


BW120 



REPUBLIC OF BOTSWANA
DEPARTMENT OF GEOLOGICAL SURVEY

MATSHENG AREA GROUNDWATER INVESTIGATION
(TB 10/2/12/92-93)

TECHNICAL REPORT T3:
INVENTORY REPORT

SEPTEMBER 1994

Prepared by

WELLFIELD  **INTER-CONSULT**

In association with:

BRITISH GEOLOGICAL SURVEY
Keyworth, Nottingham, UK

LIST OF CONTENTS

1.	INTRODUCTION	1
2.	BACKGROUND	2
2.1	Project Objectives	2
3	SETTLEMENTS AND LAND USE	3
3.1	Population	3
3.2	Land Use and Land Use Planning	4
3.2.1	Land Use Planning	4
3.2.2	Livestock	6
3.2.2	Crop Production	7
3.2.3	Wildlife	7
3.3	Water Supply	7
4	METEOROLOGY	9
4.1	Meteorological Stations	9
4.2	Rainfall	9
4.3	Evapotranspiration	13
4.4	Sunshine Hours	13
4.5	Wind Speed and Direction	13
5.	REMOTE SENSING	14
5.1	Objectives	14
5.2	Methodology	14
5.3.	Results	14
6.	BOTANICAL SURVEY	16
6.1	Objectives	16
6.2	Methodology	16
6.3	Identification of Potentially Shallow Groundwater	16
7.	RECONNAISSANCE SURVEYS	19
7.1	Ground Control Point Survey	19
7.2	Borehole Reconnaissance	20
7.3	Water Sampling	23
7.4	Borehole Siting Methods	24
7.5	The Project Database	24
7.5.1	Sources of Data	25
7.5.2	Field Data	29
7.5.3	Main Reconnaissance Database	29
7.5.4	Hydrochemistry Database	29
7.5.5	Vegetation Database	30
7.5.6	Use of the Database	30

8	GEOLOGY	31
8.1.	Previous Work	31
8.2	Lithology	31
8.2.1	Stratigraphic Sequence	31
8.2.2	Basement	33
8.2.3	Pre Karoo Sedimentary Strata	33
8.2.4	Karoo Supergroup	33
8.2.5	The Kalahari Sequence	35
8.3	Structure	36
9.	GEOPHYSICS	42
9.1	Regional Geophysical Interpretation	42
9.2	Geophysical Calibration Survey	43
9.2.1	Investigation of Shallow Aquifers	43
9.2.2	Investigations at of Deeper Aquifers	53
9.2.3	Investigation of a Calcrete Ridge	54
9.2.4	Recommendations	54
10	HYDROGEOLOGY	57
10.1	Previous Work and Information Sources	57
10.2	Groundwater Occurrence	57
10.3	Aquifer Distribution and Properties	58
10.3.1	Basement	58
10.3.2	Pre-Karoo	58
10.3.3	The Dwyka Group	58
10.3.4	The Ecca Group	58
10.3.5	Lebung Group	63
10.3.6	Kalahari Sequence	64
11	A CONCEPTUAL HYDROGEOLOGICAL MODEL	70
11.1	General	70
11.2	The Aquifer Units	70
11.3	Recharge	73
12.	FIELD INVESTIGATION PHASE	74
12.1	Geophysics and Exploratory Drilling	74
12.1.1	Karoo Aquifer Units	74
12.1.2	Kalahari Aquifer	75
12.2	Drilling and Aquifer Testing Operations	76
	REFERENCES	77

LIST OF TABLES

TABLE 1	Population Statistics for the Matsheng Villages	3
TABLE 2	Estimate of cattle numbers	6
TABLE 3	Monthly climatological data for the Tshane Meteorological Station (1958-85)	10
TABLE 4	Sources of Data	25
TABLE 5	Project Database Structures	26
TABLE 6	Stratigraphic Units in the Matsheng Area	32
TABLE 7	Frequency Distribution of Conductivity for Karoo and Kalahari water samples	61
TABLE 8	A Summary of Aquifer Test Results from Kalahari Boreholes . . .	68

LIST OF FIGURES

- Figure 1 Land Use Plan for the Matsheng Area
- Figure 2 Monthly Climatological for the Tshane Meteorological Station (1958-85)
- Figure 3 Monthly Total Rainfall (1989-1994) for Tshane, Hukuntsi, Lehututu and Lokgwabe
- Figure 4 Botanical Survey: Areas Potentially Shallow Groundwater
- Figure 5 Borehole Reconnaissance Data Form
- Figure 6 A Cross Section through Deep Stratigraphic Boreholes
- Figure 7 Locations of Deep Boreholes in the Matsheng Area
- Figure 8 Thickness of the Karoo Supergroup and Kalahari Sequence
- Figure 9 Lehututu Pan Traverse: Interpretation of HLEM data
- Figure 10 Lehututu Pan Traverse: Interpretation of TDEM data
- Figure 11 Lehututu Pan Traserse: TDEM Pseudo Section from Smooth Inversion
- Figure 12 Lehututu Pan Traverse: Electrical Sounding at 100E
- Figure 13 Hukuntsi Calcrete Ridge: Interpretation of HLEM data
- Figure 14 Cross Section Through Boreholes Penetrating the Kalahari to the South of Lehututu
- Figure 15 A Conceptual Hydrogeological Model

LIST OF MAPS

- | | |
|-------|--------------------------|
| Map 1 | Borehole Locations |
| Map 2 | Well Locations |
| Map 3 | Groundwater Conductivity |
| Map 4 | Groundwater Levels |

APPENDICES

- | | |
|------------|---------------------------|
| Appendix 1 | Ground Control Point Data |
| Appendix 2 | Borehole Data |
| Appendix 3 | Well Data |
| Appendix 4 | Hydrochemistry Data |

1. INTRODUCTION

This report marks the culmination of the Inventory Phase of the Matsheng Area Groundwater Investigation Project. The report provides a detailed account of all field reconnaissance activities undertaken to date, as well as an account of all data gathered regarding geological, hydrogeological and hydrochemical aspects of groundwaters in the area. Also included is information regarding land use and meteorology together with results obtained from Regional Geophysics, Remote Sensing and Botanical Studies.

The entire range of information is utilised to develop an integrated interpretation of current hydrogeological knowledge for the Project area. This in turn provides the basis for the formulation of the initial hydrogeological conceptual model, presented in this report. Recommendations are provided regarding objectives for geophysical surveys and exploratory drilling to be carried out in the Field Investigation Phase of the Project.

2. BACKGROUND

The Matsheng Area includes the villages of Tshane, Lokgwabe, Hukuntsi and Lehututu and the surrounding area and is located in the middle of the southern portion of the Kalahari. These four settlements, originally developed as a consequence of the presence of shallow groundwater associated with the adjacent major pans. They now form the focal point of development in the region and both human and cattle populations have been growing steadily. In recent years development at Hukuntsi, associated with the establishment of a sub office of the Kgalagadi District Council, has been particularly marked. As a result of the excessive concentrations of both people and animals in the vicinity of the villages, both the land carrying capacity and the water supply system are under great strain.

In an attempt to alleviate this problem, a number of land use planning exercises undertaken over the past two decades, have proposed the redistribution of cattle (and hence to a degree human) population over a much broader area. This has been attempted by the establishment of commercial ranches (under the Tribal Grazing Lands Programme - TGLP) and better defined communal grazing areas. These plans have been partially implemented but their success has been severely hampered by the lack of adequate water supplies. This in turn has resulted in the continued growth of the villages, with a consequent increase in demand on the already limited local water sources.

The availability of adequate water is clearly critical to any future development, in the Matsheng area. The Matsheng Area Groundwater Investigation Project was therefore formulated to assess groundwater resources which may be utilised to satisfy this growing village water demand, and at the same time to resolve the future of the proposed, more widespread, cattle grazing in the area.

2.1 Project Objectives

The essential objectives of the Project as stated in the Revised Technical Proposal (RTP) (Wellfield Consulting Services, 1994) were to;

- a) assess the overall groundwater resources of the project area, including aquifer dimensions and parameters, regional piezometry, potential recharge mechanisms, and hydro-chemical regimes and evolution.
- b) identify, investigate and quantify suitable groundwater resources which may enable the establishment and maintenance of both the TGLP ranches, the communal grazing units and horticultural enterprises.

3 SETTLEMENTS AND LAND USE

The Kgalagadi District occupies the south west corner of Botswana, the entire District covering an area of approximately 100 000 km². It is bordered by the Kweneng and Southern Districts to the east, South Africa to the south and south west, Namibia to the west, and Ghanzi District to the north.

