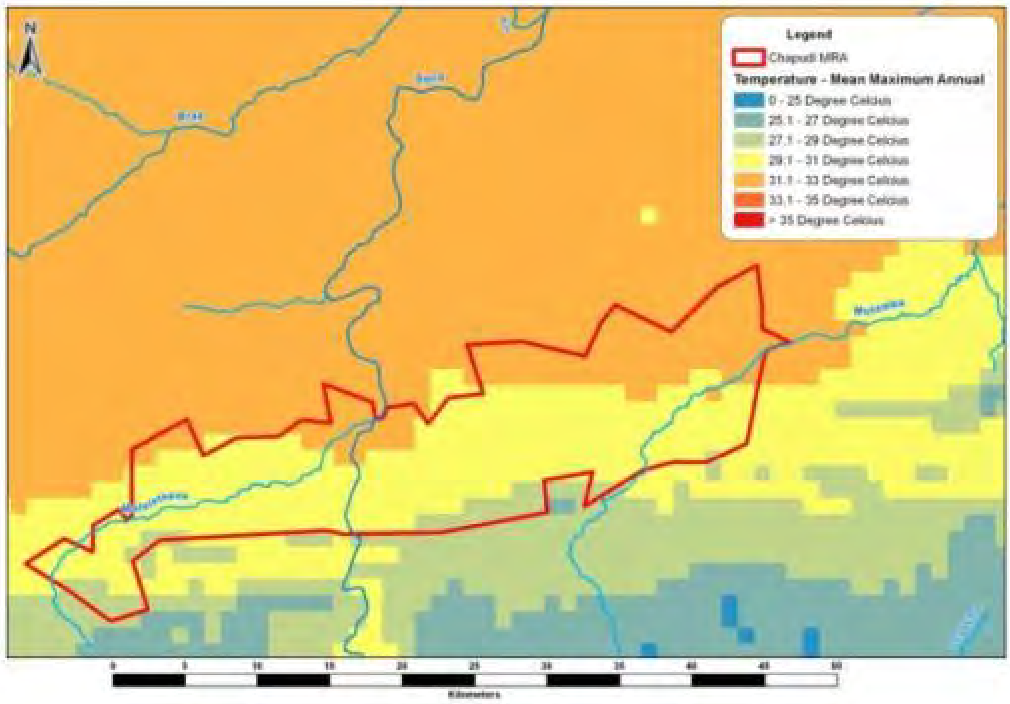

FIGURE 5: MEAN ANNUAL MAXIMUM TEMPERATURE

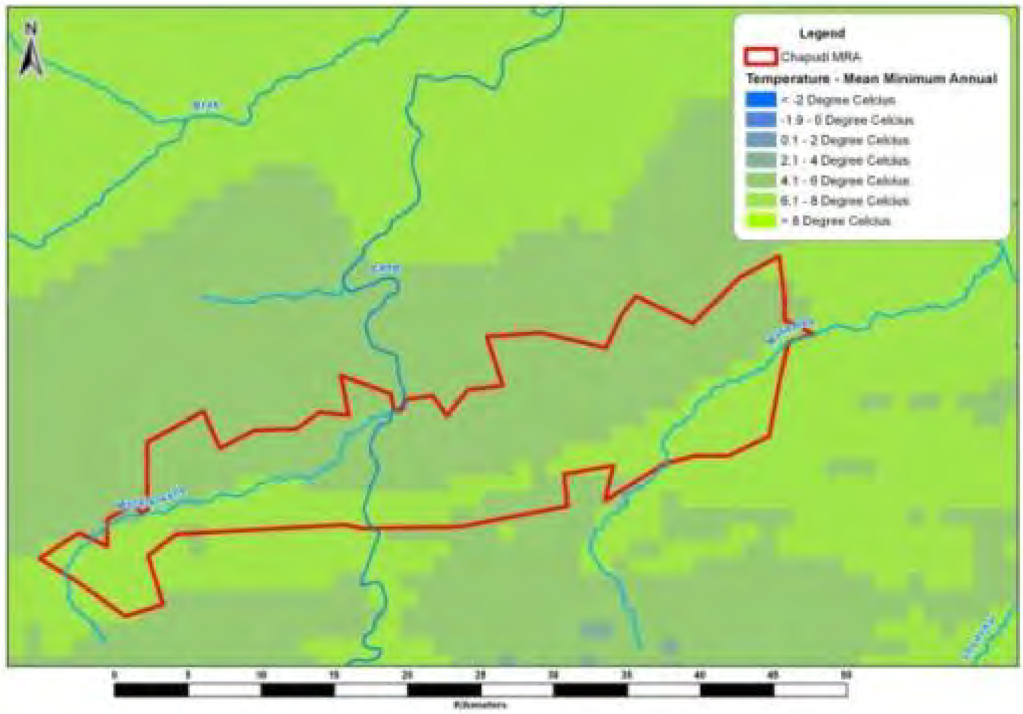

FIGURE 6: MEAN ANNUAL MINIMUM TEMPERATURE

3.2.4 EVAPORATION

The mean annual evaporation data for the 2 quaternary catchments are summarized in the tables below. Mean Annual Evaporation data is given in Table 4 and the monthly evaporation pattern (as percentages of the total) is given in Table 5 below. Note that both the Sand River (A71J) and the Mutamba River (A80F) fall within the same evaporation zone, Evaporation zone 1B

Table 4: Evaporation data per quaternary (from WR2005)

Quaternary catchment	Net area (km^2) A	Mean Annual Precipitation (mm) MAP	Mean Annual (gross) Evaporation (mm) (Zone 1B) MAE
A80F	491	388	1750
A71J	905	396	1800

Table 5: Monthly evaporation distribution
(Source: WR90 Study, Evaporation zone 1B)

Month	Evaporation (%)
October	10.46
November	10.03
December	10.68
January	10.43
February	8.49
March	8.49
April	6.94
May	6.55
June	5.40
July	6.08
August	7.42
September	9.03

3.3 TOPOGRAPHY

Topography is formed as a consequence of the landscaping effect of erosional forces (wind and water) on rocks of variable susceptibility to weathering. The topography is described in the Terrain Morphological Map of Southern Africa consists of “low mountains” to the south“, with extremely irregular plains with moderate relief (almost hilly)” to the east and “slightly undulating plains” to the west of the MRA area.

The Sand River cuts through the Soutpansberg mountain range and emerges at Waterpoort. The mountain range is made up of erosion resistant quartzite and lavas. The flatter terrain to the north of the mountain is underlain by the less erosion resistant sediments of the Karoo Sequence. The sandstone formations within the Karoo sequence form flat topped hills surrounded by undulating plains. The slope in the valley plain gradually increases southwards towards the Soutpansberg Mountains suddenly steepening to 1: 4 up the mountain face. See figure 7.

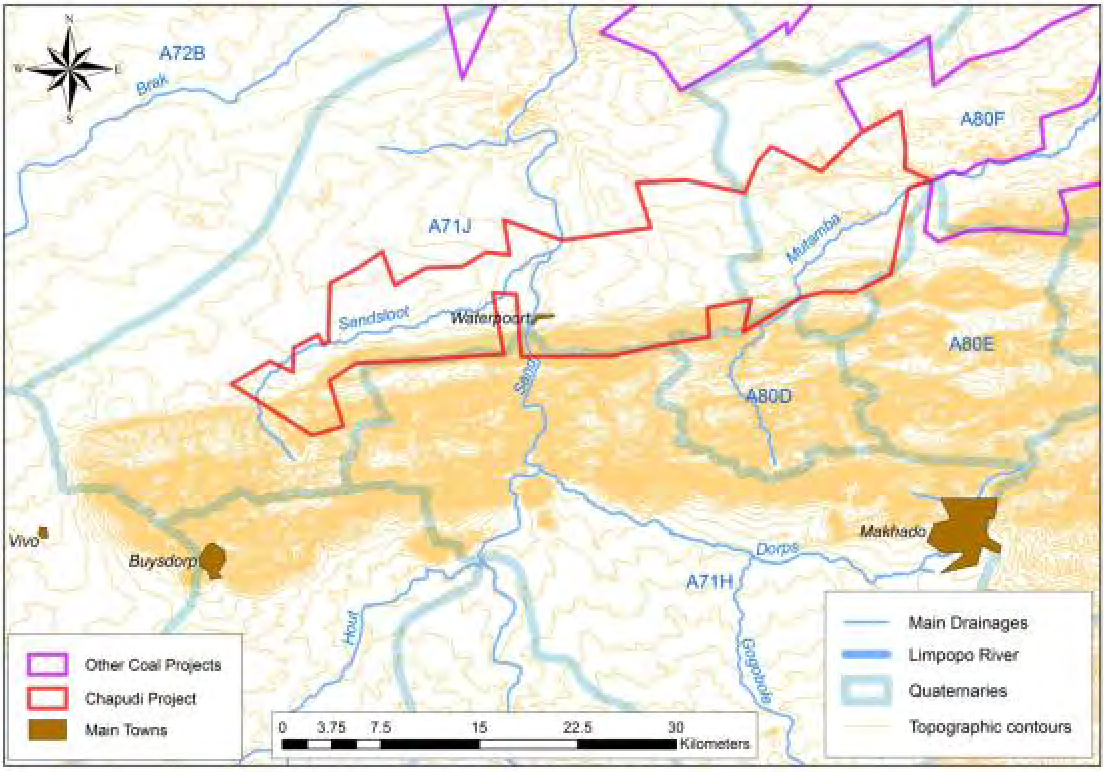

FIGURE 7: TOPOGRAPHY AND DRAINAGES

3.4 CATCHMENTS AND DRAINAGES

The Chapudi Project extends across two quaternary catchments belonging to two separate river systems i.e. the Sand River (A71J) and the Mutamba River (A80F) which is the main tributary to the Nzhelele River, see Figure 7. Both river systems flow into the Limpopo River. The Sand River originates south of Polokwane in a cold semi-arid zone summer rainfall area of 500 to 600 mm precipitation. The Mutamba and Nzhelele Rivers originate in the Soutpansberg Mountains which receive a high precipitation (800 – 1000) and have a high local run-off.

3.5 GEOLOGY

3.5.1 REGIONAL GEOLOGY

The regional geology consists of 3 main lithological groups i.e. the Limpopo Mobile Belt, the Soutpansberg Group and the Karoo Sequence rocks:

i) <u>The Limpopo Mobile Belt (LMB)</u>; forms the gneissic basement on which the overlying strata (Soutpansberg Group and the Karoo Sequence) was deposited. The LMB rocks are the metamorphic expression of the collision and welding together of the Kaapvaal craton and the Zimbabwe craton. The LMB has a long and complex history of deformation occurring from 3200 Ma (million years ago) to 2000 Ma. The LMB gneisses are made up of inter-cratonic sediments and volcanics, deformed and metamorphosed to granulite facies and intruded by granite bodies which have themselves been metamorphosed to varying degrees. The rift fault systems controlling the various basins, in which the Soutpansberg and Karoo strata have been preserved, are major zones of crustal weakness preferentially re-activated during periods of tectonic instability over time.

ii) <u>The Soutpansberg Group</u> strata were deposited into rift basins controlled by these major fault systems between 1900 Ma and 1600 Ma. The strata consist of basaltic lavas, arenites and shales attaining a maximum preserved thickness of 5000m. Dips can vary from 20° to 80° to the north.

iii) The Karoo Sequence strata were deposited on LMB basement and/or Soutpansberg Grp. strata between 300 – 180 Ma. Karoo deposits are preserved in rift basins and are often terminated against major east-west trending faults on their northern margins. The dips are between 3° and 20° to the north with coal located at the base of the sequence. The nature of the coal deposits changes from a multi-seam coal-mudstone association (7 seams) approximately 40m thick in the west (Mopane Coalfield), to two thick seams in the east (Pafuri Coalfield in the Tshikondeni area).

3.5.2 COAL DISTRIBUTION OF THE SOUTPANSBERG COALFIELD

The Chapudi Colliery Project lies within the Soutpansberg Coalfield which stretches for ± 190km from Waterpoort in the west to the Kruger National Park in the east. The Soutpansberg Coalfield has been divided into 3 separate coal fields i.e. the Mopane Coalfield, the Tshipise Coalfield and the Pafuri Coalfield.

The Pafuri Coalfield terminates at the northern limit of the Kruger National Park in the east and is not part of this study.

The Mopane and Tshipise Coal fields are host to several CoAL mining projects at an advanced stage of development (Figure 8).

- The Mopane Coalfield, lies between the towns of Mopane and Waterpoort in the west and is the target of 2 mining projects;
  i) The Chapudi Project
  ii) The Mopane Project

- The Tshipise Coalfield, stretching east of the town of Mopane to Tshipise and is the target of 2 mining projects;
  i) The Makhado Project
  ii) The Generaal Project

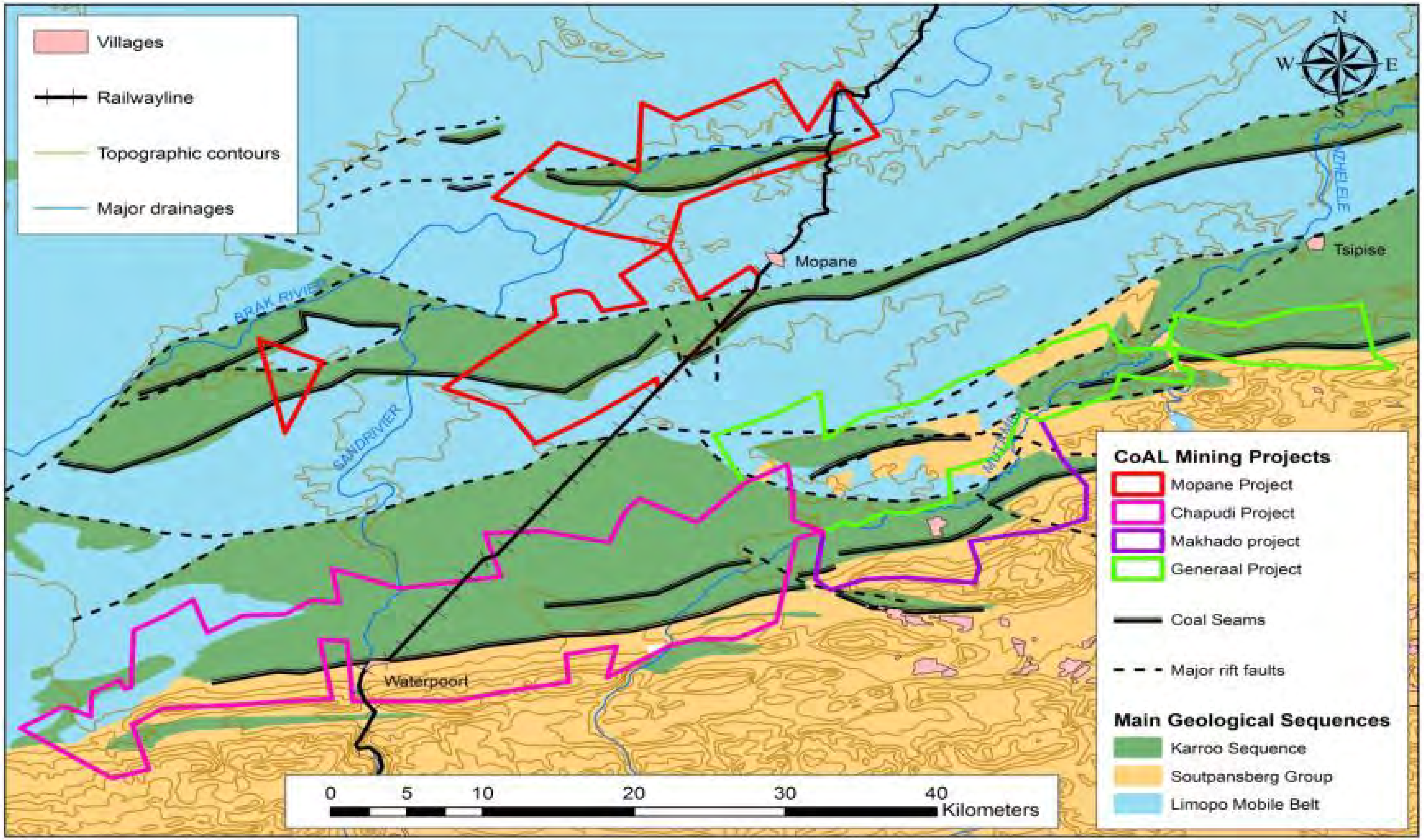

FIGURE 8: REGIONAL GEOLOGY OF COAL MINING PROJECTS WITHIN THE SOUTPANSBERG COALFIELD

3.5.3 CHAPUDI PROJECT GEOLOGY

The Chapudi Project is a 36 km strike length of coal deposited and preserved in a down fault basin at the base of the northern face of the Soutpansberg Mountain range. Karoo strata are deposited unconformably onto Soutpansberg Group strata. The coal deposit targeted by the Chapudi Project has also been labelled as the Waterpoort Coalfield. The coal “seams” are numbered from the base as Seam 1 to 7 at the top. The top of the coal/carbonaceous package ends against a gritty sandstone marker (Fripp Formation). Current estimates indicate that only Seam 6 is economic at present. The strata dip on average at 12^0 to the north and can be mined open cast to a depth of 200m.

The coal will be mined in three sections

i) Wildebeesthoek Section
ii) The Chapudi Section
iii) The Chapudi West Section

The footprint of each section is indicated in Figure 9. The Wildebeesthoek Section (LOM - 30 years) will be mined first followed by The Chapudi Section, starting in 2031 and The Chapudi West section in 2041 with a combined LOM of 43 years.

Stratigraphy

The various stratigraphic units are described in chronological order from oldest to youngest.

<u>Limpopo Mobile Belt</u> rocks occur to the north of the MRA area as the up thrown block of the Tshipise Fault and was adequately described in the preceding section.

<u>Soutpansgroup strata</u> form the mountain range to the south of the MRA area and consist of the following formations;

i) Wylliespoort Formation, a thick weather resistant quartzite which forms the backbone of the Soutpansberg range.
ii) Musekwa Formation consists of amygdaloidal basalt lavas.
iii) Nzhelele Formation consists of red shale and quartzite lenses.

Karoo Super Group strata for purposes of representation were divided into Lower Karoo, Middle Karoo, the Clarens Formation and the Letaba basalts. See Figure 9 and 10.

The Lower Karoo consists of a basal glacial deposit overlain by carbonaceous and coaliferous mudstones. From oldest to youngest the stratigraphy is as follows;

(i) Tshidzi Formation; a 10m thick basal conglomerate/diamictite and can be correlated to glacial Dwyka Tillite in the main Karoo basin.
(ii) The Madzoringwe Formation; a succession of alternating black shale, micaceous sandstone, siltstones and inter-bedded coal seams attaining a thickness of 190m. The coals seams are of economic potential.
(iii) The Mikambeni Formation overlying the above consists of dark grey mudstone and shale with subordinate sandstone attaining an approximate thickness of 140m. The Madzoringwe and Mikambeni Formations can be correlated with the Ecca Group of the main Karoo basin.

The Middle Karoo consists of overlying fluvial deposits made up of sandstones and grey, purple and red mudstones. The stratigraphy from oldest to youngest is as follows;

i) The Fripp Sandstone Formation consists (10 – 20 m) of coarse feldspathic sandstone or “grit” and often forms a ridge on outcrop and marks a change from a mature meandering river depositional environment to a braided stream environment.
ii) The Solitude Formation; is a 110m thick inter-layered grey and purple shale with minor sandstone and grit intercalations.

iii) The Klopperfontein Formation (10 – 20 m) resembles the Fripp Sandstone Formation as a coarse, feldspathic “gritty” sandstone.

iv) The overlying Bosbokpoort consists of red very fine sandstone and dark red silty mudstone.

v) The fluviatile Red Rocks Member (150 m) of the overlying Clarens formation. is also placed in the Middle Karoo strata.

The Tshipise Member (150 m) of the Clarens Formation caps the underlying fluvial sediments with aeolian sands as the final expression of sedimentary deposition in an ever increasingly arid environment.