The Matsheng Project covers an area of approximately 7850 km², comprising a 50km radius circle, centred on the point 24°00'00"S, 21°50'33"E, midway between Hukuntsi and Tshane. Elevations rise gradually from about 1080 m in the south east, to about 1180 m in the north west. The mean altitude of the area is around 1100m, the terrain being generally featureless, broken occasionally by fossil drainage systems, low rocky hills, pans and dunes. The pans form sub-circular, sub-elliptical, or kidney shaped features, with the pans floors commonly being some 15 to 20 m below the general elevation of the surrounding land.

The climate is semi-arid, with low humidity. Temperatures are high in the summer, and low in winter. Winds are dominantly easterly in the summer, changing to northerly in the winter.

3.1 Population

Population is concentrated in the centre of the area, with the villages of Tshane, Hukuntsi, Lehututu, and Lokgwabe forming the "village quadrangle". In 1992, the *de facto* population of these villages was nearly 6000 (van der Maas, 1993). Outside of the village area, there are several RAD settlements, including Make, Monong, Hunhukwe and Zutshwa. Other settlements at Lothlake, Pepane, Manyane, and Ohe have been largely or entirely abandoned, usually for administrative reasons. The populations of the main villages and settlements of the area are given in Table 1 (from Central Statistics Office, 1992).

Locality name	Locality code	Population
Tshane	91-16-100	706
Hukuntsi	91-17-100	1394
Lehututu	91-18-100	1304
Lokgwabe	91-19-100	1037
Monong (RAD)	91-20-100	232
Ohe (RAD)	91-22-100	43
Hunhukwe	91-26-100	356
Zutshwa (RAD)	91-27-100	203
Make (RAD)	91-30-100	182

TABLE 1 Population Statistics for the Matsheng Villages

Population growth projections given by Geoflux (1994) suggest that the combined population of the four central villages could be greater than 8000 by the year 2001, with the water demand for these villages rising from the present 290 m³/ day to an estimated 345 m³/ day. However, many of the population move away from the area, and it has been suggested that out-migration may substantially reduce, or even equal, the natural growth rate (van der Maas, 1993).

3.2 Land Use and Land Use Planning

3.2.1 Land Use Planning

The history of land use planning in the Matsheng area is somewhat confused. In 1978 the Kgalagadi Land Board (KLB) and Council agreed a Land Use Plan (LUP) which included the Wildlife Management Areas (WMAs). This was an attempt to develop an integrated plan for the area, based on the population's perceived needs. They later (1982) rejected this and started an investigation into the possibilities of de-zoning the WMAs by a radius of 16km. The investigation was completed by the District Land Use Planning Unit (DLUPU) in 1986, with the recommendation that the WMAs should remain more or less as originally planned. The same year (1986), at the 111th meeting of the LDC, the Matsheng LUP was revised. It was found that the plan was not progressing for a number of reasons, one of the prime ones being that it had been previously assumed that groundwater would be readily available. This has not been the case, and further development in the area has been restricted for this reason.

In the latest development plan (DDP4: Kgalagadi District Council, 1989), the land area around the central village quadrangle is zoned as communal (Figure 1), and is surrounded almost completely by a Wildlife Management Area. Further north, there is more communal land in the vicinity of Hunhukwe and Ohe. These two communal areas are separated by a corridor within which a borehole freeze is in force. To the east, a number of TGLP Ranches have been delineated between the communal zone and the WMA. It is thought that the land use plan shown in Figure 1 may have been recently revised but it has not been possible to secure a copy of such a map.

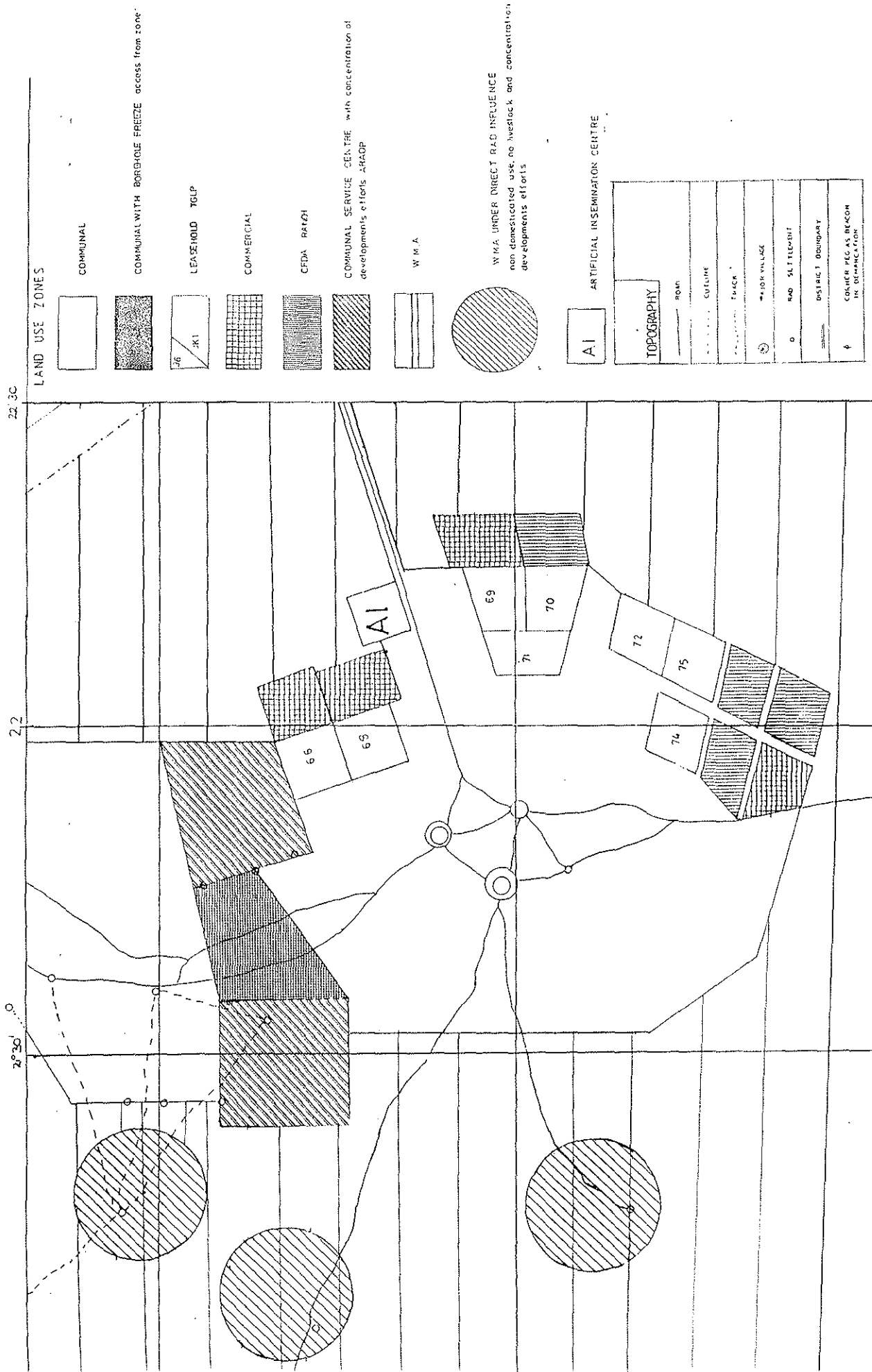


Figure 1 Land Use Plan for the Matsheng Area

Within the communal areas, traditional livestock rearing is the most important land use. In addition to this, a limited amount of arable farming is carried out. The communal area with borehole freeze has been heavily overgrazed in the past, and no more borehole sites are to be allocated, although grazing is permitted within the area from existing boreholes outside the area. The purpose of the TGLP ranches is to relieve pressure on communal grazing land, the leaseholders being required to move their cattle to the ranches.

3.2.2 Livestock

The Matsheng area is predominantly a cattle ranching area; livestock rearing is the most important means of living, and is likely to continue to be so for the foreseeable future. An estimate of number of cattle owned in the Matsheng was carried out as part of the recent socio-economic and biophysical baseline study in the area (van der Maas, 1993). The results (Table 2) should be considered in the light of the fact that cattle numbers fluctuate considerably in response to drought and periods of good rains; estimated recent maximum and minimum numbers are 30 000 (1986) and 10 000 (1987).