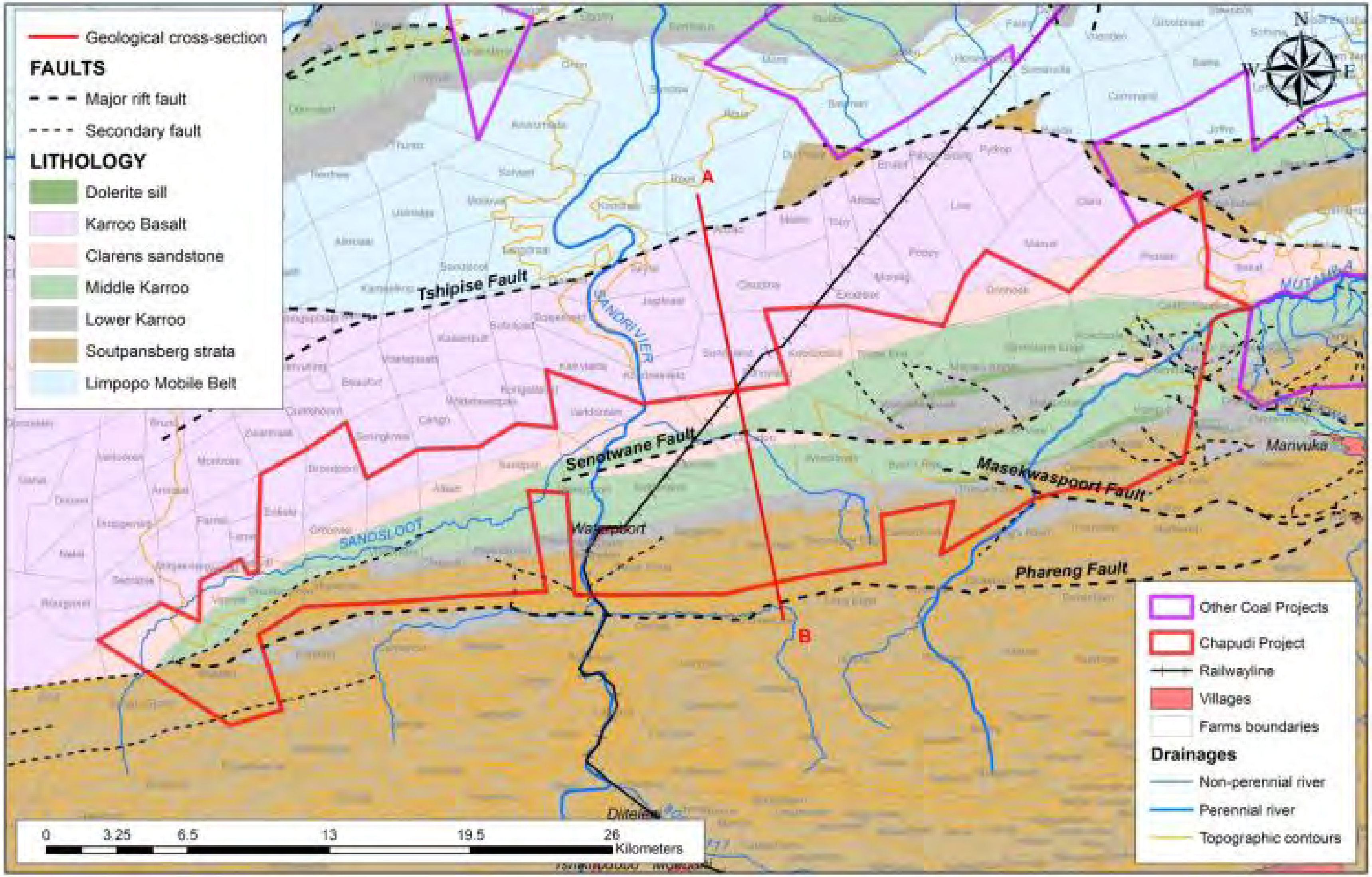

FIGURE 9: CHAPUDI MINING PROJECT GEOLOGY

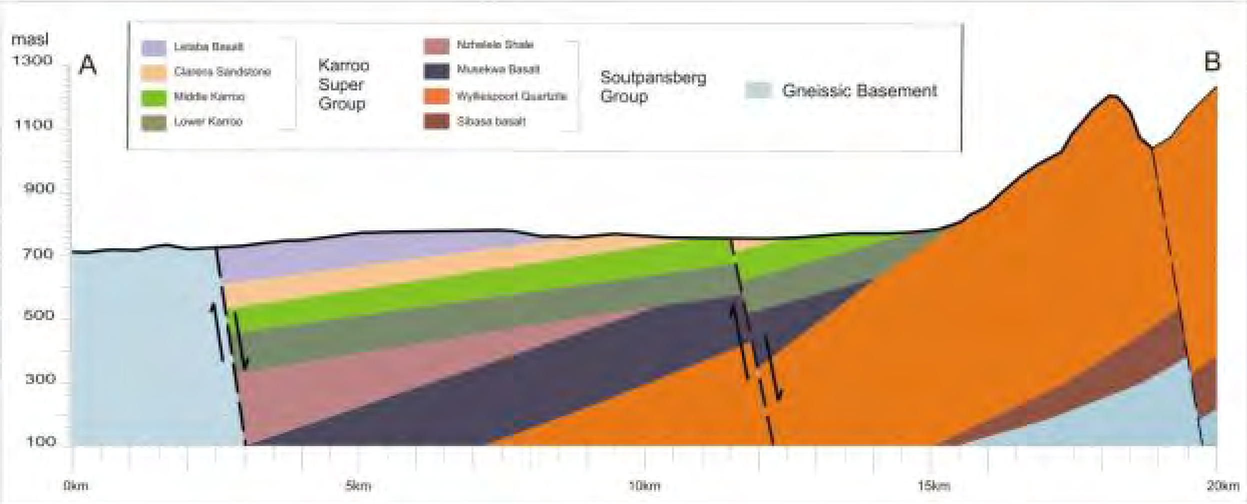

FIGURE 10: CHAPUDI MINING PROJECT GEOLOGICAL CROSS-SECTION

The Letaba basalt ends Karoo Sequence deposition with widespread outpouring of continental lavas, heralding a period of tectonic instability and the start of the break-up of Gondwanaland.

Dolerite sills and dykes served as feeders to the basalt lava and are the hyperbyssal component of this event. A large sill has intruded approximately along the contact between the Middle and Lower Karoo strata to the east. According to exploration drilling the sill has not impacted on the coal seams but can act as a fractured aquifer with high water inflows into the pit.

Quaternary Alluvial and Colluvial deposits.

Various Quaternary age deposits occur within the study area. They consist of the following;

i) Colluvium or slope scree deposited at the base of the mountain (colluvium) and can attain thicknesses of up to 30m in the west against fault scarp faces.
ii) Alluvium adjacent to the main drainages i.e. the Sand River and the Sandsloot (Moletsane River).

iii) The area is covered by sandy soils thought to be at least partially of aeolian origin.

These deposits are generally unconsolidated but have been cemented in places with ferricrete and calcrete.

Structure

The main structural feature of the Chapudi basin is the westerly extension of the east – west trending Tshipise Fault which also forms the faulted contact between the Karoo strata and the LMB gneisses. The Tshipise Fault is a regional tectonic feature which forms the structural partition between the central zone of the LMB and the southern marginal zone.

The complete sedimentary sequence is duplicated by the Senotwane fault - a normal E-W trending fault with a 30 km strike length occurring east of the Sand River. The fault terminates against another major fault striking NW at its' eastern limit. Both these faults are associated with high yielding boreholes exploited by the local farmers for irrigation purposes on the farms Coniston, Wildebeesthoek, Mountain View and Bushy Rise.

Numerous wrench faults also occur in association with these faults and also host water in extractable quantities. Another east west trending fault, possibly an extension of the Senotwane occurs at the base of the mountain on the western portion of the MRA area. The fault terminates against the Phareng fault and is also water bearing. Numerous springs occur along its strike which may have contributed salt to the salt pan deposit further west from whence the mountain range derived its' name Soutpansberg.

3.5.4 IMPACT ON HYDROGEOLOGY

The Soutpansberg Group rocks form a mountain range with shallow soil resulting in higher recharge. This is the main recharge zone of the regional aquifer.

Consequently, groundwater in this aquifer is relatively fresh. Zones of high transmissivity occur where the Karoo strata rocks are down faulted against the Soutpansberg quartzite's by East – West striking fault structures. These include the brittle coal horizon, sandstone formations such as the Fripp and Klopperfontein Formations, dolerite sills and the underlying Soutpansberg quartzites and volcanics. This water is exploited by irrigation farmers along the base of the mountain and along the Sand River.

Groundwater derived from direct recharge within the Karoo strata is generally more saline and as it flows northward, it becomes progressively more saline. The structural link between with the Karoo strata and the Soutpansberg result in differing water levels and chemistry in boreholes in close proximity with one another.

North of the Karoo strata, across the Tshipise fault, groundwater in the Limpopo Mobile Belt gneisses is also replenished by local recharge and is less saline. Groundwater in this regional aquifer conforms to the regional topographic gradient and is drained through the E-W regional faults of the Tshipise fault system.

Groundwater is also drained by evapotranspiration and numerous springs.

4. DATA COLLECTION

4.1 LITERATURE REVIEW

Numerous studies have been conducted on the hydrogeology by groundwater specialists relating specifically to the Chapudi Project since its inception, as well as studies by local agriculture which depends heavily on the groundwater resource. The information from these reports in compilation with recent data collected, form the basis of this report. Previous reports include the following;

i) ***High Level Hydrogeological Study, Chapudi Project, Limpopo Province:*** for Rio Tinto by GCS (2005).

ii) ***Geology of the Waterpoort Aquifer at Sitapo in the Limpopo Province:*** for ZZ2 by AGES (2007).

iii) ***Groundwater Risk Assessment of possible Cross Contamination at the Chapudi Mine Project Area:*** for Rio Tinto by WSM Leshika (2009).

iv) ***Chapudi Coal Project Environmental Baseline Study: Hydrogeology:*** for Chapudi Coal (Pty) Ltd and Kwezi Mining and Exploration (Pty) Ltd by SRK (2009).

4.2 BOREHOLE CENSUS

A borehole census was conducted by GCS in 2005 and the data was used in the SRK 2009 report. SRK conducted their own hydro census in 2008 during which numerous water samples were taken but very little water level data was added due to limited access to equipped boreholes. The GCS borehole census farms include the following; Chapudi, Sterkstroom, Varkfontein, Sutherland, Kliprivier, Coniston, Rochdale, Woodlands, Blackstone Edge, Bushy Rise, Prince’s Hill, Mountain View and Malapchani. The water level data is therefore largely from the 2005 census.

Although outside the mine application area, data from Sitapo was included due the close proximity and intensive irrigation on the farm.

WSM conducted groundwater baseline studies in 2012 on the farms Coniston, Wildebeesthoek, Mountain View, Sandstone Edge and Mopani Ridge which were added and augmented to 2005 data.

Borehole data was also collected by AGES (Pty) Ltd during 2013 in areas not evaluated by previous studies or where the data is too old or access to farms were potentially contentious. The AGES borehole census covered the following farms; Northwich, Blackstone Edge, Bushy Rise, Kalkbult, Sandilands, M’tamba Vlei, Generaal, Sutherland East, Malapchani, Driehoek and Woodlands, The borehole census data is summarized in Appendix B. The borehole localities are indicated on Figure 11.

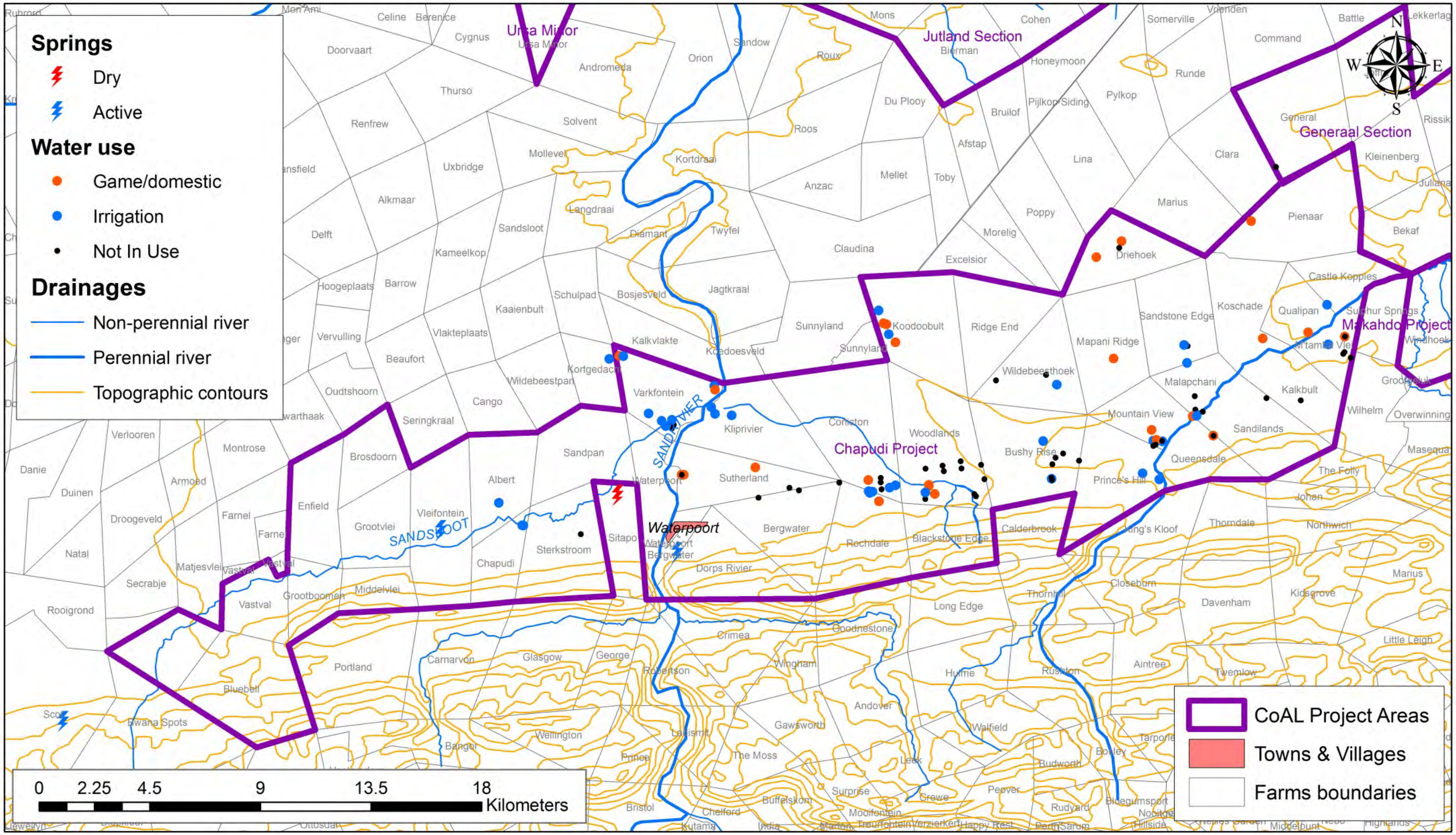

FIGURE 11: CHAPUDI PROJECT HYDROCENSUS BOREHOLE LOCALITIES

4.3 PIEZOMETRY AND GROUNDWATER FLOW

If the water table is undisturbed, the groundwater surface tends to mimic a subdued form of the topography. Water levels measured during the hydrocensus revealed water levels ranging from 0 to in excess of 50 mbgl. The water level data was colour coded according to set of piezometric height ranges from which a piezometric contour map was drawn (see Figure 12).

The map shows that the water table approximates the topographic surface. Cones of depression are visible on Secrabje, Sandilands, Wildebeesthoek, Coniston and Woodlands. Considerable groundwater development has occurred since 2005 and no doubt the piezometric surface has changed considerably since. The map shows numerous isolated highs (Varkfontein) and lows due to the 7 year difference in time between the different data sets, but also the confined character of the layered aquifers of the Karoo strata.

Springs occur where the water table intersects the surface, usually along some structure. The Sandsloot River appears to have its' origin in a spring on the farm Bwana Spots to the west of the project. The Zoutpan Salt Mine was also historically fed by springs. A spring at Luna Spa (see figure 11) existed on the farm Sitapo but has dried up probably after irrigation started. From google images springs appear to exist all along the foot of the Soutpansberg Mountain.

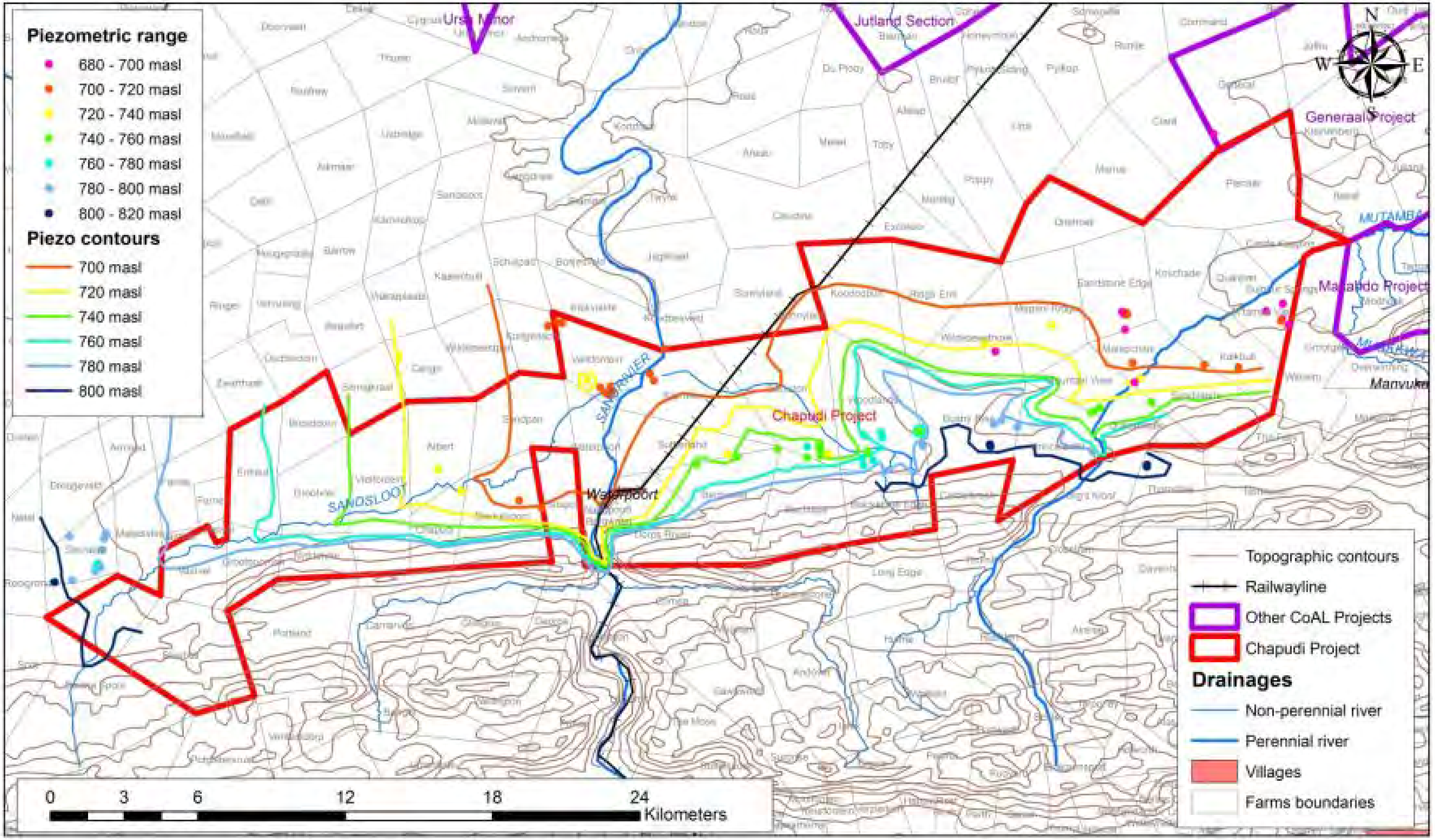

FIGURE 12: PIEZOMETRIC CONTOUR MAP SHOWING GENERAL GROUNDWATER FLOW DIRECTION

4.4 GROUNDWATER QUALITY

Groundwater quality is dependent on the concentrations of soluble salts and the residence time of water within the host rock. Water derived from secondary aquifers in the area can vary considerably. Good quality groundwater can be found in the quartzites and lavas of the Soutpansberg strata. Moderate to brackish water can be found in the Nzhelele shale and the lower Karoo strata. The Bosbokpoort formation marks a climatic change to increasing aridity which culminates in the aeolian sands of the Tshipise Member of the Clarens formation. The sediments of the Bosbokpoort Formation to Red Rocks Member reflect the changing climate with a concurrent increase in salinity up the sequence. The Sandsloot River flows eastwards and along strike over these salt rich rocks resulting in elevated salinities in the alluvial and shallow fractured aquifers along its banks.

The chemistry of 19 data points were available from the SRK 2009 report and augmented by 7 from WSM Leshika baseline studies. The samples were analysed for pH, major elements and trace metals. The chemistry data is presented with reference to the Water Quality Threshold (WQT) according to DWA Water Quality Guidelines for Rivers and Streams for the following water uses;

i Drinking water

ii Agriculture-irrigation

iii Agriculture-livestock

Macro chemistry

TABLE 6: DWAF WATER QUALITY THRESHOLD CLASSIFICATION – MACRO CHEMISTRY

Species	pH	E.C	TDS	NO_3	F	SO4	Cl	Ca	Mg	Na
Unit		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Drinking	6.0 - 9.0	150	1000	6	1	400	200	150	100	200
Agriculture (irrigation)	6.5 - 8.4	40	260	5	2		100			70
Agriculture (livestock)			1000	100	2	1000	1500	1000	500	2000

A total of 26 hydro-census samples were analysed for pH and major and micro elements. The chemistry results are listed in the table below. Concentrations exceeding the WQT for any of the above uses are marked in red.

TABLE 7: MACRO CHEMISTRY RESULTS

Species		pH	E.C	TDS	NO_3	F	SO_4	Cl	Ca	Mg	Na
Unit	date		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Brise-5	22/12/08	7.7	33	205	2.6	0.5	8.5	46	5.8	6.5	37
Brise-4	22/12/08	6.9	281	2030	12	0.2	91	915	248	109	160
Chap-BH-21	2/02/09	6.4	13	88	0.4	0.2	12	21	4.8	7.8	12
Chap-BH-25	2/02/09	6.4	9.7	75	0.9	0.2	7	16	16	5.9	8.3
Chap-BH-26	2/02/09	7.7	1820	11600	124	0.5	590	6220	223	461	3540
Con-4	15/02/13	7.0	38.7	251.6	<1.4	0.14	7.46	15.4	38.32	19.23	13.03
Con-9	22/12/08	7.7	43	270	4.5	0.2	18	24	40	23	
Klip-BH-10	22/12/08	7.5	191	1200	1	0.7	4.8	254	91	53	246
Klip-BH-13	22/12/08	8.6	121	820	0.7	2.7	4.6	171	4.7	3.8	292
Klip-BH-14	22/12/08	7.9	517	4000	32	0.8	925	1026	150	190	743
Mal-2	22/12/08	8	123	740	1	0.7	26	258	26	12	213
Mv-BH1B	22/12/08	7.9	207	1400	5.2	0.4	157	390	107	109	154
Mv-1	30/11/12	7.9	110	634	<0.2	1.10	20	191	23	13	199
Mv-2	11/12/12	7.5	196	1266	3.50	0.60	130	313	87	112	151
Roch-BH8A	22/12/08	7.6	44	292	3.5	0.2	20	30	38	21	14
Sand-3	22/12/08	7.6	178	1090	0.3	1	102	346	115	76	181
Sand-BH17	22/12/08	8.1	299	1770	11	1.1	152	591	74	102	333
Sterk-BH-22	2/02/09	6	6.5	46	2.4	0.2	2.4	10	10	3.1	3.3
SAND-1	30/11/12	7.1	337	2056	0.70	0.80	233	721	98	182	329
SAND-2	30/11/12	7.9	95.6	540	<0.2	0.80	21	141	31	34	124
SAND-3	30/11/12	7.6	41.7	252	0.40	0.30	<5	53	18	18	47
Vark-BH20C	2/02/09	8.3	83	540	2.3	0.8	8.3	116	25	5.4	175
Wpoort-BH11	22/12/08	6.4	163	980	11	0.1	62	455	64	71	147
Woo-BH6C	22/12/08	7.9	120	760	7.7	0.5	60	197	45	36	161
Wild-1	30/11/12	6.7	49.9	286	<0.2	0.40	18	55	31	20	36

The study area is characterized by a variety of groundwater quality ranges reflecting the salt content of different rock types in which the water occurs. A contour map of the TDS data against the geology as background is provided below. Samples with elevated salts are associated with local recharge to the Karoo strata and the better quality water is derived from the Soutpansberg Mountain via structure. Water quality within the Sandsloot alluvium has particularly high TDS values indicating leaching of salts from the upper Karoo strata which recharge the alluvium.