	Hukuntsi	Lehututu	Lokgwabe	Tshane	Total
Number of Cattle	9064	6628	5788	2024	23504
Average herd size	41.2	41.4	62.9	31.6	43.9
Households with cattle	44.0%	65.6%	50.0%	57.1%	51.5%

TABLE 2 Estimate of cattle numbers (after van der Maas, 1993)

Cattle grazing in the area is limited by the lack of surface water and groundwater of usable quality. This has resulted in high concentrations of livestock around the available watering points, which in the Matsheng are associated with the pans near the village centres. Huge numbers of cattle congregate in these areas, with the cattle roaming up to 20km away in order to find grazing. This causes overgrazing and consequent erosion, and leads to permanent damage to the land. Cow dung accumulating on pan surfaces also poses a potential groundwater contamination threat due to nitrate input to the groundwater. During the wet season, pans outside of the central area sometimes hold surface water, and the cattle are

able to spread over a much larger area to graze, often encroaching into the Wildlife Management Areas.

The Tribal Lands Gazing Policy (TGLP) was conceived partly as an answer to the problems of overgrazing. In the Matsheng Area, 10 ranches have been delineated and advertised, and 8 allocated (numbers 66, 68, 69, 70, 71, 72, 74, and 75). The remaining two were dezoned as it was discovered that they contained pans where hunter-gatherer groups congregated during the dry season (Tsimako, 1991). Development relies however, on the availability of fresh water. Of these Ranches, only three have equipped boreholes (68, 69 and 71). Others have had holes drilled, but to date the water has not been of sufficiently good quality to equip them.

3.2.2 Crop Production

The climate and soils of the Matsheng area are not conducive to crop production. The low and erratic rainfall imposes risks, and the soils are sandy and not very fertile. However, it is still an important activity for many households, providing a supplementary source of food.

3.2.3 Wildlife

The area has always had a substantial wildlife population, although this has been reduced in recent years by the combined effects of drought, competition from cattle, and the effects of fencing on wildlife migration patterns (van der Maas, 1993). The consequence of further drought in 1992 was to affect the wildlife further, leading to a ban on hunting in Kgalagadi District from 1992 for at least three years. The Remote Area Dwellers (RADs) were exempt from these restrictions.

3.3 Water Supply

The four central villages all have their own public supply boreholes, although these are not always sufficient to meet demand.

Tshane is now supplied by three public supply boreholes, two of which have only just been commissioned. This should ease the village's previous shortage problems, when the supply sometimes failed, leaving the population without water for two or three days at a time. These boreholes are also expected to supply water to the settlements of Shwape (3km to the east) and Ngwaborwa (2.5km to the south). Livestock is watered from wells and a single borehole on the pan margin.

Hukuntsi village is supplied by two boreholes, whose combined output is inadequate to meet present demand. The shortfall is piped from borehole sources at Lehututu. Water for livestock is obtained from wells on Mairi Pan, and one on Hukuntsi Pan.

Lehututu has three public supply boreholes; these have problems meeting the demand, as they also supply Hukuntsi and other settlements. Drilling is currently underway in the area aimed at providing additional supply boreholes. Hand dug wells on the pan supply water for the livestock.

Lokgwabe is supplied by one borehole which meets present water demands. In addition, abundant fresh water is abstracted from wells on the pan, for livestock and domestic use.

Although north of the project area, Hunhukwe is important as it supplies water to the settlements of Ohe and Monong. There are two public supply boreholes, situated adjacent to each other, south of the village.

The public supply borehole at Monong was drilled in the late 1980s, and was equipped with pump and a desalination plant by the Lutheran World Federation. The hole collapsed in 1991, since when the village has been dependent on water brought in from Hunhukwe. A second borehole was drilled at the same site in early 1994, and this will eventually be equipped. All livestock died or was sold when the water supply was lost.

Ohe village is now virtually deserted, the majority of villagers being moved to Hunhukwe when fresh water was found there. The remaining villagers rely on water tankered in from Hunhukwe, and water their livestock from one brackish well on the pan.

Make settlement is supplied with water by pipeline from Lehututu. Wells were sunk on the edge of the pan for the purpose of cattle watering, however they were all saline. In consequence, no livestock are kept at this village.

To the south west of the project area, Zutshwa is supplied by a borehole approximately 10km south of the village. This pumps saline water to a desalination plant, the water then being piped to the village. In addition, a very saline borehole on the pan itself pumps water to evaporation ponds for salt production, the salt then being marketed.

There are no village settlements in the east of the Project area. An old settlement at Lothlake Pan was abandoned several years ago, and the villagers moved to Inalegolo Settlement (south east of Gai Pan in Southern District).

4 METEOROLOGY

4.1 Meteorological Stations

There are four meteorological monitoring stations within the defined area, (Tshane, Hukuntsi, Lokgwabe, and Lehututu), and an additional two outside the area (Hunhukwe and Zutshwa). A climatological station also exists at Kang. Full climatological data (rainfall, evaporation, sunshine hours, wind speed and direction, and humidity) is available from the Meteorological Station in Tshane for which, records exist back to 1958. Rainfall data is available for the remaining stations. With the exception of Tshane, which is equipped with a recording raingauge, all have totaliser type raingauges. Within the village quadrangle, the stations are located adjacent to Tshane Police Station, at the Primary Schools in Lokgwabe and Lehututu, and at the clinic in Hukuntsi.

Daily and monthly rainfall data for the four central stations and Hunhukwe was obtained from the Meteorological Office in Gaborone in digital format. Also all other climatological data was obtained for the Tshane Meteorological station. Photocopies of rainfall charts were acquired for the Tshane raingauge; these will permit study of rainfall intensities as part of the assessment of recharge later in the Project. Some problems have been encountered with the monthly data, and also with missing daily rainfall figures; these are being followed up.

For the purpose of this project, it is intended that an additional recording raingauge will be installed at Hunhukwe.

4.2 Rainfall

Almost all the rainfall occurs during the summer period (October to April), with the winter period accounting for only 5% of the annual total (van der Maas, 1993). Mean and maximum monthly rainfall for Tshane Meteorological Station (period 1958-1985) shows the seasonality of the rainfall (Table 3 and Figure 2).

Bhalotra (1987a) described the rainfall as being mainly due to convection processes, that is, instability showers and thunderstorms. This results in rainfall being highly variable, both spatially and temporally. Much of the rainfall occurs in short, heavy showers over localised areas, during periods of between 1 and 4 days. During such events, very high intensity rainfall can occur; the maximum recorded daily rainfall for Tshane during the period 1958 to 1993, was 149.6mm. It is these high intensity events, when rainfall greatly exceeds evapotranspiration (albeit for a relatively short time period), that recharge is likely to occur. The monthly total rainfall (1989-1994) for each of the central stations is shown in Figure 3, and

illustrates both the spatial and temporal variation of rainfall across the area.

Month	Mean rain (mm)	Max rain (mm)	Free water surface evap (mm)	Potential EVT (mm)	Sunshine hours	Monthly wind speed (km/h)
	(1958-85)	(1958-85)	(1965-85)	(1965-85)	(1965-85)	(1959-85)
Jul	1	24.8	241	207	9.8	6.9
Aug	1.1	16.4	196	168	9.9	6.3
Sept	3.2	20.8	196	167	9.7	5.8
Oct	18.3	67.1	142	121	9.8	5.1
Nov	34.3	137.8	117	100	10.0	4.7
Dec	34.9	93.4	90	77	9.6	4.9
Jan	83.3	242.4	100	86	9.1	4.9
Feb	65.8	221.2	134	116	8.5	5.8
Mar	63.8	207.1	175	154	8.9	6.7
Apr	33.4	98.7	218	191	8.5	7.4
May	7.9	31.2	235	203	9.7	7.3
Jun	2.9	25.4	251	216	9.1	7.1

TABLE 3 Monthly climatological data for the Tshane Meteorological Station (1958-85) (after Bhalotra, 1987a, b, and c)

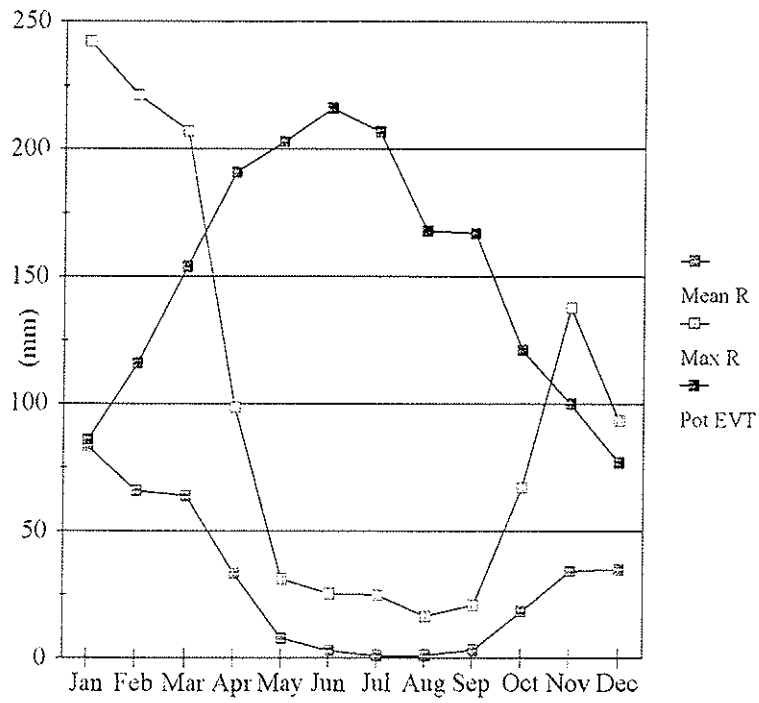


Figure 2 Monthly climatological data for the Tshane Meteorological Station (1958-1985)

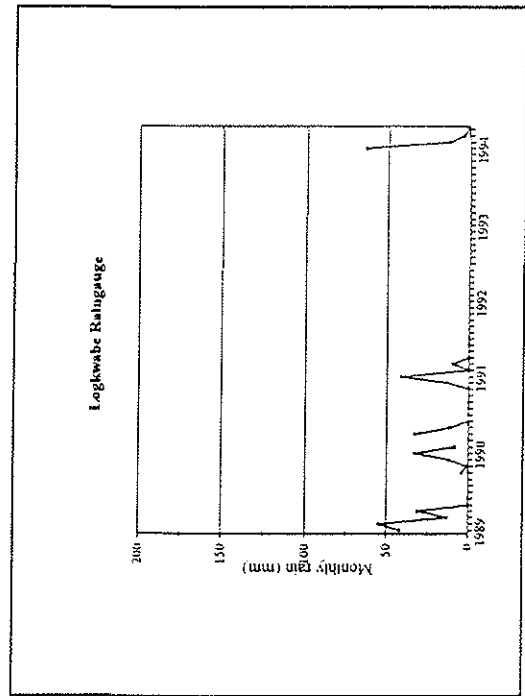
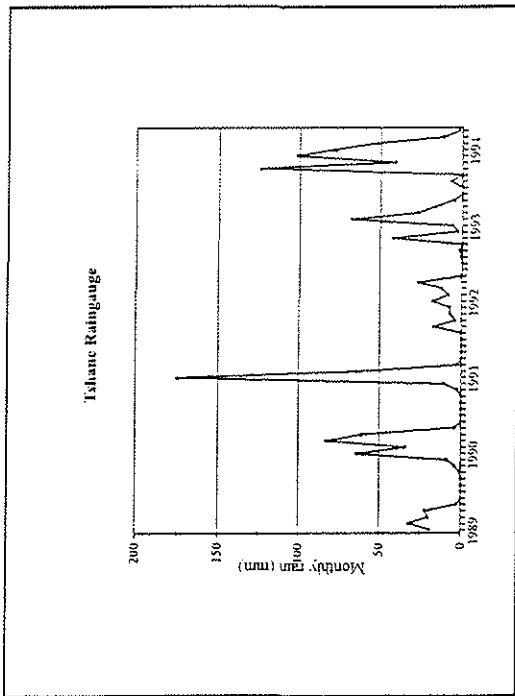
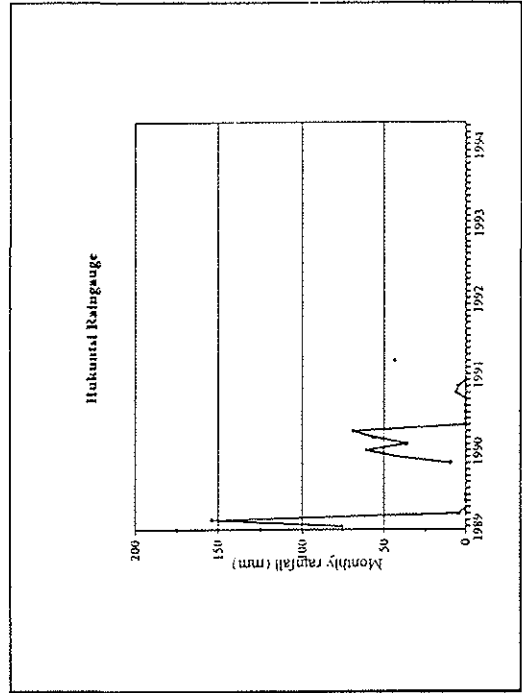
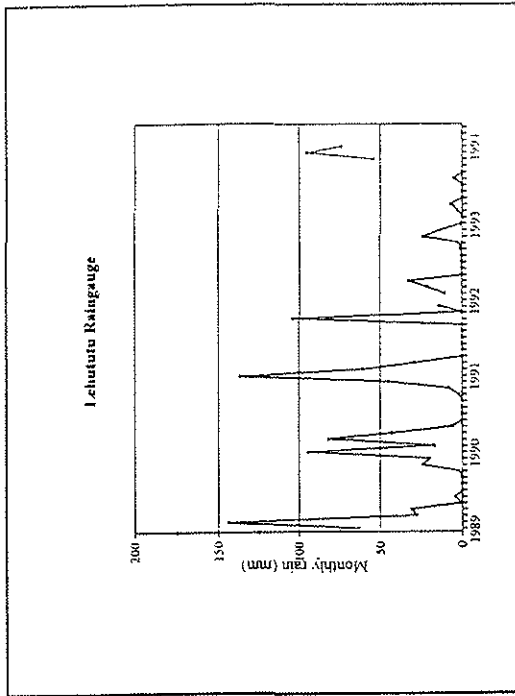


Figure 3 Monthly Total Rainfall (1989-1994) for Tshane, Hukuntsi, Lehututu and Lokgwabe

The intense rainfall has a high erosion potential, particularly during the early rainy season, when vegetation cover is low, and the rainstorms may be accompanied by high winds, and sometimes hail.

4.3 Evapotranspiration

In south-western Botswana, mean annual open water evaporation is 6 to 7 times, and mean annual potential evaporation (EVT) is 5 to 6 times, the mean annual rainfall (Bhalotra, 1987b) (Table 3). It has been reported that potential EVT exceeds mean precipitation, even for 10 day periods. This is important, not only in terms of crop stress, but also because on a monthly basis it appears that no water is available for recharge. As noted in 4.2, it is during intense rainfall events that recharge is most likely to occur.

4.4 Sunshine Hours

The mean daily sunshine hours for each month at Tshane are shown in Table 3 (Bhalotra, 1987b).

4.5 Wind Speed and Direction

In the Matsheng area, the predominant wind direction is north to north east (Bhalotra, 1987c). Average monthly wind speeds (at 2m above ground level) vary between 4.7 and 7.4 km/hour, with the months of October and November having the highest wind speed (Table 3). Strong winds tend to occur in association with thunderstorms, particularly in these month, and in also the late rainy months (March and April). The Tshane station recorded 48.8 percent frequency of calms (speed less than 2km/hour) for the period between 1979 and 1983.

5. REMOTE SENSING

5.1 Objectives

The main purpose of the remote sensing was to provide information on ground surface characteristics which could be of possible significance to groundwater investigations. It was also hoped that the data might assist in defining target areas for geophysical studies and borehole siting. This section summarises the work carried out and results as detailed in Matsheng Area Groundwater Investigation Technical Report T2 (in preparation).

5.2 Methodology

Landsat Thematic Mapper (TM) imagery for both dry- and wet-season, and two scales of aerial photographs, were analysed. The TM data were digitally processed, and false-colour composites (FCCs) prepared of reflected infrared bands 4-5-7, corrected to UTM grid using GPS ground control points. High-quality photographic prints were produced at scales of 1:250,000 and 1:125,000 from large-format negatives. Normalised Difference Vegetation Index (NDVI) images (for use in the botanical study) were also produced as 1:250,000 scale photographic hard copy on the same projection. Interpretation was carried out of the FCC images and aerial photographs, and a field correlation visit made; the results are presented on a 1:250,000 scale interpretation map and described in Technical Report T1. A 1:250,000 base/location map was prepared using information extracted from the 1993/94 Landsat imagery.