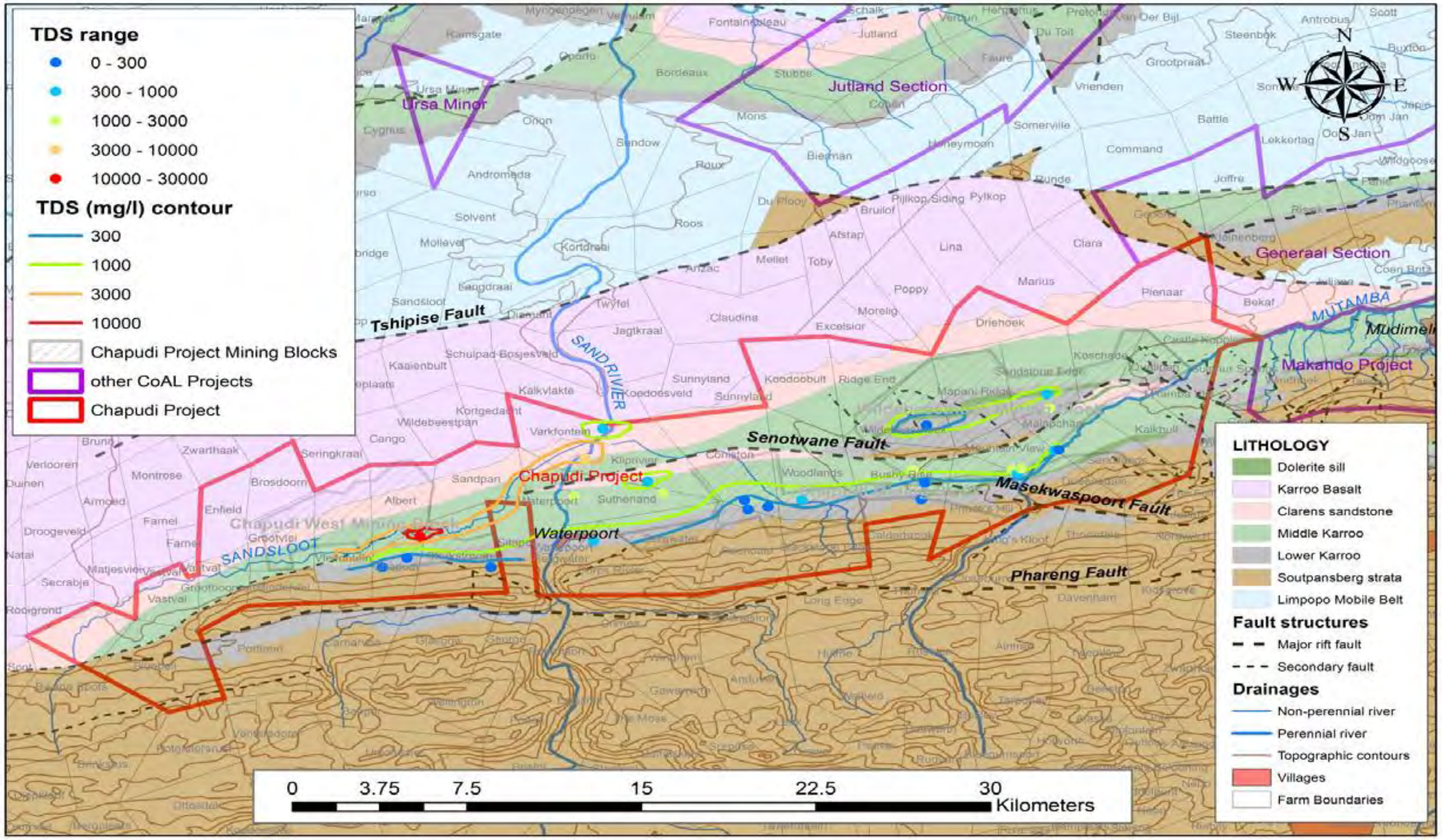

FIGURE 13: TDS CONTOUR MAP WITH GEOLOGY.

Microchemistry

TABLE 8: MICRO-CHEMISTRY WITH DWAF-WQT CLASSIFICATION.

Element	Al	As	B	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn
Unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Drinking	0.5	0.05		0.005		0.05	1.3	5	0.4			0.01	0.05	0.1	5
Agriculture(irrigation)	5	0.1	0.5	0.01	0.05	0.1	0.2		0.02	0.01	0.2	0.2	0.02	0.1	1
Agriculture(livestock)	5	1	5	0.01	1	1	0.5		10	0.01	1	0.1	0.05	1	20

Concentrations exceeding the WQT for any of the above uses are marked in red. It must be noted that concentrations exceeding the WQT are often below the detection limit for some elements.

TABLE 9: MICRO-CHEMISTRY WITH DWAF-WQT CLASSIFICATION.

Element	Al	As	B	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn
Unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Brise-BH1								<0.01	0.12						
Brise-BH2								<0.01	0.02						
Brise-BH3								<0.01	0.43						
Brise-BH5	<0.009	<0.010			<0.001	<0.003	0.01	<0.001	0.15		0.004	<0.001	0.03	0.01	0.13
Brise-BH4	<0.009	<0.010		0.02	<0.001	0.009	0.01	0.09	0.08		0.005	<0.001	0.2	0.02	0.22
Chap-BH21	<0.009	<0.010			<0.001	<0.003	0.03	0.04	0.23		<0.003	0.005	0.015	0.006	0.72
Chap-BH25	<0.009	<0.010		<0.010	<0.001	<0.003	<0.002	<0.001	0.11		<0.003	0.005	0.01	0.005	0.025
Chap-BH26	<0.009	<0.010		<0.010	0.009	<0.003	<0.002	<0.001	0.31		0.004	0.005	0.61	0.04	0.13
Con-4								<0.001	0.22						
Con-BH9	<0.009	<0.010		0.009	<0.001	<0.003	<0.002	<0.001	0.07		<0.003	0.005	0.04	0.01	<0.003
Klip-BH10	<0.009	<0.010		<0.010	0.007	<0.003	<0.002	0.02	0.12		<0.003	0.005	0.15	0.01	0.14
Klip-BH13	<0.009	0.09		0.007	<0.001	0.005	<0.002	<0.001	<0.001		<0.003	0.005	0.11	0.009	<0.003
Klip-BH14	<0.009	<0.010		0.06	0.01	0.003	<0.002	<0.001	0.08		<0.003	<0.001	0.28	0.06	0.15
Mal-BH2	<0.009	<0.010		<0.010	<0.001	<0.003	<0.002	<0.001	0.200		<0.003	0.005	0.16	0.02	0.01
Mv- BH1B	<0.009	0.12		0.005	<0.001	<0.003	<0.002	<0.001	0.1		<0.003	0.005	0.25	0.04	0.08
MV-1	<0.010	<0.010	0.257	<0.005	<0.025	<0.025	<0.025	176	<0.025	<0.025	<0.025	<0.020	<0.020	<0.025	0.044
MV-2	0.0145	<0.010	0.326	<0.005	<0.025	<0.025	<0.025	<0.001	0.036	<0.025	<0.025	<0.020	<0.020	<0.025	<0.025
Roch- BH8A	<0.009	<0.010		0.007	0.005	<0.003	0.002	<0.001	0.150		<0.003	0.005	0.04	0.001	0.8
Sedge- BH3	<0.009	<0.010		0.01	0.002	<0.003	<0.002	<0.001	0.680		0.005	0.005	0.660	0.02	0.26
Sand-BH17	<0.009	<0.010		0.01	<0.001	<0.003	<0.002	<0.001	<0.001		<0.003	<0.001	0.510	0.05	0.04
Sterk-BH22	<0.009	<0.010		0.02	<0.001	<0.003	0.140	0.02	0.03		<0.003	<0.001	0.015	0.006	0.03
SAND-1	0.0162	<0.010	0.629	<0.005	<0.025	<0.025	<0.025	0.446	0.038	<0.025	<0.025	<0.020	<0.020	<0.025	<0.025
SAND-2	<0.010	<0.010	0.312	<0.005	<0.025	<0.025	0.058	0.656	0.069	<0.025	<0.025	<0.020	<0.020	<0.025	0.245
SAND-3	0.0512	<0.010	0.168	<0.005	<0.025	<0.025	<0.025	4.41	0.243	<0.025	<0.025	<0.020	<0.020	<0.025	0.031
Vark-BH20C	<0.009	<0.010		0.006	<0.001	<0.003	<0.002	0.05	0.1		<0.003	0.005	0.07	0.008	0.007
Wpoort-BH11	<0.009	<0.010		0.01	0.03	0.01	0.02	0.26	0.25		0.07	0.005	0.12	0.01	0.59
WILD-1	0.01	<0.010	0.223	<0.005	<0.025	<0.025	<0.025	0.03	0.12	<0.025	<0.025	<0.020	<0.020	<0.025	<0.025
Woo-BH6C	<0.009	<0.010		0.01	0.006	<0.003	<0.002	<0.001	0.31		0.007	0.005	0.13	0.005	0.13

The table indicates elevated cadmium and selenium in certain boreholes in the study area. The manganese content is above the limit for irrigation purposes in most samples but is not abnormally high for groundwater. The higher Iron in some samples is probably associated with the Soutpansberg Group rocks.

4.5 GROUNDWATER USE

Groundwater use figures were derived from various sources i.e. estimates of cultivated land areas using google images from January 2009 to determine cleared lands and evaluating irrigated areas (Figure 12), verbal communication with farmers, the registered use (WARMS data) and the various report estimates.

The irrigation use was estimated by using an irrigation application of 7 880 m^3/ha/annum. Irrigation use is mainly on the farms Bergwater, Enfield, Waterpoort, Koodoobult, Varkfontein, Coniston, Albert, Princes's Hill, Kliprivier, Wildebeesthoek, Bushy Rise and Vleifontein.

Chapudi MRA area is about 40 375ha or 403 750 000m^2. Average annual recharge over the area is taken as 4.7mm/annum (see chapter 6.4) or 0.0047m/annum. Therefore average annual recharge volume is 403 750 000 X 0.0047 = 1 897 625 m^3 or 5200m^3/day. This is less than half of what irrigation is abstracting hence existing drawdown cone as a result of irrigation.

Of the other groundwater uses the relatively high use on the farms Sandstone Edge, Castle Koppies and M'tamba Vlei is mainly for aesthetic purposes i.e. irrigation of gardens around the lodges and filling of water holes.

Groundwater use within the Chapudi project area is summarized in the table 10 below.

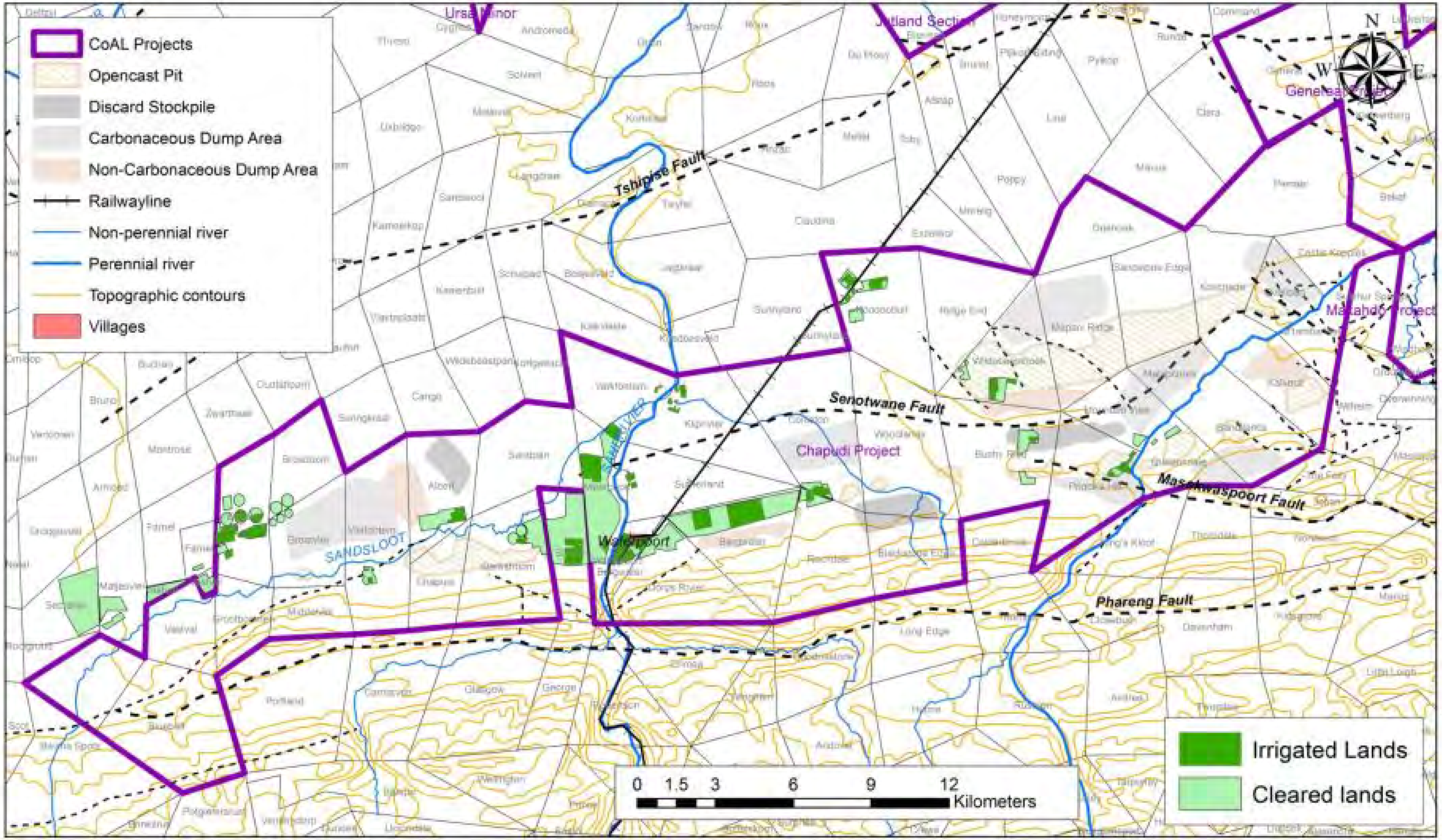

FIGURE 14: IRRIGATION AREAS

TABLE 10: CHAPUDI: GROUNDWATER USE PER FARM

Owner/Business	Farms	Total farm unit area (ha)	Census data-current pump equipment capacity (Kl/day)	Cleared area measured off Google earth (ha)	Irrigated area estimate (ha)	Ground water use - irrigation area in Kl/day	Groundwater use - other Kl/day	WARMS Registration Volume (Ml/ annum/ farm	Overall Estimated Ground water Use (Ml/ annum)
	Castle Koppies	659	130	0	0	0	130	0	
	Kalkbult	915	0	0	0	0	0	3	
	Koschade	1154	43	0	0	0	43	6	
Ekland Safaris	M'tamba Vlei	547	282	0	0	0	282	0	182
	Pienaar	1865	14	0	0	0	14	0	
	Qualipan	606	9	0	0	0	9	3	
	Sandilands	1262	22	0	0	0	22	0	
	Malapchani	500	8	0	0	0	8	0	
Bertha Trust	Sandstone Edge	1273	376	0	0	0	376	0	142
	Mapani Ridge	1411	6	0	0	0	6	0	
L Erasmus	Mountain View	687	205	16	0	0	10	0	4
Taylor/Smith etc	Princes's Hill	1371	296	30	14	296	0	0	108
Unknown	Queensdale	737	5	16.7	0	0	5	0	2
	Albert	1063	410	40	19	410	0	168	150
J.Pauer	Chapudi	666	266	0	0	0	7	30	3
	Sterkstroom	1531	No data	16	0	0	5	715	2
	Bergwater	1318	No data	420	159	3439	0	870	1255
Fanie Steyn	Bergwater-2	387	No data	80	0	0	14	5	5
	Dorprivier	1416	No data	0	0	0	5	442	2
Unknown	Brosdoorn	779	No data	36	0	0	5	0	2
HML Boerdery	Coniston	1954	552	40	25	540	7	72	200
Unknown	Enfield	1038	No data	194	110	2375	0	0	867
Unknown	Grootvlei	1003	No data	22	0	0	7	648	3
Knoetze/Burchill	Kliprivier	1484	193	91	9	194	0	45	71
Fick	Koodoobult	1584	936	150	43	928	8	321	342
Unknown	Rochdale	1361	5	45	0	0	5	284	2
JJB Knoetze	Sutherland	1072	11	20	0	0	11	57	4
MJ Scheepers	Varkfontein	1012	879	120	40	864	15	921	321
Unknown	Waterpoort	772	No data	453	100	2159	0	790	788
Piet Espag	Wildebeeshoek	1224	168	78	8	173	0	4	63
	Blackstone Edge	1019	11	0	0	0	11		
Brink Schlesinger	Bushy Rise	1690	562	70	6	121	0	32	50
	Woodlands	1850	5	0	0	0	5		
Unknown	Bluebell	1836	No data	0	0	0	5	0	2
Unknown	Bwana Spots	858	No data	0	0	0	5	0	2
Unknown	Driehoek	1032	No data	0	0	0	5	0	2
Unknown	Grootboomen	629	No data	0	0	0	5	0	2
Unknown	Middelvlei	581	No data	0	0	0	5	100	2
Unknown	Ridge End	1225	No data	0	0	0	5	0	2
Unknown	Sandpan	1300	No data	0	0	0	5	0	2
Unknown	Vastval	777	No data	84	0	0	5	0	2
Unknown	Vleifontein	1670	No data	28	5	106	0	0	39
	Totals	47117		2050	537	11604	1050		**4619**

The total groundwater abstraction for the Chapudi Project mine application area is estimated at a maximum of 4 619 Ml per annum.

5. REGIONAL GROUNDWATER FLOW

To determine the orientation of groundwater flow on a regional scale, water levels were available from 965 boreholes. Historic data from 657 boreholes was obtained from the National Groundwater Database (NGDB), and the remainder were collected by hydrocensus during the study for Makhado mine and the present study. These data were converted to absolute water levels by determining borehole elevation from Google Earth. The MODFLOW model (section 6), was utilised to generate current water levels as a piezometric map (Figure 15). The Model was also utilised to generate a map of water level under virgin conditions (Figure 16).

Regional groundwater flow is oriented northeast towards the Limpopo River (Figure 16). Flow volumes are extremely low due to the low permeabilities and low recharge, especially in the northern half of the catchment underlain by the Limpopo Mobile Belt and overlain by alluvium.

In the south, where the catchment is underlain by Karoo and Soutpansberg rocks and where mining is proposed, a local northward hydraulic gradient is present due to high recharge in the Soutpansberg Mountains. A significant cone of depression exists around the Sand River directly north of the Soutpansberg Mountains due to the large scale irrigation from groundwater. Quantifying abstraction is problematic, since not all the lands are irrigated every year. Irrigation was estimated from lands identified as being irrigated on the most recent Google Earth images, i.e. 2009.

Under natural conditions, groundwater drains via localised springs, as baseflow to the perennial tributaries flowing from the Soutpansberg, and by evapotranspiration by riverine vegetation along the main river channels.

Groundwater is of good quality in the Soutpansberg rocks, which is the main recharge zone; however, increased salinity occurs northwards as groundwater flows through saline Karoo sediments, accumulating salts. Low recharge rates in the drier terrain north of the Soutpansberg also results in low recharge rates to dilute these salts. The movement of groundwater passing through saline deposits of the Karoo rocks, and subsequent evapotranspiration by riverine vegetation, causes a rapid salt accumulation northward, with a peak salt load along the fringes of the channels lying over Karoo rocks, like the Mutamba, the Brak and Sand Rivers, resulting in poor natural water quality.

The Mufungudi entering Nzhelele dam, the Kandanama River a tributary of the Mutamba River, entering the catchment in the south along the N1 highway, and the upper reaches of the Mutamba emerging from the Soutpansberg are perennial, but lose water to groundwater as they flow out of the Soutpansberg, becoming ephemeral. This water is abstracted by boreholes for irrigation on the farms Windhoek, Grootgeluk and Overwinning along the Kandanama, and by irrigation boreholes along the Sand River on Sterkstroom, Sitapo, Sutherland and Waterpoort, or is utilized by riparian vegetation. Very little surface runoff is believed to recharge the regional aquifers north of the Soutpansberg, since high salinity levels in the Karoo aquifers suggest it is not recharged by fresh water from the river. In comparison, groundwater is of good quality in the Karoo aquifer along the southern tributaries such as the Kandanama River, where river losses take place. Isotope studies conducted during the Makhado investigation confirm this.