5.3 Results

The chosen TM band combination highlighted areas of overgrazing and of thin sand cover on duricrust (calcrete/silcrete), as well as variations in the composition and density of vegetation. Both the Landsat imagery and aerial photographs revealed lineaments of aeolian and possibly geological origin, expressed as vegetation alignments. Fine lineament patterns seen in parts of the central area where the sand cover is particularly thin correspond to more heavily vegetated, indurated calcrete/silcrete ridges. They are thought to represent fractures in the calcrete sheet and possibly reflect underlying pre-existing joints and faults; their investigation as possible drilling targets was recommended. The origin of the duricrust and pans were discussed and it was concluded that the calcrete pre-dates pan formation for the most part. A deflation origin for the pans seems likely, although other controls affecting pan location are unclear.

A comparison between the geological lineament data set and the first horizontal derivative of the aeromagnetic data was presented on a 1:250,000 image map. The generally weak correlation between features indicated that the magnetic data respond mainly to the deeper, sub-Karoo, basement and it was concluded that Karoo bedrock structures are poorly reflected at the surface.

In general, it was concluded that the Kalahari sand cover largely masked any bedrock structures that could be of potential groundwater significance. However, the lineaments described above may be a reflection of deep geology, and it was considered that the remote sensing interpretation should be re-considered as more field data became available.

6. BOTANICAL SURVEY

6.1 Objectives

The primary aim of the Botanical Study was to identify areas of potential shallow groundwater aquifers through the analysis of vegetational features. In addition the data collected should contribute to the integrated interpretations concerning groundwater balance and recharge.

6.2 Methodology

Landsat Thematic Mapper (TM) images and air photographs were used in combination with vegetation mapping in the field and vegetational association analysis to produce a detailed vegetation map based on plant association structure. In addition both wet and dry season TM images were examined in detail, using a Normalised Difference Vegetation Index (NDVI). The dry season NDVI was considered the more valuable as the pre rainfall first flush of woody vegetation growth is clearly noticeable. This early growth is likely to be associated with the presence of accessible shallow groundwater. A numeric ranking scaled from no aquifer to a high potential for a shallow aquifer was applied to the NDVI. Other factors considered to be indicative of the presence of shallow aquifers, such as plant association structures and tree canopy size, were ranked in a similar manner.

A preliminary report together with maps was prepared, primarily to provide input to this Inventory Report. The final Technical Report T2 will be prepared towards the end of the Project, when the theories regarding vegetation/shallow groundwater associations will be reviewed in the light of drilling results.

6.3 Identification of Potentially Shallow Groundwater

The rankings indicated above were combined and used, together with other aspects, such as plant association boundaries and soil characteristics, to identify areas which have the greatest potential for shallow groundwater. The six areas identified are shown in Figure 4.

The areas associated with the lineaments (1) on the Figure were thought to be associated with shallow groundwater and considered to be potentially important recharge areas. Of areas 2 and 5, the former is of particular interest as shallow groundwater at that location could conceivably be associated with the Ntane Sandstone rather than the Kalahari. Area 3 is considered to have a high potential and its position near areas designated for ranching make this a good exploration target. Area 4 although having a high potential is almost entirely outside the Project Area. The shallow

aquifer around area 6 (Lehututu) and 7 (Lokgwabe) are already utilised for groundwater abstraction.

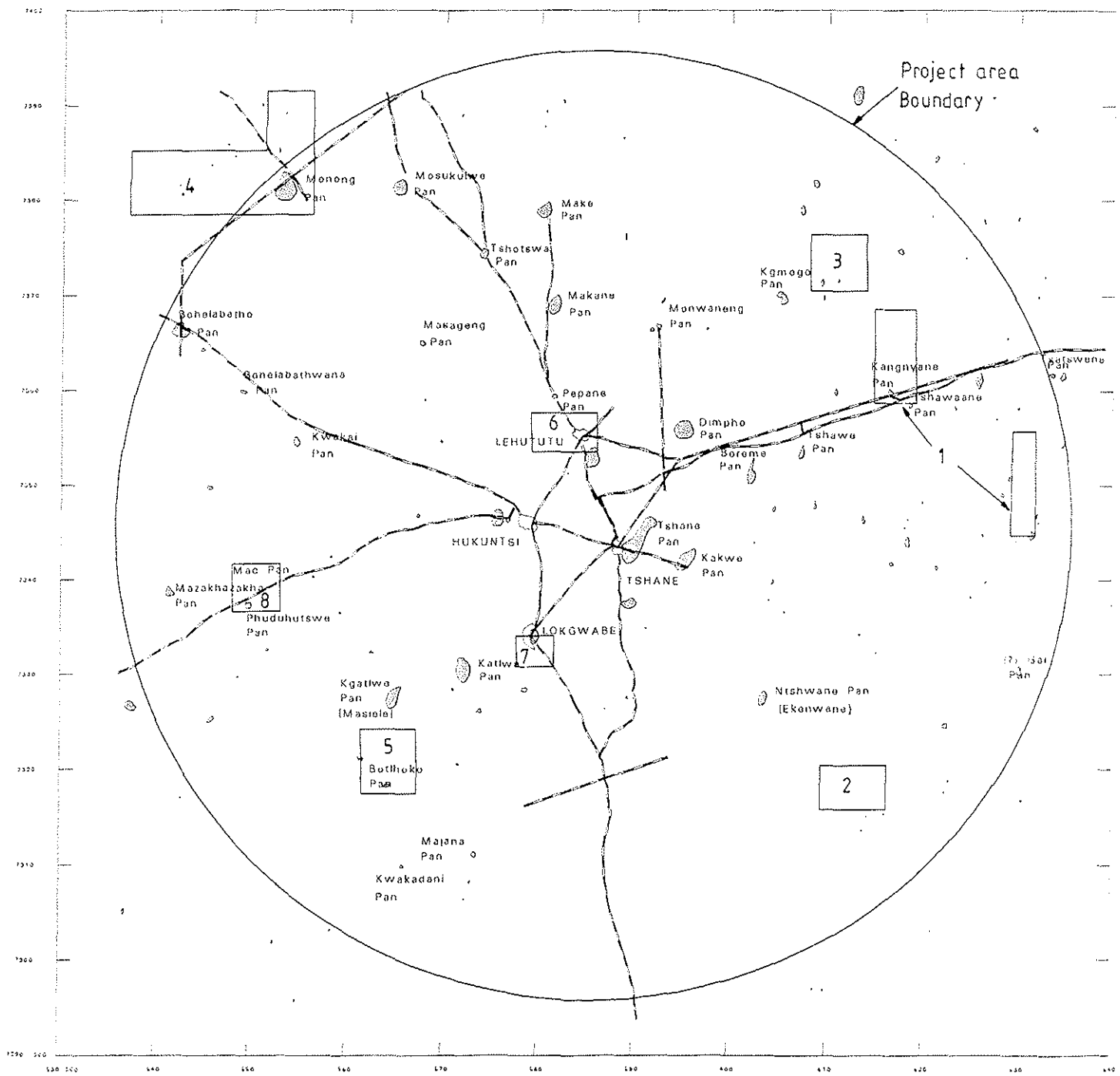


Figure 4 Botanical Survey: Areas of Potentially Shallow Groundwater

7. RECONNAISSANCE SURVEYS

7.1 Ground Control Point Survey

Ground control points were established during the initial stages of field reconnaissance, in order to provide data to allow the geometric correction of the satellite imagery. The search for ground control points and determination of their positions, took an approximate period of two weeks, (end of June to mid July 1994).

The identification of control points was assisted by the use of relevant topographic maps and aerial photographs. Two sets of aerial photographs were available; the more recent produced in 1991 at a scale of 1:20,000 covering the contract "Tshane Villages" area and those produced in 1986 at a scale of 1:50,000 which cover the entire project area. The GPS unit utilised was a Trimble Navigation TransPack I, capable of providing positional coordinates to ± 100 metre accuracy.

Ground control targets were readily available within the centre of the area because of the developed infrastructure, but it was necessary to select targets across the entire area to permit accurate geometric correction of the images. The main targets were major road junctions, intersections of cut-lines and notable pan features that could be identified on aerial photographs. All the targets selected for positioning had to be clearly visible on photographs and identifiable on the ground, in order that the locations could also be identified on the satellite imagery.

The difficulty of identifying features on the ground was compounded by inconsistency in map names, particularly with regard to pans. For example in a given area, a pan may be known by one name to the local inhabitants, with the maps giving it a different name or no name at all.

Tracks shown on the topographic maps were frequently misleading. Some tracks had changed their position and possibly had never been delineated accurately on the topographic maps. Other tracks had become overgrown and were therefore difficult to find or follow. The track from Tshane to Kokong via Gai Pan was, for example, completely overgrown in places, probably due to lack of recent use, although the topographic map and aerial photos showed the route clearly.

Despite the various problems encountered, the survey was completed within the required time scale. An adequate number of well defined targets and a good spread of points were achieved in the central area and to the north, northeast, northwest and west of Hukuntsi. Targets were difficult to obtain to the south, southeast and southwest of Lokgwabe because of the lack of access and clearly identifiable locations. The list of

control points and their positional data is presented in Appendix 1. As the satellite images could be geometrically corrected the most immediate and tangible benefit of the ground control point survey was that a high quality accurate base map could be produced for use by the Project directly from the satellite imagery. This base has been used in all four of the maps provided with this report.

7.2 Borehole Reconnaissance

The Ground Control Point Survey was followed by a borehole (and well) reconnaissance phase, the objective of which was to identify all water points and mineral exploration boreholes within the study area, regardless of their condition. Two field teams were utilised on this survey over a period of 6 weeks. A survey questionnaire was designed to establish a detailed outline of the water point type, status, use, location etc (Figure 5). Each borehole or well visited was allocated an individual WCS number for the purpose of identification. Numerous parameters including casing diameter and lining, borehole depths, rest water levels and pumping rates were measured on site. Wellhead analysis of water samples were carried out using portable chemistry kits capable of determining pH, conductivity temperature, alkalinity, dissolved oxygen (DO) and Eh. In addition, water samples were collected for later analysis (7.3), and information on vegetation types present near the water sources was collected to assist the Botanical Survey. The location of each well and borehole visited was accurately determined using GPS equipment.

The recent Kgalagadi District Water Point Survey (Knight Piesold, 1991) had previously located and identified wells and pumping boreholes. The survey had concentrated on water sources which were in use, or for which water rights were extant and even included sites which, although allocated, did not have a source of water. For these sites the positional data and other information was of good quality. However it was frequently found to be inaccurate for abandoned or sealed boreholes which had never been used. Groups of wells in the villages and the margins of pans had been mapped in detail, and in consequence detailed mapping of the wellfields was not repeated in this survey. Individual wells were in general only revisited if they had pumping equipment, and water samples could be obtained for analysis. A smaller number of unequipped wells were sampled in locations where no equipped wells were available.

**MATSHENG AREA GROUNDWATER INVESTIGATION
BOREHOLE RECONNAISSANCE**

Date of Inspection: _____ KP REF No: _____ WCS REF: _____

LOCATION DETAILS

GS Number: _____ Temp. GS number: _____

Type of Waterpoint: _____
 1. Borehole 2. Dam 3. Haffir Dam 4. Hand dug well
 5. Sip well 6. Natural source 7. Other

Village: _____

Waterpoint name: _____

Locality: _____

Description: _____

Topo map: _____ (Tshane or Lehututu) UTM: _____

Latitude: _____ Longitude: _____ Type _____

Elevation(m): _____ Type: _____ (Type codes: 1. GPS 2. Maps 3. Other)

OWNERSHIP DETAILS

Owner name: _____

Owner Type: _____
 1. Private 2. District Council 3. Dept. of Water Affairs (DWA) 4. Geol. Survey (GS)
 5. Dep. of Roads 6. Dep. of Wildlife & Parks 7. Min. of Agriculture
 8. Village dev. committee (VDC) 9. Other

User name: _____

Primary water use: _____
 1. Domestic 2. Livestock 3. Arable 4. Wildlife 5. Mixed 6. Other

Completion date: _____

TECHNICAL DETAILS

Driller: _____ Depth(m): _____ Code: _____ Fast water level(m): _____ Code _____

Diameter _____ mm/m Lining _____ Yield(l/s): _____ (m³/hr) _____ Code: _____

(Data source codes: 1. Measured 2. Estimated 3. User 4. Other)

Tank/Trough size: _____ m dia. _____ m high No hours/day pumped _____ No Days/week: _____

Estimated Annual Abstraction: _____ m³/yr

Status: _____
 1. Equipped 2. Not equipped 3. Sealed 4. Abandoned 5. Dry 6. Collapsed
 7. Filled 8. Other

Availability: _____
 1. Perennial 2. Non perennial 3. Unspecified 4. Other

Water Quality: _____
 1. Fresh 2. Brackish 3. Saline 4. Unknown 5. Other

Equipment: _____
 1. Diesel engine 2. Windmill 3. Hand 4. Solar 5. Draught 6. Other

 1. Piston pump 2. Mono type 3. Elect. Submersible 4. Bucket 6. Other

GS Borehole Log GS BH No _____

Depth (m) _____ RWL (m) _____ Yield(m³/h) _____ Dia (mm) _____

VEGETATION SURVEY

TREES WITHIN 20 m RADIUS OF WATER SOURCE

Tree Name	No.	Av. height (m)	Tree Health
1.			are any of the branches dead <u>YES/NO</u>
2.			approx % of canopy affected %
3.			evidence of fire <u>YES/NO</u>
4.			Any use of trees for eg fences <u>YES/NO</u>
5.			

WATER QUALITY

Sampling Method: _____ 1. Bucket 2. Pumped Period since start of pumping: _____ mln/hrs.

Water Samples: 1l plastic bottle (GS) _____ 200 ml filtered/acidified (GRES chemical) _____
 250 ml glass bottle (GRES isotope) _____ 100 ml (GRES chemical) _____

Well head measurements

pH _____ Eh _____ HCO₃(mg/l) _____

DO _____ SEC(μS) _____ Temp(°C) _____

Comments: _____

Figure 5 Borehole Reconnaissance Data Form

Difficulties were commonly encountered when cross-referencing boreholes found in the field with existing drilling records. This was a particular problem in the village areas where several water points often exist in close proximity to one another. Unless the boreholes had some unique feature such as a different casing size, were properly marked with a borehole number, or the owners are present to provide identification, it was often difficult to cross correlate them with borehole records from the National Borehole Archive held by the Geological Survey.

Non-pumping, abandoned boreholes were frequently difficult to locate. The completion certificate location maps were commonly inaccurate or missing completely, whilst the coordinates taken from the GS database were often highly inaccurate. Some boreholes were not located on the right map sheet. Others were not even located within the correct District. In the case of boreholes that had been abandoned for several years, the access tracks had become overgrown and often even the owners or local residents had difficulty locating them. In extreme cases, searching for such boreholes took several hours and did not always meet with success. In addition, casing had been removed from many unsuccessful boreholes and often there was little or no evidence that a borehole had been drilled at a given site. Under these circumstances total reliance had to be placed on information provided by the guide.

Despite these problems, it was possible to visit and correlate most of the registered boreholes known to be present within the Project area. A total of 104 boreholes and 39 wells were visited during the reconnaissance survey. Despite considerable efforts to locate all boreholes thought to have been drilled in the Project area, it proved impossible to find 12 of these by the end of the survey period. In addition several more close to, but outside, the project area could not be located. Further efforts will be made to locate these sites during the next phase of field work, although the prospect of success are low.

Borehole locations within the Project area are shown on Map 1. It is immediately apparent that borehole sites are heavily concentrated in the immediate vicinity of the three villages of Lehututu, Tshane and Hukuntsi in the centre of the area. Only two boreholes are located at the fourth village (Lokgwabe). Virtually no boreholes have been drilled in the intervening areas between the villages. There is also a zone, extending for a distance of at least 20 kilometres to the east, south and west of the villages, in which boreholes sites are absent. This zone would seem to roughly correspond to the communal grazing area, defined under the Land Use Plan (Figure 1), in which the establishment of private cattle posts is presumably prohibited. Other smaller clusters of boreholes are found in the vicinity of small outlying communities such as those at Monong, Ohe, Make and Zutswa. These clusters resulted from numerous attempts to

provide potable supplies for these communities, all of which have proved unsuccessful in terms of obtaining potable water.

Other scattered boreholes, many of which were privately drilled, are found in a broad zone extending from about 8 km north of Lehututu, round to the north east and east of Tshane. Many of these sites were drilled to provide water for TGLP ranches but most were unsuccessful. In the vicinity of the line of the Kang main road, boreholes have been more successful in obtaining water, which if not potable, is at least usable for livestock watering.

Map 2 shows the locations of hand dug wells visited during the Reconnaissance phase. The locations of various wellfields detailed by Knight Piesold (1991) are also indicated on the map. Due to the detailed work carried out by Knight Piesold only selected wells were visited during this phase. Again it is immediately apparent that well sites are heavily clustered in the vicinity of the four villages in the central part of the Project area. In this case however they are clustered around the margins of pans adjacent to the villages, rather than in the villages themselves. A fifth cluster is located at Pepane Pan, some 5 km to the north of Lehututu. As an illustration of the very dense clustering, Knight Piesold indicates that 39 wells are located on Mairi Pan alone, and that a total of 152 wells are located in the whole Matsheng village group. Outside the central area, well sites are generally more scattered, occurring singly or in small numbers, at pan margins.