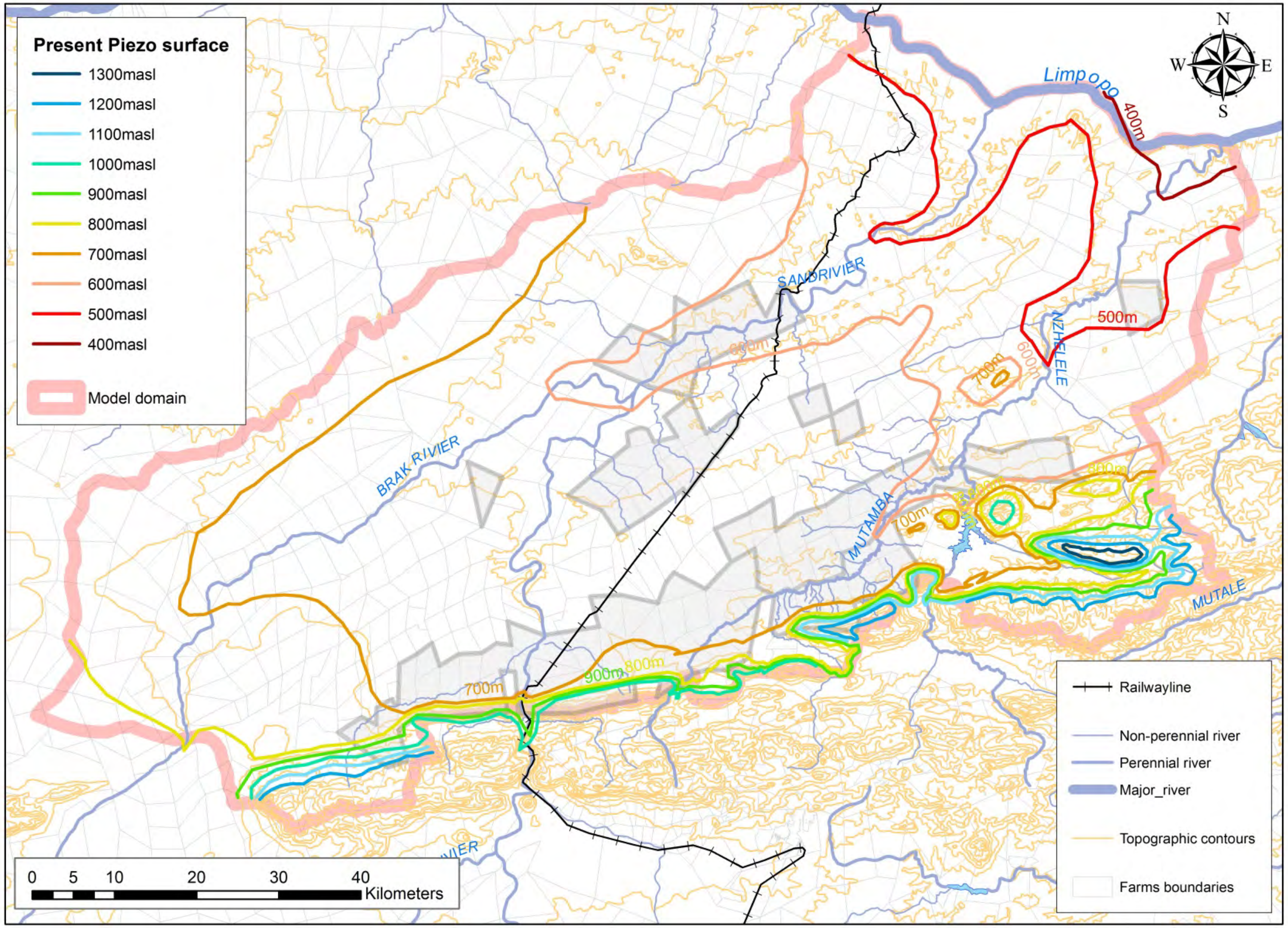

FIGURE 15: STEADY STATE WATER LEVELS UNDER CURRENT CONDITIONS (METRES ABOVE MEAN SEA LEVEL)

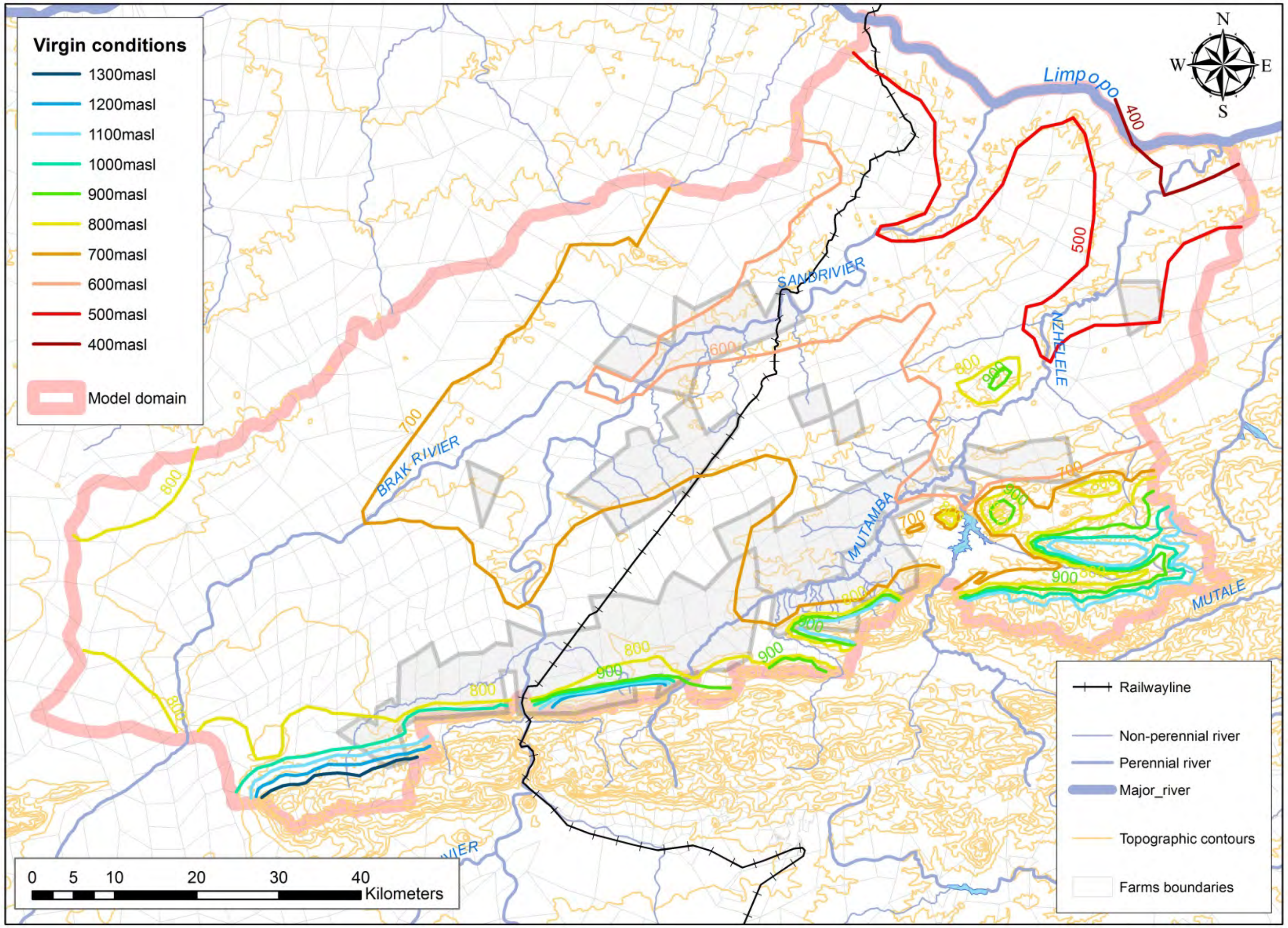

FIGURE 16: STEADY STATE WATER LEVELS UNDER VIRGIN CONDITIONS (METRES ABOVE MEAN SEA LEVEL)

6. GROUNDWATER FLOW MODEL

A regional numerical model was generated in order to quantify the impact of the proposed mine on the groundwater in the study area, and to determine inflows into the mine workings. Since many mines will be operated in conjunction, it was necessary to model this large area to determine cumulative impacts. The Makhado mine will be in operation before the Chapudi project, and will impact on water levels. In addition, the Mopane and Generaal projects will overlap with Chapudi, hence all the projects must be considered in conjunction (see figure 17) when setting up the model.

The USGS MODFLOW2000 Finite Difference groundwater model was used in the US Department of Defence GMS 9.0 (Groundwater Modelling System) interface to simulate and plot groundwater flow.

6.1 CONCEPTUAL MODEL

In every modelling study the natural system is represented by a conceptual model representing the best understanding of how the natural system operates. The development of a conceptual model includes identifying hydrogeological layers, boundaries and zones of similar properties that need to be differentiated. Subsequently, a numerical model is designed and constructed with equivalent but simplified conditions of the real world, in sufficient detail to meet the objectives of the modelling study and reproduce observed conditions. Transferring the real world situation into an equivalent conceptual model system, which can then be solved using existing program codes, is a crucial step in groundwater modelling. The following are considered in the development of a conceptual model:

- The known geological and hydrogeological features and characteristics of the area and their vertical and horizontal variations.
- The variations of permeabilities and storativities of the geological formations
- The recharge to the aquifers and its variability
- The static water levels/piezometric heads of the study area.

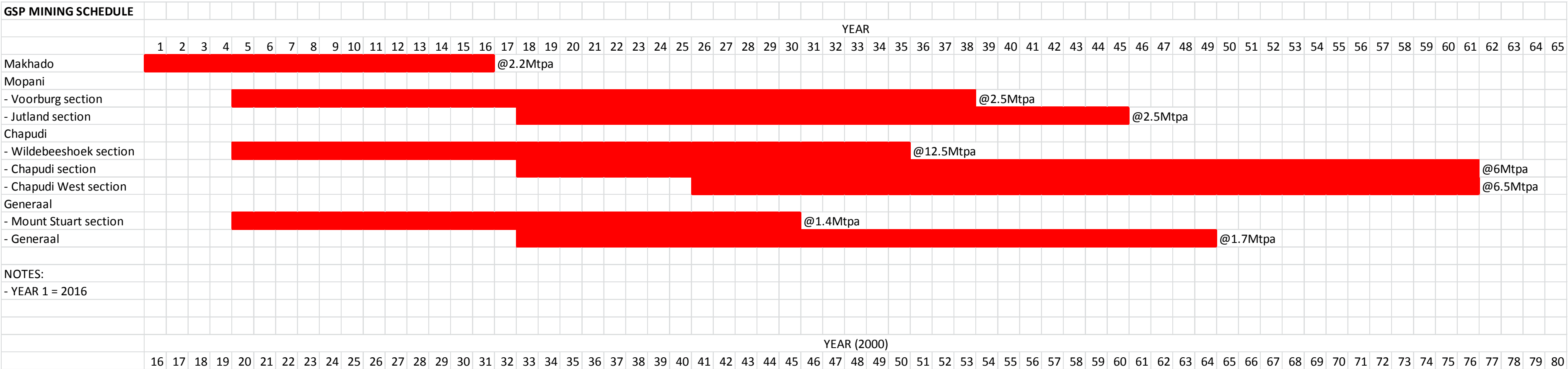

FIGURE 17: GSP MINING SCHEDULE

- The extent to which intended activities will interact with the geology and hydrogeology on the region so that the lateral and vertical boundaries of concern can be identified.
- The identification of the processes and interactions taking place within the study area that will influence the movement of groundwater, such as evapotranspiration from riverine zones, abstraction from boreholes, springs and baseflow to streams and rivers.
- Any simplifying assumptions necessary for the development of a numerical model and the selection of a suitable numerical code.

Due to the depth of mining (approximately 200 m) for the open pit mines and the dip of the strata, the model domain needs to be conceptualised as a 3 dimensional multilayer aquifer system, cut by fault zones. The faults need to be simulated using linear higher permeability zones, with major east north east permeable faults assigned a higher permeability than north south faults due to the tensional nature of ENE trending structures. These faults also need to be able to transmit water across the catchment boundary. However, due to such complexities and the large area covered by the GSP project and the number of mines in operation during the lifespan of the Chapudi project, a regional 2 layer model was first developed to determine the cumulative impact of all the mines, from which local multi-layer models for each mine will later be developed once mining plans have been finalised.

Each geological formation was assigned its own permeability and storage parameters, and these were considered to decrease with depth due to reduced weathering and fracturing, hence the use of 2 layers, each 200 m thick, resulting in a total depth of 400 m. Clastic sedimentary structures such as sandstones were assumed to have a more gradual decline in permeability with depth than non-clastic deposits like coal and mudstone. Basalts were given a high permeability due to the high yields of boreholes in basalt and the low hydraulic gradients present. Due to low borehole yields and the resistant nature of the rock, the mountainous region of the Soutpansberg was given a very low permeability.

Recharge was considered to vary, being lowest over the Karoo rocks due to low permeability mudstone layers, and slightly higher in the basalts and in Mobile Belt rocks overlain by Kalahari sands. Higher recharge in these zones was required to fit simulated water levels to observed water levels. The soils in the basalt are more permeable, and it is assumed the sand cover allows more percolation and less runoff, and allows rainwater to percolate below the evaporation zone. Recharge is significantly higher in the Soutpansberg outcrop areas due to higher rainfall and shallow soils.

Based on the observed hydraulic gradient, the aquifer was considered to discharge naturally towards the Nzhelele River, the Mufungudi, Kandanama and Nzhelele dam as baseflow, and via several springs identified on the geological map and in the field, and via evapotranspiration in the vicinity of the Mutamba, the Sand and the Brak Rivers and tributaries with significant alluvium, and in pans located north of the Soutpansberg in the western half of the study area.

In order to simulate interactions between surface and groundwater, perennial rivers were modelled as head dependent boundaries where perennial flow occurs. This implies that when aquifer water levels are above the level of the stream baseflow occurs, and when below, the river can recharge the aquifer. This allows boreholes and mining to increase losses from a river.

Water courses were considered as drains when the channels were ephemeral, and flowed only during major storm events, and considered not to recharge the aquifer. This allows baseflow for periods when aquifer levels are high, but not replenishment of the aquifer. Saline conditions in groundwater near ephemeral channels suggest that rivers do not recharge the aquifer, since dilution by fresher water from the river is not evident in the aquifer.

Rivers like the Sand, the Brak and the Mutamba contain significant alluvium, which is tapped in places by irrigators. These rivers were considered as drains, as river losses to the alluvium remains in the alluvium and is utilised by riverine vegetation and irrigators, and does not recharge the regional aquifer since hydraulic gradients are oriented towards the channels.

Where the rivers are perennial and where the alluvium is of a sandier and gravelly nature, good quality water in boreholes next to the river and the disappearance of flow in the river suggest the rivers recharge the aquifer. These lengths of river were treated as head dependent boundaries where water can flow from the river to the aquifer when groundwater levels are below the level of the river, and from the aquifer to the river when groundwater levels are above the level of the river.

It was considered necessary to include evapotranspiration to drain groundwater and prevent baseflow.

The reasons why these decisions were taken are the following:

- Without evapotranspiration, recharge to the aquifer would constantly induce groundwater discharge as baseflow under natural conditions. Natural recharge must discharge somewhere and the Mutamba, Sand, Brak and Nzhelele Rivers are the only receiving source in the catchment, however, they are ephemeral over much of their length.

- According to baseflow data in the GRAII (Groundwater Resource Assessment Phase II, a study commissioned by DWA), groundwater baseflow to surface water courses only exists along the Upper reaches of the Mutamba, Kandanama and Mufungudi, hence, natural recharge must be lost through riverine vegetation and spring discharge which is equal to at least the volume of recharge.

6.2 BOUNDARY CONDITIONS

The model domain is generally strongly influenced by boundary conditions. Boundaries control the flow direction and strongly influence the water balance of a numerical model; hence boundary conceptualisation is of critical importance.

Generally internal boundaries are fixed where known interchanges of water take place, and lateral boundaries should be sufficiently extended to zones where it is known no interchange takes place.

The model domain was envisaged as being a discrete interconnected unit bounded by various hydraulic boundaries:

- The catchment watershed containing all the Quaternary catchments where mining is planned was treated as a no flow boundary across which groundwater flow was assumed to be non-existent. The rationale behind this discretisation was that the interchange of water across the topographical divide is negligible. This served as the lateral boundary of the model domain.
- To avoid boundary condition problems, the model utilised a large model domain of 6605 km^2 (all of Quaternaries A71J and K, A72B, A80C, F and G, and part of A80E), well beyond the mining area to ensure impacts of mining would be within the model domain. It was necessary to include a portion of A80E, since that is the Quaternary catchment which contains the southern tributary of the Mutamba, and it flows into A80F.
- Major faults crossing the watershed and where major inflows are believed to occur, were treated as constant head boundaries, where the water level at the boundary is kept constant and water is allowed to enter or exit the system depending on head differences. These boundaries are sufficiently distant from the mine not to be impacted by water level drawdowns from mining. They occur where major faults enter the study area at Waterpoort along the Sand River, and along the Mutamba River at Masekwaspoort.
- The Nzhelele dam was treated as a constant head boundary
- Discharge to springs and pans were simulated using drains, which is a type of boundary that allows water to flow out of the aquifer when the water table is above the set elevation of the drain. The rate of drainage is dependent on the head difference between the elevation of the drain and the water table in that cell multiplied by the set drain conductivity. If the water table falls below the elevation of the drain, the drain dries up and discharge is terminated. Drain cells

were allocated where springs were identified. Drain conductivity was set between 0.01-1 m^2/day/m.

- The perennial Kandanama and Mufungudi rivers were treated as a head dependent river boundary, capable of discharging water to the aquifer, or receiving water, depending on the piezometric head in the aquifer in that cell. The Limpopo was also treated as a river boundary as the river recharges the alluvial sand aquifers located along its length. River conductance was calibrated to fit the water levels located adjacent to rivers, and ranged from 0.003-5 m^2/day/m.
- The ephemeral Nzhelele, Mutamba, Brak and Sand Rivers were treated as drains, capable of receiving water when groundwater levels exceed the base of the channel, but not contributing water to the aquifer. Drain conductance was 0.003-0.03, with smaller values along small tributaries.
- The alluvium along all the major channels were identified as green zones on Google Earth, were treated as an evaporation zone, where groundwater could be lost to vegetation. These were considered zones where evapotranspiration from groundwater occurs and were treated as head dependent boundaries where evapotranspiration occurs at a rate dependent on the aquifer water level. Evapotranspiration was allowed to occur to a depth of 4 m below the surface elevation. Significantly lower evapotranspiration was allowed outside these regions. Pans located at the foothills of the Soutpansberg, fed by runoff and seepage was also considered to be evaporation zones.
- Mine workings were treated as drain cells for all model layers where mining was taking place during the mining interval. Until mine plans are finalised, the pit footprint was assumed to be the drain, with depth progressing from surface to a depth of 200 m over the life of mine. The planned underground mine at Mount Stuart was treated as a drain in layer 2, progressing from surface to a depth of 400 m. This assumes inflows only take place at depth, and the upper layer is dewatered by water seeping down from surface to the lower layer. The drain conductance is equal to the coal conductivity, 0.05 m/d for open cast mines, and to 0.002 m/d for the underground mine. After mining stops the drains in the cells forming the pit were turned off, allowing water levels in the pit to recover.

- The elevation of linear boundaries, like the stream channels was interpolated from surface contours and linearly extrapolated.

Figure 18 shows the model domain, and the internal boundary conditions incorporated. Drainage channels were digitised from the topographic map, and are shown in green where considered ephemeral and as drains, and in blue where they are perennial and considered head dependant boundaries, capable of losing water to the aquifer.

Springs or fountains identified on the topographic and geological maps where treated as drains and are shown in green. Abstraction boreholes identified are shown as brown circles.

Topographic divides, which were considered no flow boundaries, across which groundwater does not flow, and served as the boundary of the model domain are shown as a black line.

Where faults cut across the model domain, allowing water to enter or leave the model domain, constant head boundaries were incorporated. These are shown in purple.

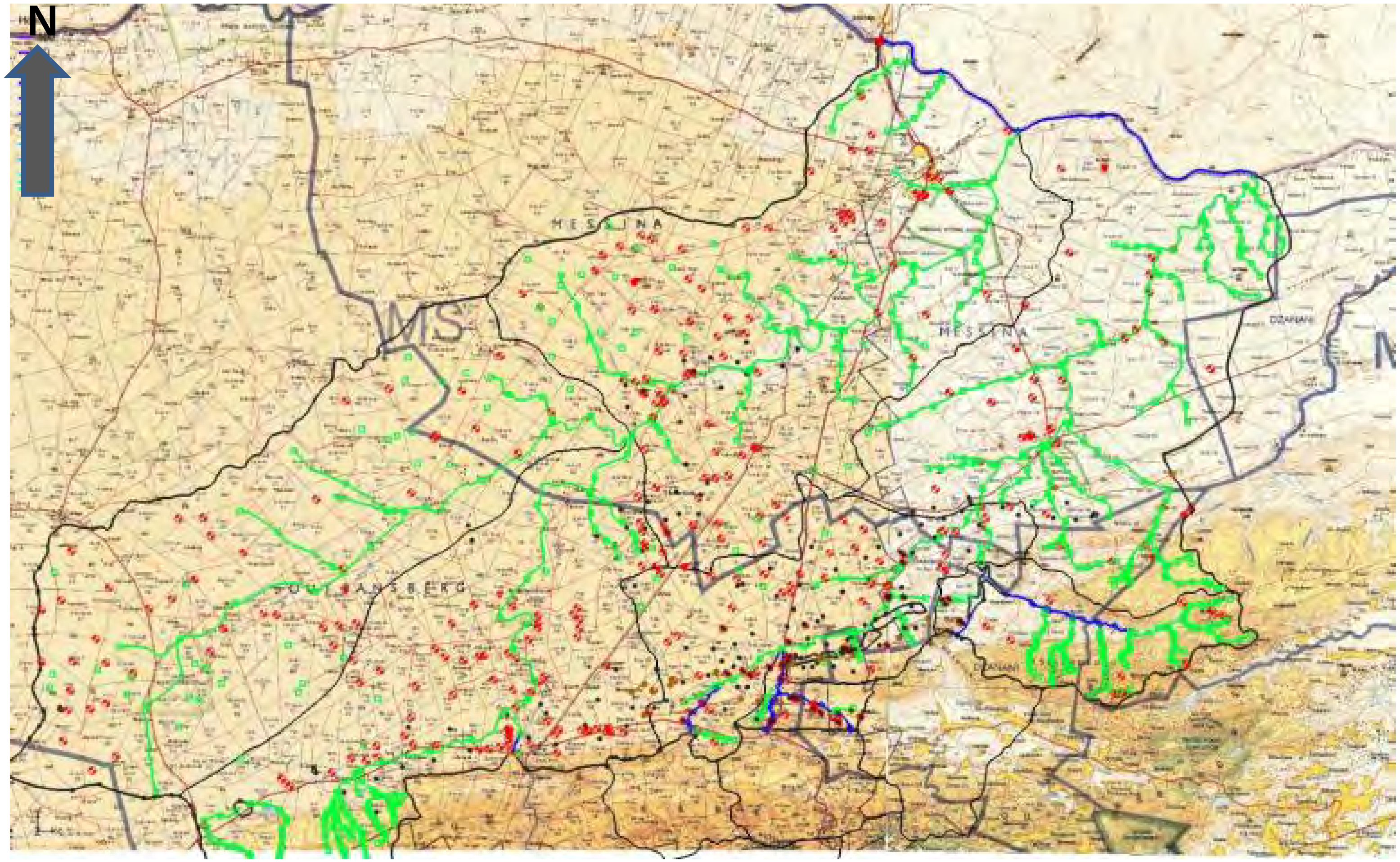

FIGURE 18: BOUNDARY CONDITIONS OF THE MODEL DOMAIN. BLUE = HEAD DEPENDENT RIVER, GREEN = DRAINS, BLACK = NO FLOW, PURPLE= CONSTANT HEAD, RED CIRCLES = EXISTING ABSTRACTION BOREHOLES

6.3 DISCRETISATION OF THE NUMERICAL MODEL

In a finite difference model the aquifer is represented by rectangular cell blocks and individual layers. Each cell is assigned a permeability, specific yield, specific storage, thickness and recharge parameter. Hydraulic heads in each cell of each layer and the exchange of water between cells and across boundaries is calculated simultaneously using finite difference mathematics until a finite solution is found within set convergence parameters. The model can be used to solve for heads under steady-state conditions, which are conditions that will occur when stability in water level and flow rates are reached, or for transient state conditions, which are flow rates and hydraulic heads that will exist after specific time intervals from an initial starting condition.

The regional aquifer was modelled as a 2 layer, 3 dimensional domain. Each layer was considered to be 200 m thick.

The grid was telescoped in the vicinity of the mining pits to provide greater resolution in zones where significant water level changes occur, as shown in Table 11.

TABLE 11: GRID DEVELOPMENT

	Base size (m)	Multiplier	Max. size (m)
Pits	100	1.5	1000

This results in cell sizes increasing outward from their base size by the multiplier up to the maximum size, giving a much finer resolution for head changes in the areas of interest, and in zones where steeper hydraulic gradients exist. For example, cells in the pits would be a minimum size of 100 x 100 m, increasing to 150 x 150 m, once outside the pit. The fine modelling interval allows the steep hydraulic gradients generated by dewatering to be represented. The domain was covered by 552 columns and 312 rows (Figure 19). The grid was oriented 65 degrees NE to be aligned with the orientation of rivers and major faults.