7.3 Water Sampling

Groundwater sampling and wellhead chemical analysis was carried out at all pumping boreholes and wells within the area, as well as at selected unequipped wells. A total of 39 samples were collected during the field reconnaissance phase; 31 pumped samples, and 8 from hand dug wells by bucket. These were submitted as early as possible to the Geological Survey for standard chemical analysis, however, the results were not available at the time of writing. Additional pumped samples were also collected for analysis by the GRES II Project. These will be sent to the Netherlands for anion, cation, and isotope analysis. This data, and the input of the GRES II project, will be used to evaluate recharge to the shallow aquifer in the area.

In the case of pumped samples every attempt was made to carry out sampling after the borehole or well had been abstracting for at least 30 minutes, although this was not always possible. Details of the volumes of samples collected are indicated on the Field Reconnaissance Form (Figure 5). Additional 1 litre samples were collected for further titrations which were carried out at the camp, for input to the GRES project.

Wellhead analyses carried out on site included measurement of:

- pH,
- conductivity,
- temperature,
- redox potential,
- dissolved oxygen (DO),
- alkalinity (expressed in mg/l as HCO₃).

Due to the delayed arrival of the Checkmate Field Systems from Britain, and the lack of a Redox electrode or dissolved oxygen meter in the equipment carried by GRES, measurements of these parameters are sparse.

It should be noted that the sampling of the water sources was inevitably biased due to the fact that boreholes and wells from which water samples may be obtained are located predominantly in the central area and in the area to ENE of Tshane. The distribution of other usable sources is sparse since saline sources have, with few exceptions, been abandoned. In such areas water samples are predominantly from the shallow aquifer obtained from hand dug wells by bucket and may be subject to contamination.

7.4 Borehole Siting Methods

The vast majority of government drilled boreholes in the Project area appear to have been drilled on a random basis, close to or within the immediate areas of water demand. A small number are known to have been sited using geophysical techniques, for example near Hukuntsi (Peart and Bruno, 1982) and at Make (Wellfield Consulting Services, 1985). The use of geophysics resulted in little improvement in the success rate, although the prospects were in any case low at both locations.

Many privately drilled boreholes were sited by dowzers. Despite assurances of the presence of fresh water the success rate has been very low. The positioning of private borehole sites is often restricted by the Land Board who, when allocating an area for the establishment of a cattle post, demarkate an area of only one square kilometre, within which the borehole must be drilled.

7.5 The Project Database

Various data were collected in the field and from other sources. These data were organised into computerised databases, such that information could be retrieved quickly and easily, and queries carried out to select records based on specific criteria.

7.5.1 Sources of Data

Historical data was collected from a variety of sources, as was reported in detail in the Matsheng Area Groundwater Investigation: Inception Report (Wellfield, 1994), Table 4 shows the type of data obtained from each source.

Source of data	Format	Type of data
Geological Survey Borehole Archive	dBase file	Locational, ownership, technical and hydrogeological data about registered boreholes
Geological Survey Completion Certificates	Photocopies	Geological and hydrogeological details about registered boreholes
Knight-Pieshold Kgalagadi District 1990/91 Water Point Survey	ASCII file	Locational, ownership and hydrogeological data about boreholes, wells, and other water points in the Northern Kgalagadi
Geological Survey Chemistry Database	dBase file	Chemical analyses of water samples, plus some field measurements
Department of Water Affairs Chemistry Database	Hardcopy	Chemical analyses of water samples, plus some field measurements
Meteorological Office	ASCII file	Rainfall data for Tshane, Hukuntsi, Lehututu, and Lokgwabe, plus full climatological data for Tshane

TABLE 4 Sources of Data

Some problems were encountered with obtaining the Meteorological Office data, largely due to confusion about what data was required. In addition, the Meteorological Office's digital records are not up to date, and daily rainfall figures had to be copied by hand, and then added to the digital records. There are still problems with the monthly rainfall figures and evaporation data but this is being resolved.

Structure for database: C:\MATSHENG\DATA\RECONN.DBF

Number of data records: 285

Date of last update : 22/09/94

Field	Field Name	Type	Width	Dec	Index
1	INSPEC_DAT	Date	8		N
2	KP_REF_NO	Character	13		N
3	WCS_NO	Numeric	4		Y
4	BH_NUM	Character	6		Y
5	TEMP_NO	Logical	1		N
6	TYPE_WTRPT	Character	1		N
7	DISTRICT	Character	10		N
8	VILLAGE	Character	15		N
9	WTRPT_NAME	Character	15		N
10	LOCATION	Character	80		N
11	PROJECT	Character	30		N
12	MAP_SHEET	Character	12		N
13	UTM_E	Numeric	10	2	N
14	UTM_N	Numeric	10	2	N
15	LAT_DEG	Numeric	2		N
16	LAT_MIN	Numeric	2		N
17	LAT_SEC	Numeric	2		N
18	LONG_DEG	Numeric	2		N
19	LONG_MIN	Numeric	2		N
20	LONG_SEC	Numeric	2		N
21	COOR_ACC	Character	10		N
22	ELEVATION	Numeric	7	2	N
23	EL_ACC	Character	10		N
24	OWNER	Character	30		N
25	OWNER_TYPE	Character	1		N
26	USER_NAME	Character	30		N
27	USE	Character	2		N
28	CATAGORY	Character	2		N
29	BH_COMP	Date	8		N
30	DRILLED_BY	Character	20		N
31	MEAS_DPTH	Numeric	7	2	N
32	DEPTH	Numeric	7	2	N
33	MEASUR_RWL	Numeric	7	2	N
34	REST_W_LEV	Numeric	7	2	N
35	DIAM	Numeric	5	1	N
36	LINING	Character	20		N
37	YIELD	Numeric	7	2	N
38	AV_ANN_ABS	Numeric	10		N
39	MAIN_AQ	Character	4		N
40	DPTH_BASEK	Numeric	5	1	N
41	STATUS	Character	1		N
42	AVAIL	Character	1		N
43	WTR_QUAL	Character	1		N
44	EQUIPMENT	Character	1		N
45	COMMENTS	Character	150		N
** Total **			581		

Table 5(a) Project Database Structures: Reconnaissance database

Structure for database: C:\MATSHENG\DATA\PECHEM.DBF

Number of data records: 285

Date of last update : 19/09/94

Field	Field Name	Type	Width	Dec	Index
1	INSPEC_DAT	Date	8		N
2	KP_REF_NO	Character	6		N
3	WCS_NO	Numeric	4		N
4	BH_NUM	Character	6		N
5	DATETEST	Date	8		N
6	SMPLE_METH	Numeric	1		N
7	TM_STRT_PU	Numeric	4	1	N
8	WTR_SAMPLE	Numeric	1		N
9	FLD_PH	Numeric	4	2	N
10	FLD_EH	Numeric	5		N
11	FLD_HCO3	Numeric	5		N
12	FLD_DO	Numeric	3		N
13	FLD_EC	Numeric	5		N
14	TEMP	Numeric	5	2	N
15	COMMENTS	Character	150		N
**	Total	**	216		

Table 5(b) Project Database Structures: Chemistry database

Structure for database: C:\MATSHENG\DATA\RECVEG.DBF
 Number of data records: 285
 Date of last update : 19/09/94

Field	Field Name	Type	Width	Dec	Index
1	INSPEC_DAT	Date	8		N
2	KP_REF_NO	Character	6		N
3	WCS_NO	Numeric	4		N
4	BH_NUM	Character	6		N
5	TREE1_NAME	Character	15		N
6	TREE1_NO	Numeric	2		N
7	TREE1_HGHT	Numeric	2		N
8	TREE2_NAME	Character	15		N
9	TREE2_NO	Numeric	2		N
10	TREE2_HGHT	Numeric	2		N
11	TREE3_NAME	Character	15		N
12	TREE3_NO	Numeric	2		N
13	TREE3_HGHT	Numeric	2		N
14	TREE4_NAME	Character	15		N
15	TREE4_NO	Numeric	2		N
16	TREE4_HGHT	Numeric	2		N
17	TREE5_NAME	Character	15		N
18	TREE5_NO	Numeric	2		N
19	TREE5_HGHT	Numeric	2		N
20	BRANCH_DED	Logical	1		N
21	CANOP_AFFE	Numeric	3		N
22	EVID_FIRE	Logical	1		N
23	FENCING	Logical	1		N
** Total **			126		

Table 5(c) Project Database Structures: Vegetation database

7.5.2 Field Data

Field data was collected as detailed in 7.2. The information was entered onto field reconnaissance sheets at site, and entered into the database at the field camp. Data entry was completed on return to Gaborone, and the data checked and validated.