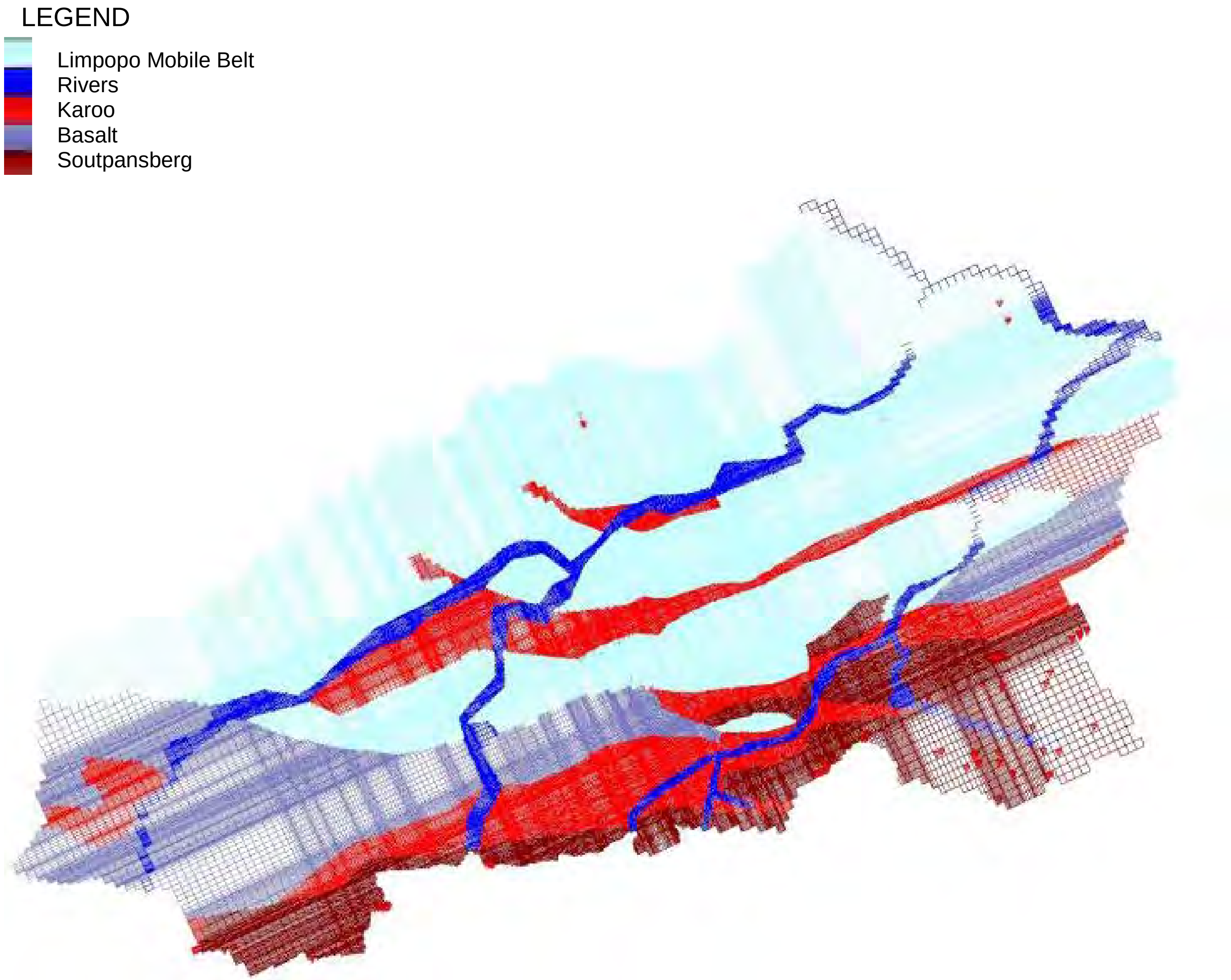

FIGURE 19: ACTIVE CELLS IN THE MODEL DOMAIN, CODED BY LITHOLOGY

The aquifer layer cells were set as confined, becoming unconfined when water levels dropped below the aquifer top. Horizontal anisotropy was set to 1 in the horizontal direction, meaning hydraulic conductivities are the same in the x and y plane, and 10 in the vertical direction, making vertical hydraulic conductivity 10% of the horizontal for flow between layers.

6.4 RECHARGE

Mean annual rainfall in the Quaternary catchments varies from 305-622 mm/a. Rainfall is significantly higher in the Soutpansberg and the catchments of the Kandanama and Mufungudi, hence recharge rates are highly variable, being high in the Soutpansberg, and lower to the north. Recharge also varies by geology due to the presence of low permeability mudstones in the Karoo and Kalahari sand cover in the north-western part of the study area, which reduces runoff and enhances recharge slightly. Recharge was simulated using a constant inflow into defined parameter zones and calibrated against borehole water levels in the steady state model. Recharge was higher in the Soutpansberg where higher rainfall and shallow soils occur and slightly less in regions of the Soutpansberg where vegetation indicates lower rainfall. Low recharge rates were applied to the plains north of the Soutpansberg.

Average recharge across the model domain is 4.7 mm/a, or 1.3% of rainfall. The recharge to the delineated recharge zones are shown in Table 12. Mine pits (brown were considered to have a high recharge of 255 mm/a post mining, declining to 73 mm/a after 3 years, then to 36 mm/a after 6 years (10% of rainfall) when rehabilitation is complete. Mine dumps were considered to grow from 0-3 years after start of mining, have a recharge rate of 73 mm/a, declining to 50 mm/a after the life of mine and rehabilitation.

TABLE 12: RECHARGE IN MM/A

	Mining	Post mining	
		3 years	6 years
Mine pits	0	255	73
Soutpansberg, steep slopes, shallow soil	11-55	11	55
Soutpansberg, deeper soils	1-5	1-5	1-5
Karoo	0.5-6.5	0.5-6.5	0.5-6.5
Basalt	1.2-5	1.2-5	1.2-5
Limpopo Mobile Belt	1-6	1-6	1-6

6.5 EVAPOTRANSPIRATION

Evapotranspiration was assumed to occur from groundwater at a maximum rate of 5.5-25 mm/a) from evapotranspiration zones along rivers, if the water level was at surface, dropping linearly to zero if the water level dropped to 4 m below surface. Away from river channels the maximum evapotranspiration rate was set at 1.5 mm/a. The evapotranspiration rate was calibrated to ensure that no baseflow occurs in rivers known to be ephemeral.

6.6 GROUNDWATER ABSTRACTION

Groundwater abstraction over the whole regional model area was simulated by discharge boundaries in cells containing production boreholes. Groundwater abstraction was estimated from the DWA WARMS database of registered water use, and from a hydrocensus, however, it was found that the registered use of 46

Mm^3/a is much higher than recharge and that irrigated lands could not be observed to account for the registered water use. The following was concluded:

- The registered water use was not utilised every year
- Farmers along the Nzhelele scheme only utilise boreholes when surface water from the Nzhelele scheme isn't sufficient, hence don't utilise the entire registered use from groundwater
- Much of the groundwater use is from well points or caissons in alluvial sand, replenished during storm events and hence isn't abstraction from the regional aquifer.

Consequently the following resolution was undertaken:

- Irrigated lands were digitised from Google Earth as opposed to cleared irrigable lands in order to estimate water use. Water use was estimated at 7 880 $m^3/ha/a$ due to the seasonal nature of crops.
- Lands located along channels where the hydrocensus indicated abstraction by caissons were not considered, as they assumed to utilise only alluvial water
- Lands along the Nzhelele had only a fraction of the estimated use met from boreholes
- Irrigation was only simulated during calibration if observed water levels in the NGDB were post 1985. The irrigation was subsequently turned on to derive present day water levels.

Actual water use over the whole regional model area was calculated as 6 Mm^3/a of which Chapudi MRA area contributes 4.6 $Mm^3/annum$ (see table 10). In addition, the MODFLOW NWT package was utilised, which reduces borehole abstraction proportionally to keep water levels above a present level. A maximum water level of 100 metres below ground level was selected. The subsequent current groundwater abstraction simulated was 5.3 Mm^3/a.

6.7 PERMEABILITY AND STORAGE COEFFICIENTS

The surface elevation contours were utilised to form a Triangular Irregular Network (TIN), from which the ground surface was derived. A 200 m depth below the surface was taken as model layer 1. The subsequent 200 m to a depth of 400 m was considered as layer 2. Permeabilities in m/day were assigned to geological zones (Table 13), differentiated by lithology, topography and the proximity to fault zones.

Permeability was calibrated to fit against observed water levels in a steady state model. Results of the packer tests undertaken in Karoo rocks and the coal also show that conductivities for layer 1 range from 0.003-0.08 m/day, which is within the range of calibrated values (Table 13).

TABLE 13: HYDRAULIC CHARACTERISTICS OF LAYERS

Layer	Permeability (m/d)	Transmissivity (m2/d)	Vertical anisotropy	Specific yield	Specific storage
Limpopo mobile belt					
Layer 1	0.001-0.009	0.2-1.8	10	0.001	0.00005
Layer 2	0.0005-0.001	0.1-0.2	10	$1.7x10^{-6}$	$1.7x10^{-8}$
Soutpansberg					
Layer 1	0.005-0.02	1-4	10	0.001	0.00005
Layer 2	0.001	0.2	10	$1.7x10^{-6}$	$1.7x10^{-8}$
Soutpansberg Range					
Layer 1	0.001-0.006	0.2-1.2	10	0.001	0.00005
Layer 2	0.0001-0.0005	0.02-0.1	10	$1.7x10^{-6}$	$1.7x10^{-8}$
Karoo					
Layer 1	0.03-0.08	6-16	10	0.001	0.00005
Layer 2	0.005	1	10	$1.7x10^{-6}$	$1.7x10^{-8}$
Clarens Formation					
Layer 1	0.02-0.05	4-10	10	0.001	0.00005
Layer 2	0.005	1	10	$1.7x10^{-6}$	$1.7x10^{-8}$
Basalt					
Layer 1	0.02-0.07	4-14	10	0.001	0.00005
Layer 2	0.005	1	10	$1.7x10^{-6}$	$1.7x10^{-8}$
Rivers					
Layer 1	0.06-0.08	12-16	10	0.001	0.00005
Layer 2	0.005	1	10	$1.7x10^{-6}$	$1.7x10^{-8}$
Mine fill					
Layer 1	1	200	10	0.1	0.0016

The specific yield value was calibrated from abstraction data collected during the bulk sample excavation of Makhado mine. The bulk sample pit was established over 60 days, during which pumped volumes to keep the cut dry were monitored. The elevation of the bottom of the bulk sample pit was set as a transient state drain in a 90 day transient state model. The specific yield was then calibrated so that inflows into the cut matched pumped volumes. The calibrated specific yield was adjusted downward, since the model layers in this simulation are 3 times thicker than those utilised as Makhado. The specific yield was calibrated so that similar pit inflows were derived for the Makhado mine pits in this study as in the Makhado modelling study.

6.8 HORIZONTAL BARRIERS

The presence of steeply dipping dolerite sills within the Karoo, which act as a low permeability barrier to northerly flow, was incorporated by using horizontal flow barriers. Observed water level differences of 20 m exist across this sill in the vicinity of Fripp. This was simulated as a horizontal flow barrier across both 4 layers. The barrier has a conductance value to restrict the flow of water across the barrier. The conductance value was calibrated to 5 x 10^{-6} to match water levels in observation boreholes on either side of the barrier.

Horizontal barriers were digitised into the model from existing geological maps. In the vicinity of the proposed mine, drilling data allowed the position of sills to be more accurately established.

6.9 INITIAL HEAD

In order to assess the transient state impact of mining on water levels and on the water balance, a model requires an initial hydraulic head distribution. This is usually achieved by calibration of a steady state model against observed water levels, which serves as the initial head distribution for the subsequent transient state model to simulate what will occur during mining and post-mining. Hence a steady state model is necessary prior to simulating impacts.

The simulated present day steady state flow model was assumed to represent pre-mining conditions with abstraction.

The resulting head distribution from the steady state model was used as the input into a transient state model starting in 2016 once mining begins and water levels begin to be affected.

6.10 MODEL SIMULATIONS

The simulations undertaken are shown in Table 14.

TABLE 14: MODEL SIMULATIONS PERFORMED

Simulation	State	Time steps (years)	Year From start of mining	Purpose	Impacts
1	Steady			Model calibration,	Abstraction on farms with recent water levels
2	Steady	`		present day water levels	Addition of all abstraction
3	Transient	16	16	Impact of mining	Makhado life of mine, Voorburg, Jutland, Wildebeesthoek, Mount Stuart mine start ups
4	Transient	22	38	Impact of mining	Makhado closure and water level recovery, Voorburg, Wildebeesthoek, Mount Stuart life of mine,

					Generaal, Chapudi start up
5	Transient	11	49	Impact of Mining	Jutland, Chapudi and Generaal up to the closure of Generaal
6	Transient	12	61	Impact of Mining	Closure of all mines

6.11 MINING LEVELS AND INFLOWS

To simulate expected inflows, dewatering requirements and impacts on water levels, the pit extent were entered as drain polygons. The pit floor was linearly extrapolated from ground surface to 200 m depth over the life of the pit using a transient state drain elevation. The mining plan was utilised to determine the area being mined. Drain conductance was set at 0.05, similar to an average Karoo permeability.

Annual time steps were utilised to calculate inflows into the mine workings.

To simulate post mining water levels, the drain polygons were removed, allowing the workings to fill to the decant level, which was identified as the lowest point of the pit surface using Google Earth. Decant points were created by setting a high permeability drain at the appropriate location and elevation. The pit conductivity and specific yield were set as mining fill (Table 13).

Mine pits were considered to have a high recharge of 255 mm/a after being filled, declining to 73 mm/a after 3 years, then to 36 mm/a after 6 years (10% of rainfall) when rehabilitation is complete. Mine dumps were considered to grow from 0-3 years after start of mining, have a recharge rate of 73 mm/a, declining to 36 mm/a after the life of mine and rehabilitation.

6.12 MODEL CALIBRATION

Calibration is the process whereby model parameters and boundary conditions are systematically altered in numerous consecutive simulations until simulated groundwater levels and flows match observed field measurements to within an acceptable error margin. Calibration under known conditions is critical if the model is to be used to forecast scenarios for which no observed data is available.

The trial and error manual calibration method was utilised.

Calibration of the model was based on water levels in 965 observation boreholes identified in the original and subsequent hydrocensus, in the NGDB, and the GRIP database and newly drilled boreholes. 657 boreholes were historic water levels from the NGDB, while remainder were verified in the field from the Makhado and current hydrocensus surveys.

Water levels utilised for calibration were taken at various moments in time, especially from older boreholes in the NGDB, hence, depending on the date when borehole monitoring was undertaken, variations in water levels may exist. Some of the water levels were historic and considered un-impacted by recent abstraction, hence in the vicinity of these water levels, abstraction was excluded.

Measured water levels below ground surface had to be converted to absolute water levels in terms of metres above mean sea level (mamsl). Absolute calibration of water levels is hindered by the fact that errors exist in absolute observed water levels. These can be attributed to:

- Errors in borehole elevation obtained from Google Earth
- Errors in borehole position for historic NGDB boreholes
- Deviations in water level seasonally (± 3 m) due to the different times at which water levels were taken.

- Variations in pumping cycles and local impacts by abstraction on water levels

The results of the calibration are shown in Figures 20-22.Calibration statistics are:

Mean Residual (Head)	-1.367645824981
Mean Absolute Residual (Head)	9.3788558502275
Root Mean Squared Residual (Head)	14.497181873258

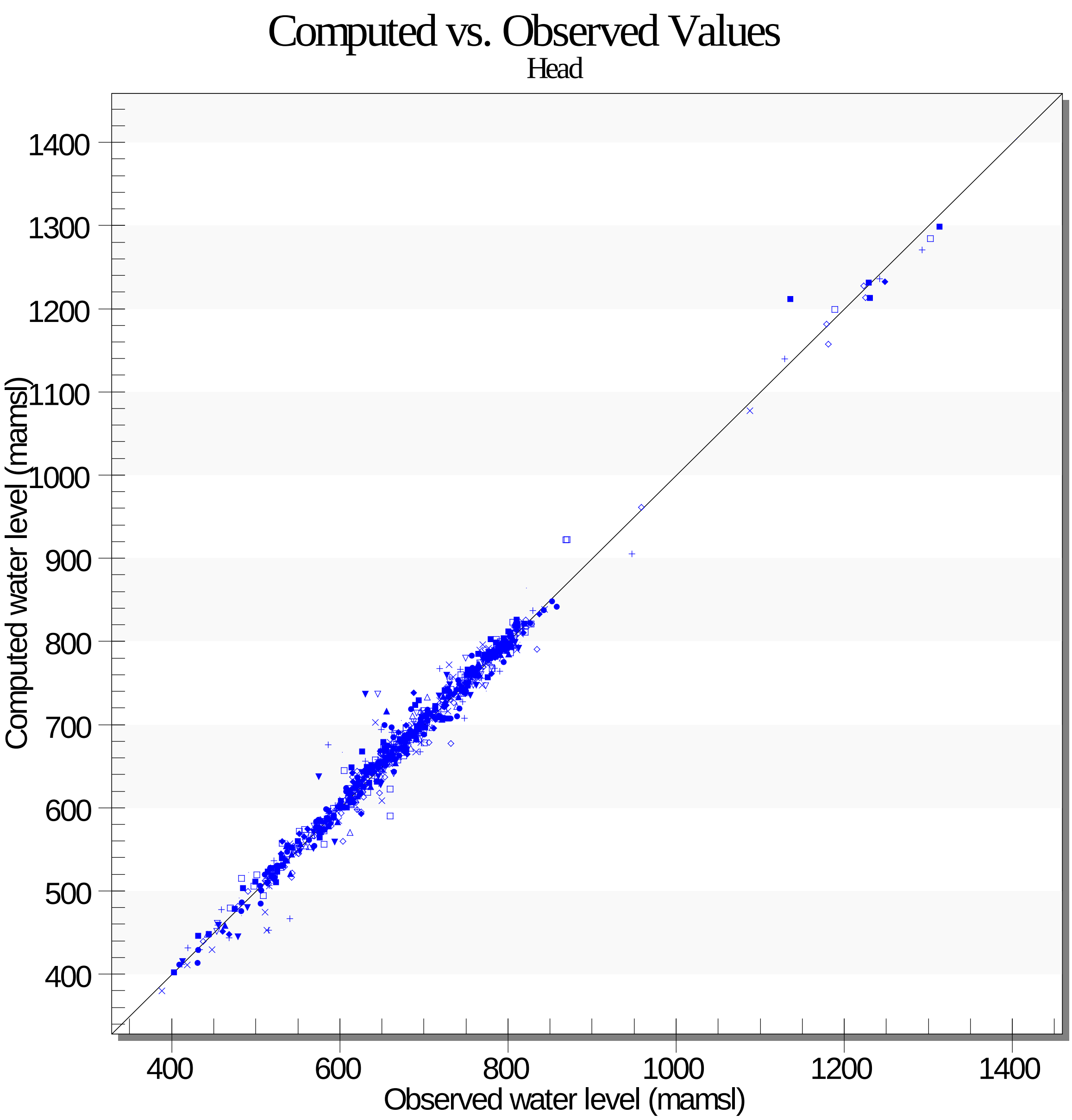

FIGURE 20: OBSERVED VERSUS SIMULATED WATER LEVELS IN METRES

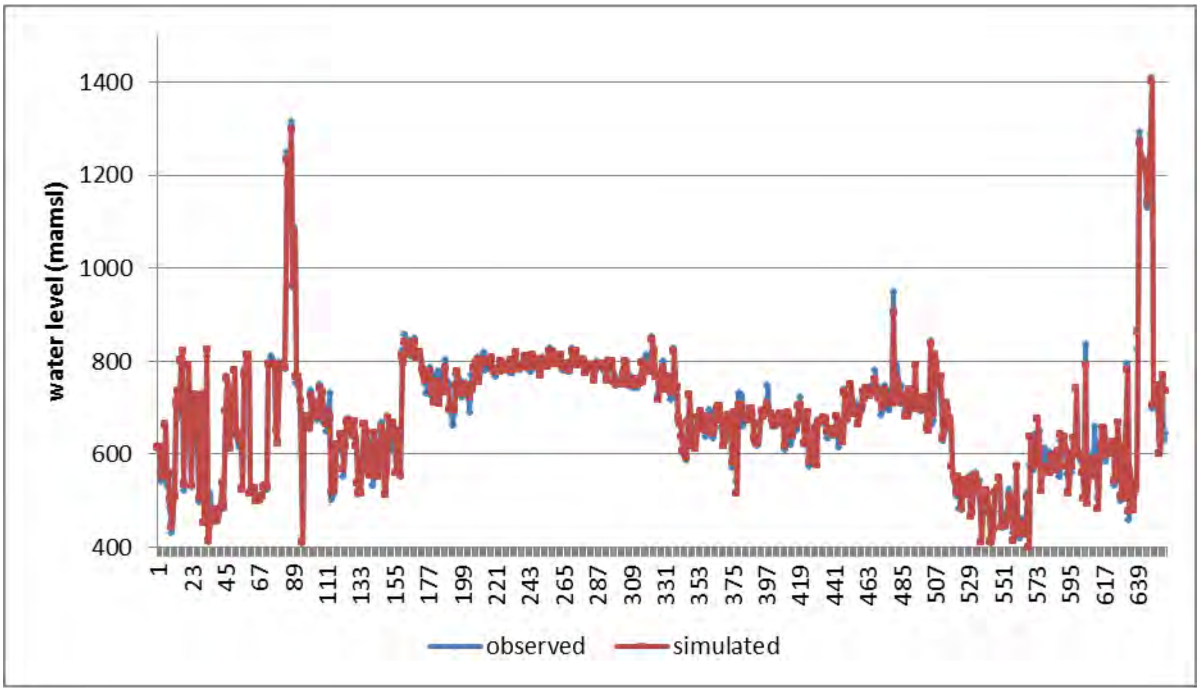

FIGURE 21: CALIBRATION AGAINST NGDB BOREHOLES IN THE CATCHMENT

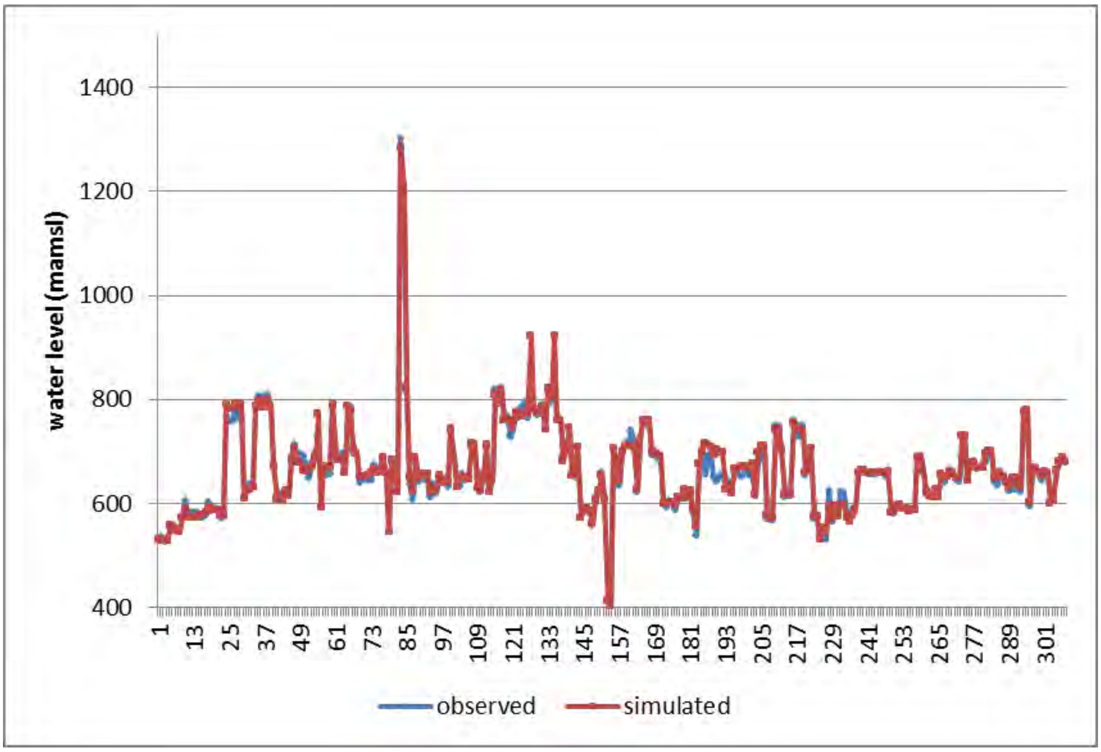

FIGURE 22: CALIBRATION AGAINST HYDRO-CENSUS IN THE VICINITY OF THE CHAPUDI MINE

The residual error plot (figure 23) shows no systematic error in heads, with some over and some under simulated. High lying boreholes with water level elevations above 1200 metres above mean sea level show a slight positive residual head, suggesting water levels can be up to 20 m too low.

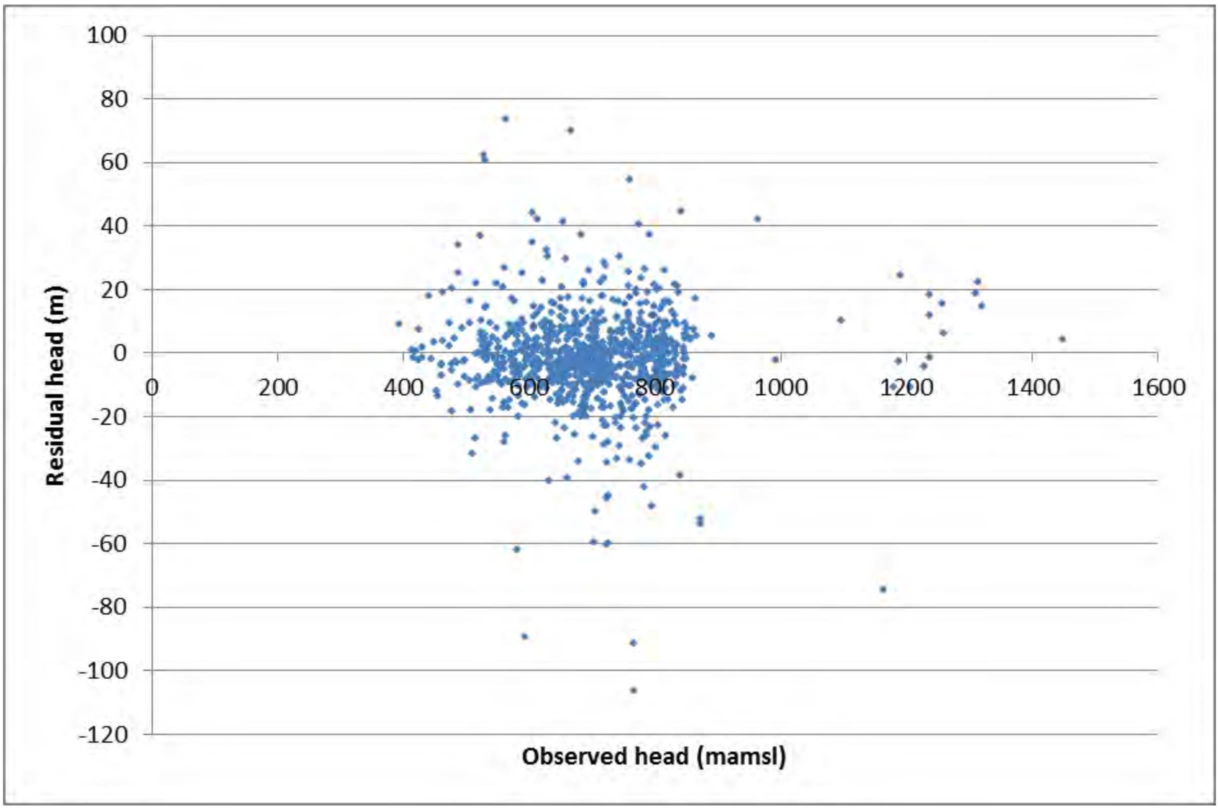

FIGURE 23: RESIDUAL ERROR OF SIMULATED VERSUS OBSERVED VALUES

A plot of residual head versus water levels in metres below ground level (mbgl) shows that boreholes with water levels below 60 mbgl have water levels over simulated (figure 24). These include many historic water levels from the NGDB impacted by abstraction which was not considered in the survey of present abstraction.

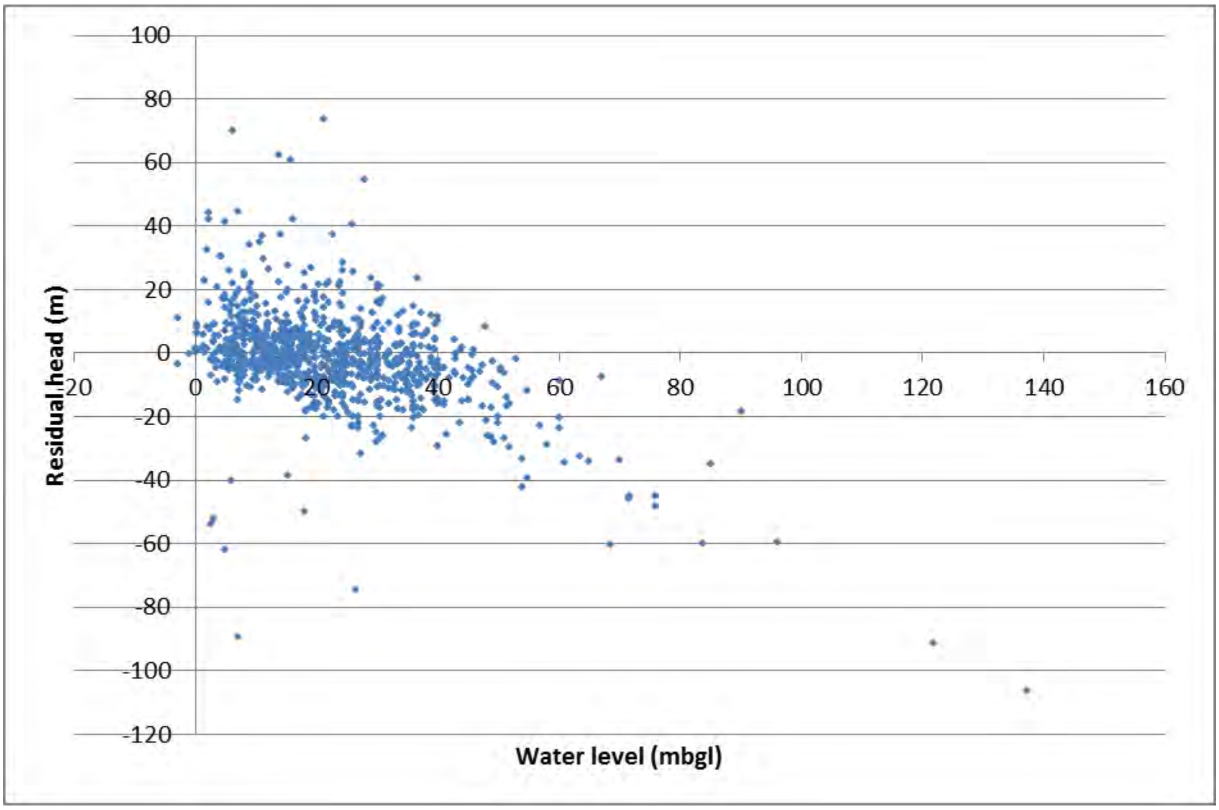

FIGURE 24: RESIDUAL HEAD VERSUS WATER LEVELS BELOW GROUND SURFACE

Model calibration was also undertaken via a water balance done per Quaternary catchment, to ensure recharge and discharge figures approximate the water balance per quaternary published in other sources.

7 MODEL RESULTS

Modelling results are expressed as water level drawdowns from a pre-existing condition, or as a water balance, which is a calculation whereby the inflows and outflows of a groundwater system are determined. This is done by considering all the external and internal groundwater gains and losses in the aquifer such as:

Inflow: - groundwater flow into a specific area as a result of difference in gradients, groundwater recharge as a result of rainfall infiltration and losses from rivers.

Outflow: - groundwater leaving the system through the defined flow boundaries of the model due to the hydraulic gradient, borehole abstractions, baseflow to rivers and springs, and evapotranspiration.

7.1 WATER BALANCE

7.1.1 STEADY STATE - PRE MINING CONDITIONS

The water balance of the entire aquifer under natural conditions and present is shown in Table 15. Inflows from rivers occur from the perennial tributary flowing northward to the Mutamba from the Soutpansberg. This tributary loses water to the aquifer due to pumping on Windhoek, Eckland and Overwinning, and flow disappears before it reaches the Mutamba. Inflows also occur along the Tshipise fault and other faults entering the study area from the west and south. Outflows from the aquifer to rivers occur in the south, where the tributary of the Mutamba is perennial and fed by baseflow. Outflow from the study area occurs eastward along the Tshipise fault, and other faults, and to the Nzhelele dam. Evapotranspiration losses occur in alluvium along the Mutamba. Outflow also occurs to numerous springs and water courses as spring flow.

TABLE 15: STEADY STATE WATER BALANCE PRIOR TO MINING

Flow Component	Inflow (m^3/d)	Outflow (m^3/d)
Virgin Conditions		
Faults	768	701
Rivers	2700	11501
Nzhelele dam	186	1681
Evapotranspiration		49485
Springs and ephemeral channels		26438
Recharge	86155	0
Abstraction	0	0
Total	89809	89810
Current Conditions		
Faults	3105	170
Rivers	3517	8725
Nzhelele dam	187	1567
Evapotranspiration		47820
Springs and ephemeral channels		20542
Recharge	86155	0
Abstraction	0	14510
Total	92964	93335

7.1.2 TRANSIENT STATE – MINING CONDITIONS

The water balance of the aquifer during mining is altered due to inflows into the pits, which impact on water levels, and consequently on the aquifer water balance. The simulated water balance of the aquifer is shown in Table 16 for the following years:

Year 4: prior to the start of Wildebeesthoek, with Makhado 4 years in operation

Year 16: final year of Makhado in operation, Voorburg, Mount Stuart and Wildebeesthoek in operation

Year 17: Closure of Makhado

Year 30: Voorburg, Jutland, Wildebeesthoek, Mount Stuart, Chapudi and Chapudi west, Generaal in operation

Year 38: Voorburg, Jutland, Generaal, Chapudi and Chapudi west in operation

Year 49: Chapudi, Chapudi west and Generaal in operation

Year 61 Last year of Chapudi, Chapudi west in operation

TABLE 16: SIMULATED WATER BALANCE OF THE AQUIFER AT VARIOUS STAGES OF THE GSP MINES

Flow Component	Inflow (m^3/d)	Outflow (m^3/d)
Year 4		
Storage	1465	594
Faults	3454	199
Rivers	3513	8670
Nzhelele dam	189	1548
Evapotranspiration	0	47719
Springs and ephemeral channels	0	20440
Recharge	86155	0
Abstraction	0	14862
Wildebeesthoek	0	0
Makhado	0	745
Total	94777	94776
Year 16		
Storage	8496	279
Faults	3469	198
Rivers	3556	8437

Nzhelele dam	346	1214
Evapotranspiration	0	47216
Springs and ephemeral channels	0	18733
Recharge	86155	0
Abstraction	0	14343
Wildebeesthoek	0	0
Other Mines	0	11645
Total	102022	102064
Year 17		
Storage	7210	11683
Faults	3470	197
Rivers	3562	8408
Nzhelele dam	357	1212
Evapotranspiration	0	47190
Springs and ephemeral channels	0	18615
Recharge	92710	0
Abstraction	0	14467
Wildebeesthoek	0	0
Chapudi	0	0
Other Mines		5650
Total	107309	107422
Year 30		
Storage	9757	3672
Faults	3558	186
Rivers	3581	8323
Nzhelele dam	385	1205
Evapotranspiration	0	46729
Springs and ephemeral channels	1	19710
Recharge	87200	0
Abstraction	0	14350
Wildebeesthoek	0	2600

Chapudi	0	69
Chapudi West	0	0
Other Mines		9754
Total	104483	104598
Year 38		
Storage	7660	5850
Faults	3755	170
Rivers	3614	8198
Nzhelele dam	358	1207
Evapotranspiration	0	46590
Springs and ephemeral channels	0	17698
Recharge	87200	0
Abstraction	0	14120
Wildebeesthoek	0	0
Chapudi	0	1489
Chapudi West	0	00000
Other Mines		7303
Total	102589	102624
Year 49		
Storage	6558	6901
Faults	4134	157
Rivers	3659	8039
Nzhelele dam	332	1213
Evapotranspiration	0	46432
Springs and ephemeral channels	0	16127
Recharge	89405	0
Abstraction	0	16354
Wildebeesthoek	0	00000

Chapudi	0	4000
Chapudi West	0	38
Other Mines		3748
Total	104089	104010
Year 61		
Storage	3324	9914
Faults	4083	157
Rivers	3688	7975
Nzhelele dam	311	1219
Evapotranspiration	0	46157
Springs and ephemeral channels	0	19190
Recharge	91725	0
Abstraction	0	14258
Wildebeesthoek	0	00000
Chapudi	0	4315
Chapudi West	0	518
Other Mines		0

7.2 IMPACTS OF MINING

The impacts of mining on the water balance are shown in Figure 25.

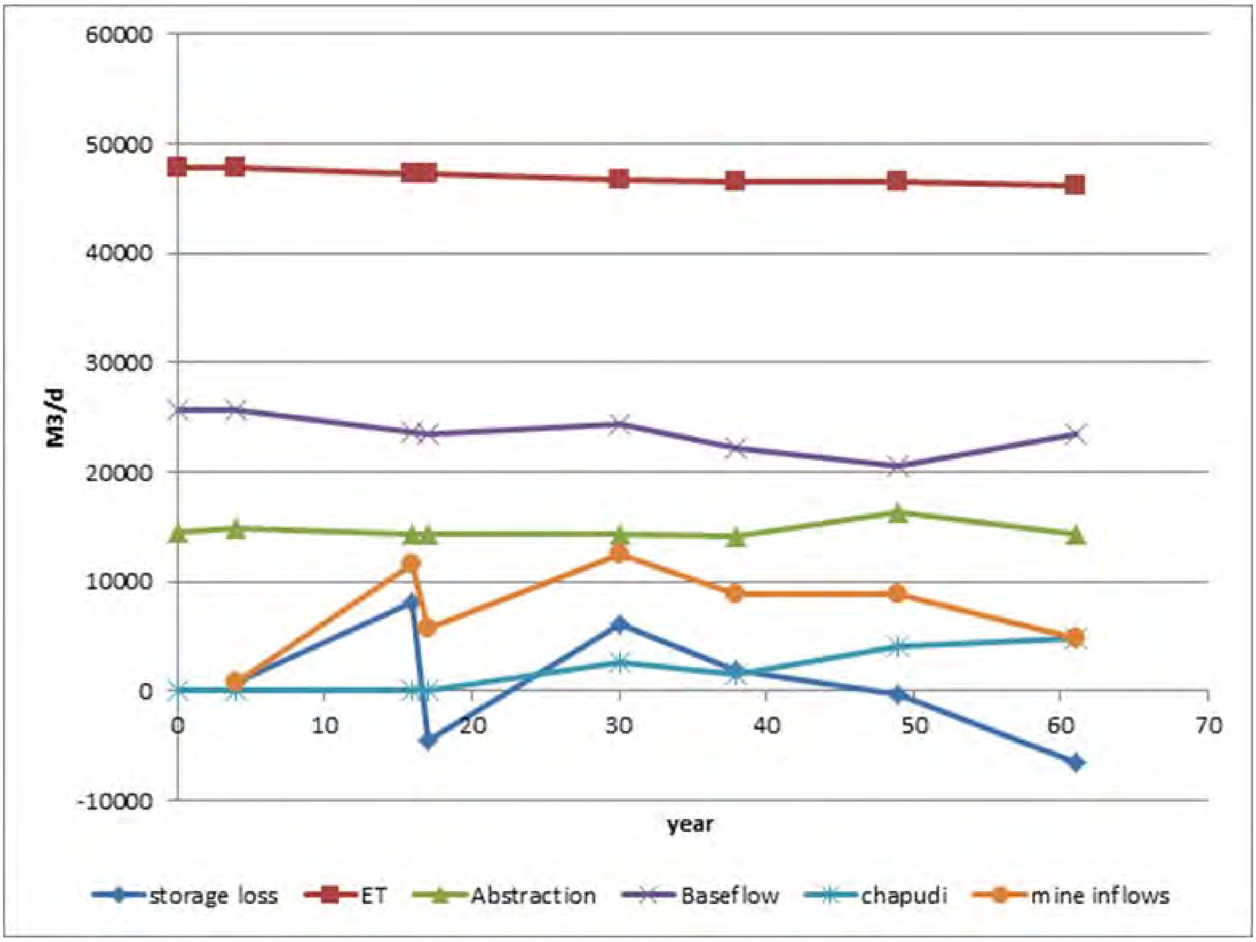

FIGURE 25: MINE ABSTRACTION AND IMPACT ON THE GROUNDWATER

Evapotranspiration from riverine areas is impacted and decreases from 47.8 Ml/d to 46.4 Ml/d. This reduction occurs largely along the river channels and the springs and seeps along the foot of the Soutpansberg Mountains, where drawdown of the water level reduces the availability of shallow groundwater.

Abstraction of groundwater for existing users is reduced from 14.5 Ml/d to a minimum of 14.1. Due to the way that the model has been set up i.e. 2 layers of 200m thickness each, losses from abstraction may be significantly more, as in the model, boreholes can abstract water down to 200m, which is not the real situation.

The bulk of inflows into the pits and to boreholes originate from storage losses from the aquifer, which rises to 8.1 Ml/day by the end of the life of mine of Makhado. They subsequently decline due to the refilling of Makhado and the closure of Mount

Stuart underground mine and Wildebeesthoek. Inflows into mines peak at 12.4 Ml/d when all mines except Makhado are in operation, then decline to 8.7 Ml/d by the end of the life of Mopane. During the peak inflows, 2.7 Ml/d are inflows into the Chapudi mines. Inflows into Chapudi rise to 6.2 Ml/d by year 59, and then fall to 4.8Ml/d at year 61.

Mine inflows exclude direct rainfall into mine workings, and surface runoff which is not diverted. This is because such inflows are not part of the average daily inflow, and occur only during storm events, which are highly variable. Post mining, recharge to the pits is included in the water balance, since this volume will not be removed as storm water and will replenish the pits.

7.3 INFLOWS INTO WILDEBEESTHOEK, CHAPUDI AND CHAPUDI WEST PITS

Inflows into Wildebeesthoek increase to 2.9 Ml/d in mining year 34, 29 years after the pit starts, which were simulated assuming a progressive deepening of the pit. The first 18 years mining will be above the water table, hence no inflows due to the deep present water level (up to 70 mbgl).

Inflows into Chapudi, located close to the high recharge zone in the Soutpansberg, increase to 5.4 Ml/d by year 59. During the first 8 years mining will be above the water level and thus no inflows.

Inflows into Chapudi West increase to 0.8 Ml/d by year 59, before starting to decline. During the first 20 years mining will be above the water table and thus no inflows

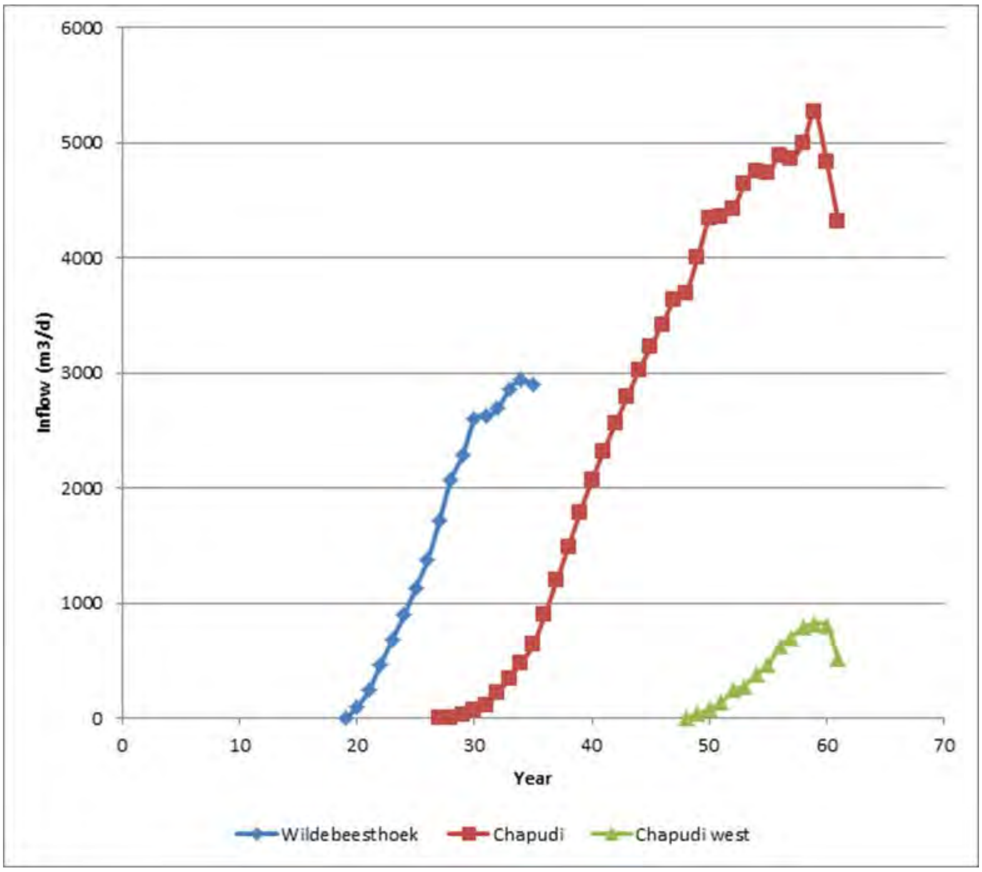

FIGURE 26: INFLOWS INTO PIT

7.4 DRAWDOWN

Drawdown is the measure of water level decline taken from a bases point, in this case prior to commencement of mining i.e. year 2013. Drawdown of the water level after mining commences is shown for various periods of time in Figures 27-30.

Not much drawdown in water level occurs around Wildebeesthoek by year 16, 12 years after the start of Wildebeesthoek, due to the existing deep water levels already present in the area prior to mining, Figure 27. By mining year 38 and 49 significant drawdown occur around Wildebeesthoek and the Chapudi sections but not much around Chapudi West due to existing deeper water levels as a result of irrigation. By mining year 61, the end of life of mines significant drawdown occurs northwards for more than 25 kms as the impacts from Chapudi, Generaal, Mopane and Makhado are cumulative and overlap.

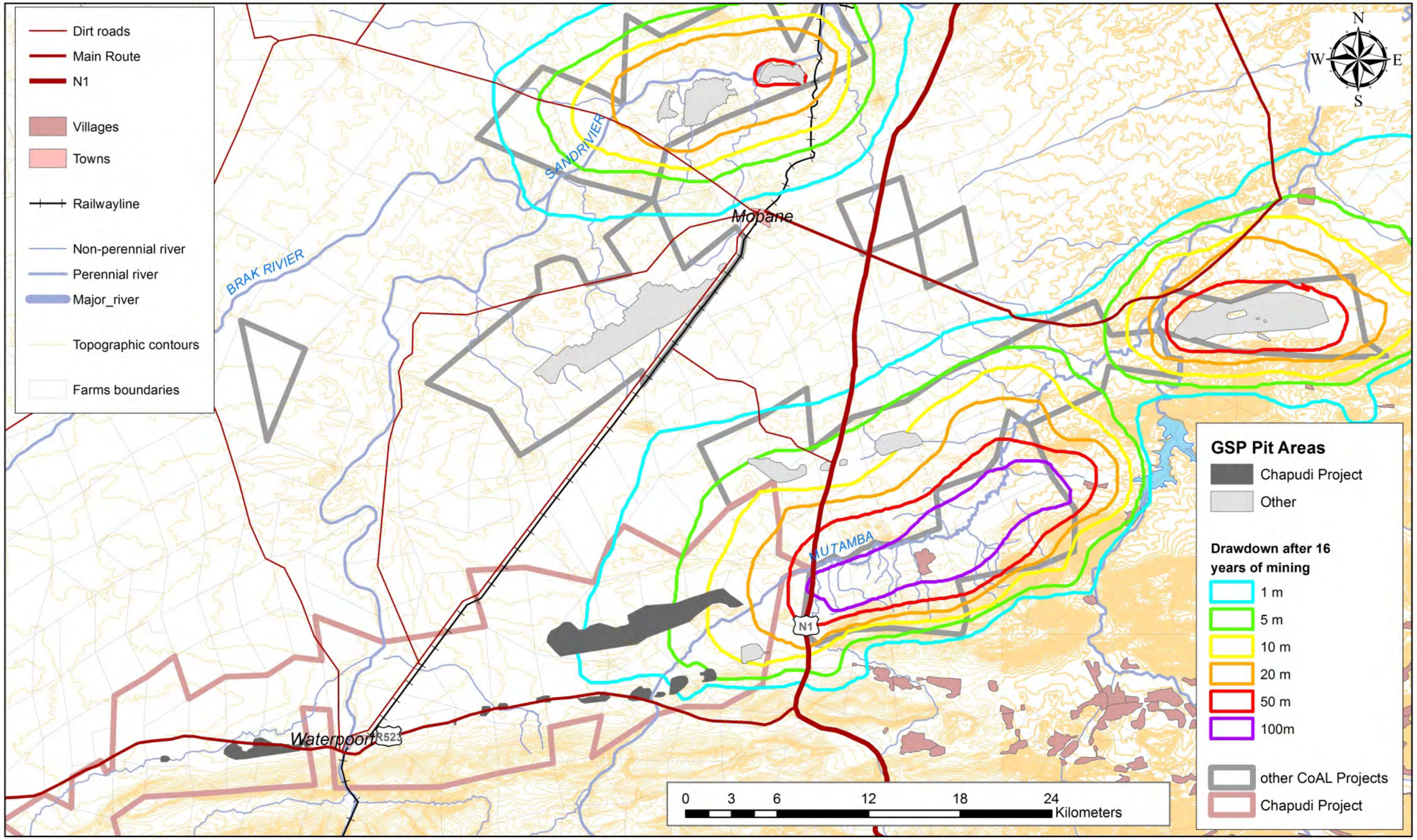

FIGURE 27: DRAWDOWN IN MINING YEAR 16

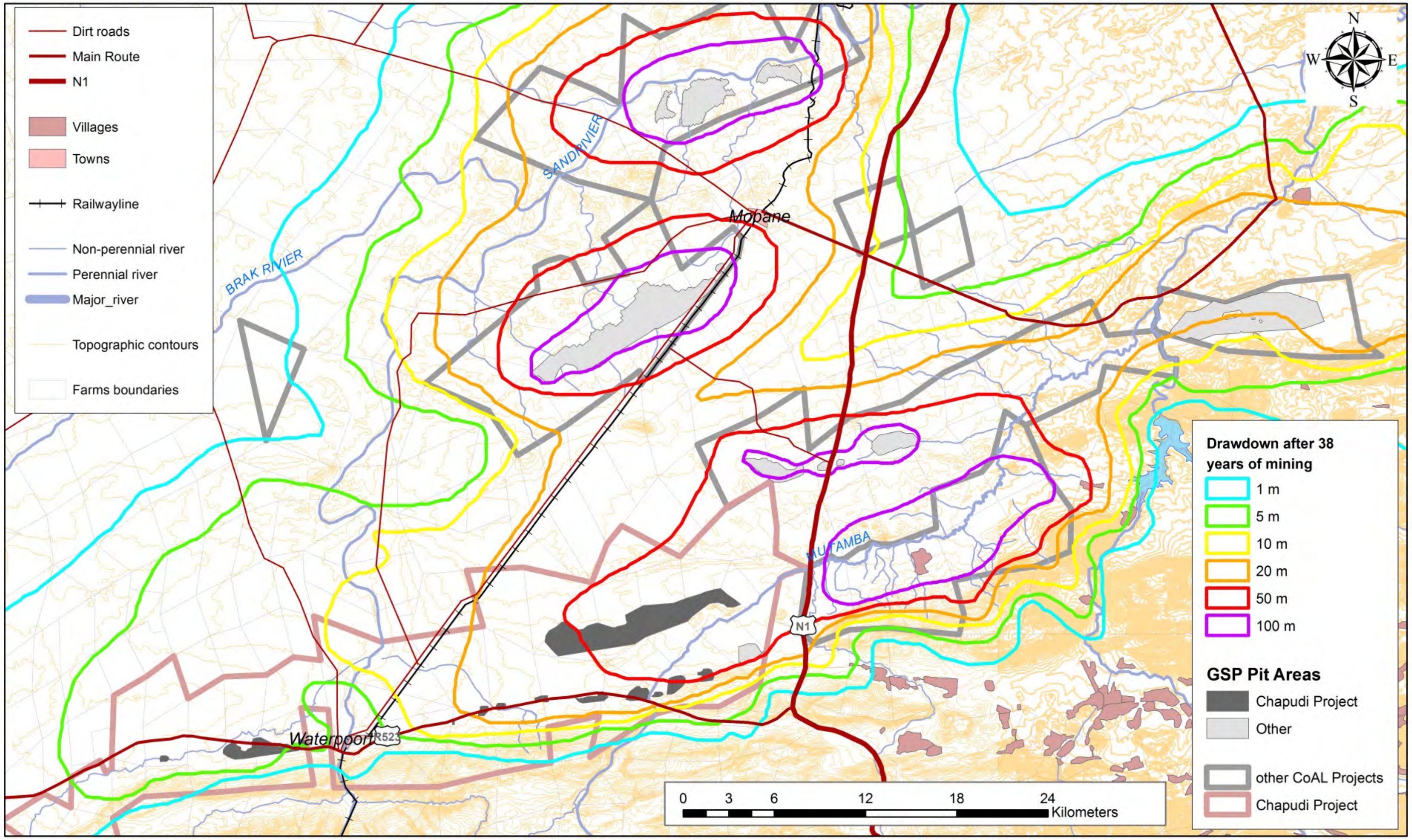

FIGURE 28: DRAWDOWN IN MINING YEAR 38

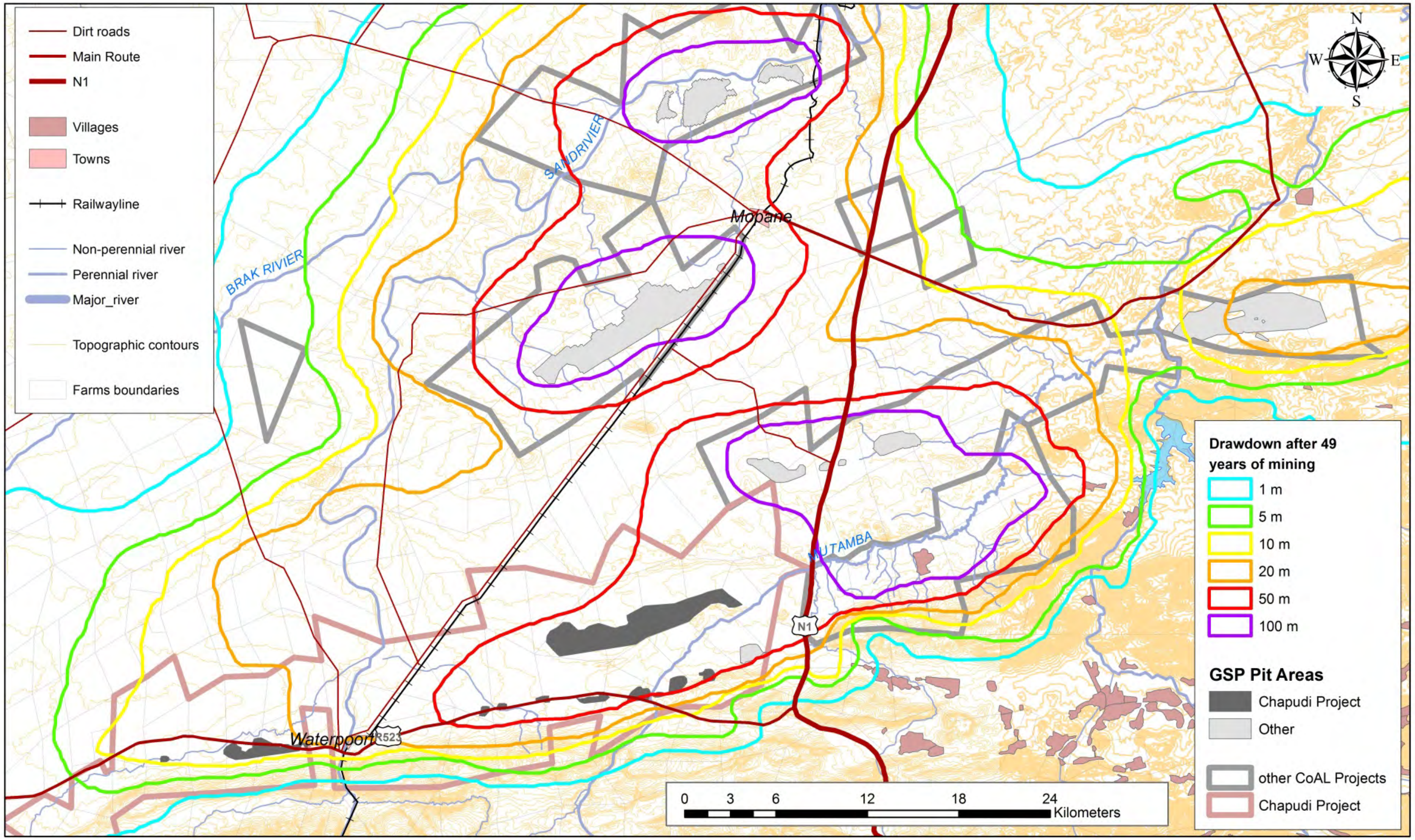

FIGURE 29: DRAWDOWN IN MINING YEAR 49

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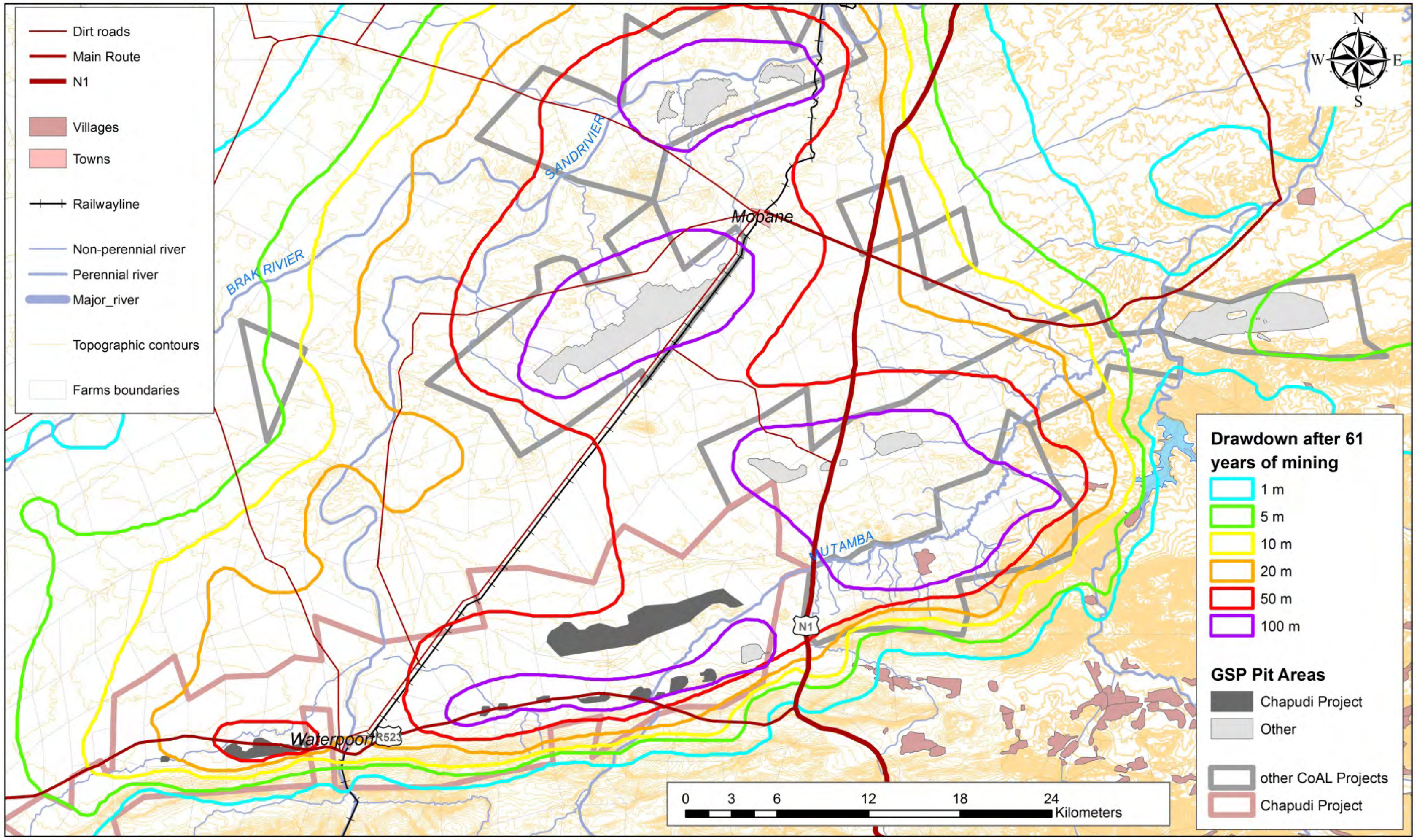

FIGURE 30: DRAWDOWN IN MINING YEAR 61

8 SHORTCOMINGS AND LIMITATIONS

Although, all available data was collected and utilised to develop the groundwater model, and ensure that the model presents the actual situation as accurately as possible, some limitations can be noted:

- Limited and inaccurate data on actual groundwater usage, hence abstraction estimates are based on hectares observed under irrigation. Registered and claimed water uses do not correlate with observed water use based on lands under irrigation. Since recharge to the area is low, abstraction estimates have a significant impact on water levels.
- Current water levels were only obtained from a local hydrocensus. Due to the cumulative impacts of several mining projects, current water levels need to be obtained over a broad area covering the entire impacted area
- Data collected in a relatively wet period
- Aquifer storage data based solely on best estimate and inflows into the bulk sample pit undertaken at Makhado. Similar data is required at Chapudi to calibrate projected inflows.

9. FURTHER RECOMMENDED WORK

To further improve the conceptual model and validate the conclusions made in this report, several items require additional work:

- Monitoring: Establishment of monitoring piezometers near where initial mine workings will commence. Transient state parameters of mining are at present best estimates based on data collected during the box cut exploration at Makhado. Predictions cannot be calibrated without data collected after mining commences. Water level changes once open bit mining begins should be used to further refine storage parameters in the groundwater model and drain conductance's used for the mine workings. These estimates will affect projections of inflows at other mines and the cumulative impacts of all mining operations in the region.

- Verification of inflows and water levels by monitoring is required to validate model after mining commences.
- Verification of abstractions especially from irrigation farmers.
- Derivation of local more detailed multilayer models at a monthly time scale for each mine once a more detailed mining plan becomes available.
- Model Sensitivity analysis: Once the model is complete with all the required information, supported by monitoring data, a sensitivity analysis needs to be undertaken to determine how sensitive the model results are to parameters with some uncertainty. This involves simulations with parameter values increased and reduced to determine how it affects the calibration results, and the confidence in the selected parameter values
- Model Verification: Model verification means comparing model results against an independent data set from that which the model was calibrated against. Monitoring data can be used, as well as the extended model data, and additional data to be obtained from farmers private records not previously submitted to the consulting team.

10. GROUNDWATER IMPACT ASSESSMENT FOR THE CHAPUDI PROJECT

Mining at Chapudi will involve open cast mining along extended open cuts down to 200m below surface.

A Multiple layered aquifer system is thought to occur in the Chapudi west area where aquifers of different quality overly each other. These aquifers are separated by shale aquitards. An example is the saline alluvial aquifer which overlies fresh aquifers associated with the coal seams and the faults. Mining will disturb the aquitards allowing for mixing of these aquifers resulting in the fresh water aquifers becoming more saline.

Groundwater flow will be intersected by the pits when below the water table. The water flowing into the pits will need to be pumped out (dewatered) for safe mining operations to continue. The water pumped from the pits will be used on the mine for process water in the plant and dust suppression. The dewatering will result in a lowering of the water table (cone of depression) around the mine pits, extending for more than to 25 kilometres northwards of Chapudi at the life of mine. This is because water is taken mostly from aquifer storage, as recharge in the area is low and unable to sustain the dewatering. The east-west striking faults such as the Tshipise, Senotwane and Phareng faults are far more transmissive resulting that the cone of depression is elongated along their axis.

Impacts of mining could be significant. These, in order of significance, include:

- Reductions in water available for abstraction and discharge i.e. lower borehole yields or drying up of boreholes and springs along the foot of the Soutpansberg Mountains within the radius of influence.
- Cross contamination of aquifers due to the disturbance of aquitard layers and the down gradient contamination due to seepage from the rehabilitated pits, discard dumps, stock piles and dirty water dams.
- A reduction in water available for evapotranspiration. Groundwater dependant floral species around springs and seeps could be affected as the water table drops. Riverine vegetation is mostly sustained from surface flows and water stored in the alluvial deposits, however shallow groundwater may be important during extended dry periods.

The classification of all environmental impacts identified is assessed in terms of: -

- their duration,
- their extent,
- their probability,
- their severity.

The above will be used to determine the significance of impact without any mitigation, as well as with mitigation (table 17).

Table 17: ENVIRONMENTAL RISK AND IMPACT ASSESSMENT CRITERIA

DURATION		
Short term	6 months	1
Construction	36 months	2
Life of project	16 years	3
Post rehabilitation	Time for re-establishment of natural systems	4
Residual	Beyond the project life	5
EXTENT		
Site specific	Site of the proposed development	1
Local	Farm and surrounding farms	2
District	Makhado Municipal district	3
Regional	Vhembe region	4
Provincial	Limpopo Province	5
National	Republic of South Africa	6
International	Beyond RSA borders	7

PROBABILITY		
Almost Certain	100% probability of occurrence – is expected to occur	5
Likely	99% - 60% probability of occurrence – will probably occur in most circumstances	4
Possible	59% - 16% chance of occurrence – might occur at some time	3
Unlikely	15% - 6% probability of occurrence – could occur at some time	2
Rare	<5% probability of occurrence – may occur in exceptional circumstances	1
SEVERITY		
Catastrophic (critical)	Total change in area of direct impact, relocation not an option, death, toxic release off-site with detrimental effects, huge financial loss	5
Major (High)	> 50% change in area of direct impact, relocation required and possible, extensive injuries, long term loss in capabilities, off-site release with no detrimental effects, major financial implications	4
Moderate (medium)	20 – 49% change, medium term loss in capabilities, rehabilitation / restoration / treatment required, on-site release with outside assistance, high financial impact	3
Minor	10 – 19% change, short term impact that can be absorbed, on-site release, immediate contained, medium financial implications	2
Insignificant (low)	< 10 % change in the area of impact, low financial implications, localised impact, a small percentage of population	1

RISK ESTIMATION (Nel 2002)					
	SEVERITY				
PROBABILITY	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Critical (5)
Almost certain (5)	H	H	E	E	E
Likely (4)	M	H	H	E	E
Possible (3)	L	M	H	E	E
Unlikely (2)	L	L	M	H	E
Rare (1)	L	L	M	H	H

E	Extreme risk – immediate action required, detail considerations required in planning by specialists – alternatives to be considered	4
H	High risk – specific management plans required by specialists in planning process to determine if risk can be reduced by design and management and auditing plans in planning process, taking into consideration capacity, capabilities and desirability – if cannot, alternatives to be considered, senior management responsibility	3
M	Moderate risk – management and monitoring plans required with responsibilities outlined for implementation, middle management responsibility	2
L	Low risk – management as part of routine requirements	1

IMPACT SIGNIFICANCE	
Negligible	The impact is non-existent or insubstantial, is of no or little importance to any stakeholder and can be ignored.
Low	The impact is limited in extent, even if the intensity is major; whatever its probability of occurrence, the impact will not have a significant impact considered in relation to the bigger picture; no major material effect on decisions and is unlikely to require management intervention bearing significant costs.
Moderate	The impact is significant to one or more stakeholders, and its intensity will be medium or high; therefore, the impact may materially affect the decision, and management intervention will be required.
High	The impact could render development options controversial or the entire project unacceptable if it cannot be reduced to acceptable levels; and/or the cost of management intervention will be a significant factor in project decision-making.
Very high	Usually applies to potential benefits arising from projects.

Risk is a combination of the probability, or frequency of occurrence of a hazard and the magnitude of the consequence of the occurrence (Nel 2002). Risk estimation (RE) is concerned with the outcome, or consequences of an intention, taking account of the probability of occurrence and can be expressed as P (probability) x S (severity) = RE. Risk evaluation is concerned with determining significance of the estimated risks and also includes the element of risk perception. Risk assessment combines risk estimation and risk evaluation (Nel 2002).Potential impacts were identified and assessed by considering the criteria as outlined in table 17.

The significance of each impact was determined “without mitigation” and “with mitigation”, taking into consideration alternatives, preventative and mitigation measures.

The groundwater risk and impact assessment is provided in Table 18.

TABLE 18: IMPACTS ON GROUNDWATER

Impact	Extent	Duration	Severity	Probability	Risk estimation	Without mitigation	Mitigation
Reductions in water available for abstraction and discharge	4	5	4	5	4	**Extreme** - Drawdown from mining extends to surrounding farms (up to 25kms). Springs along the foot of the Soutpansberg will probably dry up.	Provision of alternative water supply. Implement ASR to limit drawdown cone
A reduction in water available for evapotranspiration.	3	5	3	3	3	**High** – vegetation around the springs and seeps is supported by groundwater and will be severely stressed.	Implement ASR to limit drawdown cone
Cross contamination of fresh and saline aquifers Chapudi West	3	5	3	3	3	**High –** mixing of fresh and saline aquifers due to the disturbance of aquitards during mining	Grout off saline aquifers
Contamination of aquifers down gradient due to seepage from the rehabilitated pits, discard dumps, stock piles and dirty water dams.	2	5	2	3	3	**Moderate** - the Karoo aquifer is already high in sulphates and salts	Placing of carbonaceous material at the bottom of the pit. Lining of discard dumps and dirty water dams.

11. MITIGATION MEASURES PROPOSED

The following mitigation measures should be considered to address the impacts of the proposed mining:

- Revise the mining schedules of the proposed GSP mines to limit the cumulative impacts
- Enter into negotiations with surrounding land owners impacted regarding compensation or alternative water supply
- Implement Aquifer Storage and Recovery (ASR) to minimise depletion of aquifer storage thus limiting the extent of the drawdown cone.

12. MONITORING AND MANAGEMENT

Monitoring of groundwater water levels, water quality, inflows and pumping volumes is necessary to determine if the groundwater system is reacting as predicted. The monitoring programme should be audited for compliance to the stated objectives and adapted when and where required. It must be noted that the monitoring programme is a dynamic system changing over the different life cycle phases of the mine. A proper data and information management system should also be established to ensure that the monitoring is done effectively and that the information created is best utilised for the management of the mine. The following monitoring components have been identified:

- Monitoring Climate: rainfall, rainfall intensity and evaporation would be required
- Monitoring of water levels should be done up gradient and down gradient of the mining area, along geological structures. Continuous recorders can be installed on selected boreholes and monthly readings taken at other boreholes.
- Groundwater Quality to be monitored in all the aquifers surrounding the mine, and in the pits, area should be done on a quarterly basis. All macro elements should be determined.
- Inflows to the opencast and underground areas should be monitored by means of measuring the volume of water pumped out. Measurements should be done on at least a monthly basis

- Any leachate formed should be monitored for quantity and quality on at least a monthly basis. Sulphates, pH and trace metals need to be included in the quality analysis
- All abstraction including dewatering, irrigation, plant and domestic use, needs to be measured on at least a quarterly basis.

It is recommended that a monitoring committee be established and that these monitoring activities be done in conjunction with the neighbouring farmers in order to obtain a greater regional perspective and ensure transparency.

13. LEGAL CONSIDERATIONS

The approval of the mining right application is dependent on the compliance with various legislative requirements. With respect to groundwater these would include the following, (National Water Act, Act 36 of 1998, Section 21):

-21a) taking water from a water resource

-21d) engaging in a stream flow reduction activity (any activity that can impact on the flow or reserve of a water course);

-21e) engaging in a controlled activity (any activity deemed by the minister to have a detrimental impact on a water resource such as irrigation with water containing waste);

-21g) disposing of waste in a manner which may detrimentally impact on a water resource;

-21g) Removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people.

10 December 2013

Signed for the Team **Date**

Team	Person	Qualifications	Professional Registration SACNASP
Responsible Director	C Haupt	BSc(Hons)	Geology (400031/94)
Report and modelling by	K. Sami	MSc	Geology and Hydrology (400043/01)
Assisted by	P Wilken	BSc(Hons)	Geology (400038/97)
Assisted by	E Mmbi	BSc(Hons)	In training

APPENDIX A
STATEMENT OF INDEPENDANCY AND PROJECT TEAM CV'S

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ENGINEERS,HYDROGEOLOGISTS, ISD PRACTITIONERS & PROJECT MANAGERS

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TO WHOM IT MAY CONCERN

DECLARATION

We the undersigned hereby declare that, as professionally registered Scientists, employed by WSM Leshika Consulting (Pty) Ltd, an independent consultancy firm, that we have prepared the report entitled "Chapudi Project, Groundwater Flow Impact Assessment" free from influence or prejudice.

C J Haupt BSc(Hons) Pr.Sci.Nat. (400031/1994)
Hydrogeologist
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WSM LESHIKA CONSULTING (Pty) Ltd is a multi-disciplinary firm of consultants whose core business is to provide comprehensive and professional consulting services through the following specialist divisions:

- Civil & Agricultural Engineering
- Hydrogeology and Geotechnical Investigations
- Project Management
- Hydrology and hydraulic structures

BACKGROUND

WSM Leshika has a staff compliment of over 30 professionals and 19 administrative staff members with offices that service Limpopo, Gauteng, E Cape, North West and Mpumalanga Provinces in South Africa. Our pool of professional staff enhances the potential of the Company's ability to provide top class engineering and scientific services to our valued clients. Our personnel have worked extensively throughout Africa, South Africa and internationally, providing consulting services to various government departments, non-governmental organisations, industries and mines.

SERVICES AND EXPERTISE PROVIDED

Our professional team, many of whom have more than 30 years' experience in their field provided the following technical specialist skills to the Chapudi Coal Project:

TECHNICAL EXPERTISE PROVIDED

- Groundwater Specialist Services

KEY PROFESSIONAL STAFF

Carel Haupt Pr.Sci.Nat. (Director, Principal Hydrogeologist)

Carel Haupt is a registered natural scientist with more than 30 years' experience. He has a post graduate degree in Engineering Geology specialising in the evaluation of ground water potential and hydrogeological mapping. He has worked on numerous groundwater development projects, developing groundwater resources for water supply to mines, towns and villages, hydrogeological evaluations for mines and the design and development of monitoring systems for groundwater wellfields. He is the director responsible for all the Hydrogeological aspects of the Chapudi Project. He is a founder member and director at WSM Leshika Consulting and has held the position of Chairman of the Ground water Division of the Geological Society of South Africa as well as an executive member of the South African Chapter of the International Association of Hydrogeologists.

Karim Sami Pr.Sci.Nat. (Principal Hydrogeologist)

Karim Sami is registered as a geological and hydrological scientist with the South African Council of Natural Scientific Professions. He has a Master's Degree in Hydrology from Trent University in Canada and has 22 years' work experience throughout Africa. He specializes in groundwater development and has published internationally on ground water exploration, ground water recharge estimation, groundwater surface water interactions, borehole and aquifer test pumping, borehole and aquifer sustainable yield evaluation, groundwater geochemistry, saturated and unsaturated zone hydraulics, rural water supply implementation and planning, hydrological modeling, environmental tracers for hydrogeology, acid rock drainage and contamination from mining activities. He is responsible for the hydrogeological modeling and impact assessment for the Chapudi Project. Karim is an associate at WSM Leshika Consulting.

Pierre Wilken Pr.Sci.Nat (Principal Hydrogeologist)

Pierre graduated with an honours degree in geology at Rhodes University, Grahamstown South Africa in 1986 and has 27 years' experience. He has worked over Africa in the geological and hydrogeological fields and has specialized in ground water exploration and development, data manipulation using GIS, ground water recharge estimation, borehole and aquifer test pumping, borehole and aquifer sustainable yield evaluation, ground water geochemistry and geophysical surveys. Pierre is responsible for the data collation, geological interpretation, mapping and water quality evaluation for the Chapudi Project. He is an associate at WSM Leshika Consulting.

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APPENDIX B

BOREHOLE CENSUS DATA

Farm Name	Report BH No	Longitude	Latitude	y	x	Elevation (mamsl)	Date	Data source	BH Depth	SWL (mbgl)	Use ID	Volume (m^3/day)
Albert	Alb-BH-1	29.56194	-22.89900	-57655	2533463	748	2005	GCS	140	13.9	IU	160
Albert	Alb-BH-2	29.56239	-22.89906	-57701	2533469	749	2005	GCS	140	13.9	IU	160
Albert	Alb-BH-3	29.55342	-22.89078	-56784	2532549	757	2005	GCS	120	20.0	IU	90
Blackstone Edge	Bedg-B3	29.71074	-22.88461	-72930	2531935	789	2013	Ages		29.9	IU	3
Blackstone Edge	Bedg-B4	29.72727	-22.88763	-74625	2532278	805	2013	Ages			NIU	
Blackstone Edge	Bedg-B5	29.73095	-22.88213	-75005	2531670	803	2013	Ages		12.5	NIU	
Blackstone Edge	Bedg-B6	29.70869	-22.88679	-72718	2532175	782	2013	Ages		21.3	NIU	
Blackstone Edge	Bedg-B7	29.70934	-22.88940	-72784	2532465	789	2013	Ages		18.3	NIU	
Blackstone Edge	Bedg-BH21a	29.71078	-22.88424	-72934	2531894	782	2013	Ages		30.9	IU	5
Blackstone Edge	Bedg-BH21b	29.71292	-22.88758	-73152	2532265	788	2013	Ages		26.0	IU	3
Blackstone Edge	Bedg-S1	29.72790	-22.88841	-74689	2532364	807	2013	Ages			NIU	
Bushy Rise	Brise-3	29.75561	-22.88199	-77536	2531668	816	2013	Ages	110	8.3	IU	216
Bushy Rise	Brise-4	29.75972	-22.87281	-77963	2530653	790	2013	Ages	300	6.7	NIU	
Bushy Rise	Brise-5	29.75551	-22.88166	-77526	2531631	817	2013	Ages		8.0	NIU	
Bushy Rise	Brise-6	29.75578	-22.88238	-77553	2531711	811	2013	Ages		8.2	NIU	
Bushy Rise	Brise-7	29.76561	-22.87543	-78566	2530946	797	2013	Ages		10.1	NIU	
Bushy Rise	Brise-B1	29.75249	-22.86823	-77223	2530142	805	2013	Ages	108		IU	130
Bushy Rise	Brise-B2	29.75700	-22.87430	-77683	2530817	797	2013	Ages		13.0	IU	216
Bushy Rise	Brise-BH23	29.72972	-22.87694	-74882	2531095	804	2005	GCS		50.5	NIU	
Bushy Rise	Brise-BH25b	29.75583	-22.87667	-77561	2531079	808	2008	GCS	94		NIU	
Castle Koppies	EKL-14	29.85636	-22.81847	-87915	2524689	694	2011	WSM			IU	130
Chapudi	Chap-BH-4	29.22000	-22.91028	-22570	2534619	809	2005	GCS	70	15.0	IU	7
Coniston	Con-1	29.68867	-22.88654	-70664	2532137	781	2013	WSM	121	34.0	IU	96
Coniston	Con-2	29.68915	-22.88713	-70713	2532204	782	2013	WSM			IU	144
Coniston	Con-3	29.69015	-22.88672	-70816	2532159	782	2013	WSM			IU	84
Coniston	Con-4	29.69638	-22.88523	-71456	2531996	784	2013	WSM	84	54.1	IU	56
Coniston	Con-5	29.69848	-22.88442	-71672	2531907	784	2013	WSM			IU	168
Coniston	Con-BH18a	29.68861	-22.88250	-70660	2531690	779	2005	GCS	28	6.7	IU	4
Coniston	Con-Ex1	29.69333	-22.88583	-71143	2532061	784	2005	GCS		32.5	NIU	
Coniston	Con-Ex2	29.69306	-22.88333	-71116	2531784	783	2005	GCS		32.5	NIU	
Coniston	Con-Ex3	29.69306	-22.88167	-71117	2531601	780	2005	GCS		32.5	NIU	
Driehoek	Drie-1	29.77197	-22.80111	-79261	2522719	729	2013	Ages			IU	1
Driehoek	Drie-2	29.78125	-22.79523	-80218	2522073	718	2013	Ages			IU	2
Driehoek	Drie-3	29.78031	-22.79771	-80120	2522347	721	2013	Ages			NIU	
Generaal	Gen-1	29.83764	-22.76818	-86025	2519109	707	2013	Ages		25.1	NIU	
Kalkbult	Kblt-1	29.84665	-22.85342	-86896	2528554	729	2013	Ages		22.0	NIU	
Kliprivier	Klip-BH-13	29.63250	-22.85833	-64914	2528988	722	2005	GCS	80	9.0	IU	64
Kliprivier	Klip-BH-14	29.63111	-22.85583	-64772	2528710	716	2005	GCS	100	8.8	IU	65
Kliprivier	Klip-BH-15	29.63861	-22.85889	-65541	2529053	729	2005	GCS	100		IU	64
Koodoobult	Kood-BH-17a	29.69236	-22.82056	-71077	2524832	756	2005	GCS	90		IU	720
Koodoobult	Kood-BH17b	29.69411	-22.82522	-71254	2525349	762	2005	GCS	90		IU	18
Koodoobult	Kood-BH17c	29.69519	-22.82561	-71365	2525393	763	2005	GCS			IU	7
Koodoobult	Kood-BH17d	29.69608	-22.82922	-71455	2525793	768	2005	GCS	100		IU	180
Koodoobult	Kood-BH17e	29.69853	-22.83214	-71705	2526118	776	2005	GCS	90		IU	11
Koschade	EKL-5	29.83284	-22.83080	-85493	2526041	728	2011	WSM			IU	43
Malapchani	Mal-1	29.80529	-22.83357	-82663	2526332	738	2013	Ages		35.9	NIU	
Malapchani	Mal-2	29.80868	-22.85900	-82996	2529150	746	2013	Ages		33.8	IU	3
Malapchani	Mal-3	29.80722	-22.85917	-82846	2529168	751	2013	Ages		29.5	IU	2
Malapchani	Mal-4	29.80813	-22.85675	-82941	2528901	737	2013	Ages			NIU	
Malapchani	Mal-5	29.81087	-22.85756	-83221	2528992	733	2013	Ages		4.2	NIU	
Malapchani	Mal-6	29.80795	-22.85183	-82925	2528356	739	2013	Ages		25.2	NIU	
Malapchani	Mal-BH30a	29.80722	-22.85917	-82846	2529168	748	2005	GCS			IU	3
Mapani Ridge	Map-1	29.77831	-22.83808	-79891	2526817	754	2012	WSM		29.5	IU	6
Mountain View	Mv-BH29a	29.79611	-22.86833	-81700	2530177	768	2005	GCS	65	16.7	IU	90
Mountain View	Mv-BH29b	29.79278	-22.86806	-81358	2530145	775	2005	GCS	100		IU	108
Mountain View	Mv-BH29c	29.79222	-22.86417	-81303	2529714	767	2005	GCS	0	0.0	IU	4
Mountain View	Mv-1	29.79273	-22.87004	-81352	2530365	778	2012	WSM		19.8	NIU	
Mountain View	Mv-2	29.79401	-22.86779	-81485	2530116	771	2012	WSM		-	IU	3
Mountain View	Mv-3	29.79597	-22.86819	-81685	2530161	768	2012	WSM		18.7	NIU	
Mountain View	Mv-4	29.79363	-22.86951	-81445	2530306	774	2012	WSM		22.4	NIU	
M'tamba vlei	EKL-10	29.85685	-22.83294	-87956	2526292	700	2011	WSM			IU	9
M'tamba vlei	EKL-11	29.86287	-22.83009	-88576	2525980	693	2011	WSM			IU	14
M'Tamba Vlei	Mvlei-1	29.86503	-22.83786	-88793	2526842	709	2013	Ages		15.4	NIU	
M'Tamba Vlei	Mvlei-2	29.86268	-22.83578	-88553	2526610	702	2013	Ages		2.8	NIU	
M'Tamba Vlei	Mvlei-3	29.86222	-22.83641	-88505	2526680	703	2013	Ages		1.4	NIU	
M'Tamba Vlei	Mvlei-4	29.85682	-22.83294	-87953	2526292	700	2013	Ages		14.5	IU	259

Farm Name	Report BH No	Longitude	Latitude	y	x	Elevation (mamsl)	Date	Data source	BH Depth	SWL (mbgl)	Use ID	Volume (m^3/day)
M'Tamba Vlei	Mvlei-5	29.86286	-22.83010	-88575	2525981	693	2013	Ages		5.9	NIU	
Pienaar	EKL-6	29.82861	-22.78793	-85085	2521291	707	2011	WSM			IU	14
Princes's Hill	Phill-BH26a	29.78889	-22.88000	-80952	2531465	792	2005	GCS	47		IU	200
Princes's Hill	Phill-BH26b	29.79500	-22.88222	-81578	2531714	809	2005	GCS	47		IU	96
Qualipan	EKL-13	29.84944	-22.82857	-87199	2525804	703	2011	WSM			IU	9
Rochdale	Roch-BH19	29.69250	-22.89028	-71055	2532554	786	2005	GCS	90		IU	5
Sandilands	Sand-1	29.81476	-22.86625	-83615	2529957	765	2013	Ages		15.3	IU	22
Sandilands	Sand-2	29.81479	-22.86630	-83618	2529962	765	2013	Ages		16.8	NIU	
Sandilands	Sand-3	29.83418	-22.85252	-85617	2528447	724	2013	Ages		19.2	NIU	
Sandstone Edge	Sand-1	29.80408	-22.83319	-82539	2526289	739	2012	WSM		50.0	IU	168
Sandstone Edge	Sand-2	29.80865	-22.85899	-82993	2529149	746	2012	WSM		50.0	IU	168
Sandstone Edge	Sand-3	29.80517	-22.83969	-82647	2527010	736	2012	WSM		45.5	IU	40
Sterkstroom	Sterk-BH-5	29.58333	-22.90222	-59848	2533828	749	2005	GCS	120	47.0	NIU	
Sutherland	Suth-BH-11	29.62111	-22.88056	-63735	2531445	731	2005	GCS	80		IU	5
Sutherland	Suth-BH-12	29.62028	-22.88056	-63649	2531444	730	2005	GCS	80		IU	
Sutherland	Suth-1	29.67786	-22.88342	-69557	2531787	775	2013	Ages		15.8	NIU	
Sutherland	Suth-2	29.66315	-22.88623	-68046	2532091	765	2013	Ages		13.2	NIU	
Sutherland	Suth-3	29.65966	-22.88533	-67688	2531990	764	2013	Ages		35.8	NIU	3
Sutherland	Suth-4	29.64834	-22.88894	-66525	2532385	758	2013	Ages		8.4	NIU	
Sutherland	Suth-5	29.64724	-22.87784	-66417	2531155	750	2013	Ages	23		IU	3
Sutherland	Suth-BH12	29.62028	-22.88056	-63649	2531444	730	2008	GCS	80		NIU	
Varkfontein	Vark-BH31a	29.61661	-22.86372	-63281	2529578	722	2005	GCS	100	10.2	NIU	
Varkfontein	Vark-BH31b	29.61731	-22.86231	-63353	2529422	725	2005	GCS	80	11.5	NIU	
Varkfontein	Vark-BH31c	29.61450	-22.86275	-63064	2529469	725	2005	GCS		15.4	IU	144
Varkfontein	Vark-BH31d	29.61672	-22.86047	-63293	2529218	722	2005	GCS	80	15.0	IU	216
Varkfontein	Vark-BH31e	29.61294	-22.86086	-62905	2529260	723	2005	GCS	80	15.0	IU	216
Varkfontein	Vark-BH31f	29.60817	-22.85819	-62417	2528962	728	2005	GCS	60	5.0	IU	34
Varkfontein	Vark-BH31g	29.59739	-22.83719	-61320	2526632	725	2005	GCS	45	15.0	IU	11
Varkfontein	Vark-BH31h	29.59894	-22.83725	-61479	2526639	724	2005	GCS	48	15.0	IU	72
Varkfontein	Vark-BH31i	29.59383	-22.83825	-60954	2526748	726	2005	GCS		15.0	IU	54
Varkfontein	Vark-BH-8	29.63222	-22.84806	-64890	2527850	713	2005	GCS	100		IU	120
Varkfontein	Vark-BH-9	29.63250	-22.84944	-64918	2528003	713	2005	GCS	80		IU	12
Wildebeeshoek	Wild-1	29.75753	-22.84764	-77752	2527864	779	2012	WSM		84.0	IU	168
Wildebeeshoek	Wild-2	29.75351	-22.84408	-77342	2527468	775	2012	WSM		43.9	NIU	
Wildebeesthoek	Wild-3	29.73522	-22.84606	-75463	2527678	791	2012	WSM			NIU	
Woodlands	Woo-1	29.70941	-22.88702	-72792	2532201	784	2013	Ages			IU	5
Woodlands	Woo-2	29.71567	-22.87723	-73440	2531120	791	2013	Ages		15.3	NIU	
Woodlands	Woo-3	29.71609	-22.87921	-73482	2531339	789	2013	Ages		15.3	NIU	
Woodlands	Woo-4	29.72225	-22.87566	-74116	2530949	795	2013	Ages	94	>94	NIU	
Woodlands	Woo-5	29.72259	-22.87821	-74149	2531232	793	2013	Ages			NIU	
Woodlands	Woo-BH20	29.70944	-22.87833	-72800	2531239	788	2005	GCS		16.0	NIU	