Three main dBase IV databases have been set up: borehole reconnaissance, hydrochemistry, and vegetation, which are linked via their WCS number. The database structures are detailed in Table 5 (a to c).

7.5.3 Main Reconnaissance Database

The main Reconnaissance database includes locational, ownership, technical, and hydrogeological data on boreholes and wells. All relevant borehole data (such as location, elevation, date of completion, borehole depth, etc) was imported from the GS database into the database prior to input of the field data. The boreholes identified during the reconnaissance phase were correlated with GS records and, where details differed (for example locational details), the field reconnaissance information was used to update the GS records. Using this approach, the GS records can be easily updated at the end of the project.

Any boreholes that could not be correlated with GS boreholes, were allocated a temporary number. Wells were also cross-correlated with Knight-Pieshold data, and a KP number added where possible.

A copy of all relevant data currently held on this database is presented in Appendix 2 and 3. The data items listed are as specified in the Terms of Reference (ToR). The database will continue to be upgraded and expand throughout the Project, as, for example, data from new boreholes becomes available.

7.5.4 Hydrochemistry Database

Historical hydrochemical data was obtained from the Geological Survey and Department of Water Affairs. There were also some problems with the chemistry data obtained from the Department of Water Affairs (DWA), due to the fact that many of the boreholes did not have a GS number attached. Where possible these were correlated, but most had to be discarded.

The Geological Survey (GS) database was found to be out of date, compared to that kept by the DWA. These data were used to supplement the project data, and were of particular value where samples had been obtained at the time of drilling, from abandoned boreholes. In the event that more than one record existed for a particular borehole, the latest dated sample was preferred.

The database was set up with a similar field structure to the GS and DWA hydrochemistry databases, and data was appended from these. As it can be linked to the main Reconnaissance Database using the WCS number, locational details were not included. All data held on this database is presented in Appendix 4.

7.5.5 Vegetation Database

Vegetation details collected to assist the Botanical Survey were stored separately, again linked to the main Reconnaissance Database by WCS number. This data together with water level and strike data was supplied to the Botanical subcontractor for use in the assessment of possible relationships between vegetation types and shallow groundwater.

7.5.6 Use of the Database

Using dBase, the databases could be linked, and specific filtering operations carried out. The required data, (for example, borehole locations), could then be output to XYZ files, and displayed using Geosoft software. The base map developed from the satellite imagery was also imported into Geosoft, in order that the borehole locations and other data could be overlaid on it. These plots were used for analysis of the data, and development of the Conceptual Model.

8 GEOLOGY

8.1. Previous Work

The project area has not been geologically mapped but considerable amounts of information concerning the sub-surface geology is available in a number of DGS reports. Those relating to the National Aeromagnetic Survey (Reeves, 1978 and 1979) and the Kalahari Drilling Project (Meixner and Peart, 1984) are particularly relevant, whilst Smith (1984) provided a definitive lithostratigraphy for the Project area. More recent reports prepared for DGS by Petro-Canada International Assistance Corporation (PCAIC) (Jessen and Bujak Davies Group, 1988; Wasilenkoff, 1988; Stokes and McMaster, 1990) and Compagnie General de Geophysique (CGG) (1988). These reports provide considerable detailed information for the Nossop/Ncojane basin, part of which underlies the western section of the project area. The PCAIC reports deal predominantly with the interpretation of seismic surveys and provides details of a follow up deep stratigraphic borehole. The CGG report provides additional detail from the interpretation of a magnetotelluric (TM) survey. By comparison, relatively little information is available regarding the sub-surface geology in the area to the east of the Kalahari line.

Limited geological data is available for the north of the area from a report on deep water boreholes (Geotechnical Consulting Services, 1991) and for the centre of the area (Geoflux, 1994). A considerable quantity of basic lithological data is also available from the drillers logs on the Borehole Completion Certificates but this data can sometimes be misleading and incomplete. The logs are often difficult to interpret with any great degree of certainty and the logs should therefore be viewed with caution.

8.2 Lithology

8.2.1 Stratigraphic Sequence

The general stratigraphic sequence present in the Matsheng Project area is provided in Table 6. Two separate but related nomenclatures, for the Karoo to the east and west of the Kalahari line (approximately longitude 22°E), were established by Smith (1984). Both are shown in the Table but to avoid confusion and simplify reporting, it is intended that only the former will be used. A brief description of the lithologies of each of the stratigraphic units is provided below.

Stratigraphic Unit		Group	Supergroup	Age
Western Central Kalahari (east of 22°E)	Southwest Botswana (west of 22°E)			
Kalahari Beds	Kalahari Beds	-	-	Cretaceous to Recent
Ntane Sandstone	Nakalatlou Sandstone	Lebung	(Upper) Karoo	Triassic to Permian
Mosolotsane Formation	Dongong Formation	Lebung	(Upper) Karoo	
Kwetla Formation	Kule Formation	Upper Ecca	(Middle) Karoo	
Boritse Formation	Otshe Formation	Middle/Upper Ecca	(Middle) Karoo	
Kweneng Formation		Middle Ecca	(Middle) Karoo	
Bori Formation	Kobe Formation	Lower Ecca	(Middle) Karoo	
Dukwi Formation	Middlepits Formation Khuis Formation Malogong Formation	Dwyka	(Lower) Karoo	Permian to Carboniferous
		Nama	-	Vendian to Cambrian
		Gariep	-	Riphean
Tshane Complex/Archean Basement		-	Basement	pre Karoo

TABLE 6 Stratigraphic Units in the Matsheng Area
 (adapted from Smith, 1984)

8.2.2 Basement

The Tshane Complex constitutes the pre Karoo basement, over an zone some 10 to 40 kilometres wide in a north/south direction through the centre of the project area. The Tshane Complex consists of basic rocks of gabbroic or doleritic type, intruded semi-vertically and of pre-Karoo age.

To the west, gravity and magnetic evidence suggest that the basement present at depth, beneath the basin area, is composed of dense mafic rocks similar in character to those of the gabbroic Tshane Complex (Wasilenkoff, 1988).

In the eastern part of the Project area, the Reconnaissance Aeromagnetic Survey interpretation maps (Sheets 24-Lehututu and 29-Tshane) indicate that, to the south of the Zoetfontein Fault, basement is present at a depth of about 1000 metres, (becoming more shallow to the south), and composed of folded magnetic metasediments. This was confirmed by the recently completed Mabuasehube borehole (Figure 6), located about 40 kilometres to the south east of the project area, which penetrated granitic gneiss at a depth of 365 metres. To the north of the Zoetfontein Fault, the aeromagnetic interpretation indicates that the basement probably consist of schists and gneissic rocks, although no sufficiently deep boreholes are present in the area to confirm this.

8.2.3 Pre Karoo Sedimentary Strata

An interpretation of seismic data for the western basin area indicated the presence of Nama and Gariep Group strata beneath the Karoo. These strata were confirmed to a depth of over 4000 metres in the Masetlheng Pan borehole drilled by PCAIC to the north west of the Project area (Figure 6). The Nama Group and upper part of the Gariep Group consists of well indurated, non porous, arkosic sandstones with occasional shales, although shales became more common towards the base Stoakes and McMaster (1990). Seismic data also indicates the presence of older strata at greater depth in the basin (Wasilenkoff, 1988).

8.2.4 Karoo Supergroup

Dukwi Formation

The lowermost Karoo unit in the area is the Dukwi Formation which comprises a relatively massive mudstone, sandy in places and exhibiting rhythmites and varvites typical of glacial deposition. This

unit is present in the southern, and probably the western, portion of the area but appears to be absent in the northeastern quadrant where higher Karoo units rest directly on Tshane Complex strata.

Bori Formation

Above the Dukwi Formation, the Bori Formation indicates a waning of the early Karoo glacial depositional environment. It comprises a series of dark micaceous siltstones, thin fine sandstones and mudstones, becoming more arenaceous towards the top of the unit. The unit may be several hundred metres in thickness.

Kweneng Formation

The transition from the siltstones of the Bori Formation to grits and coarse sandstones of the overlying Kweneng Formation indicates a change to a short transport/rapid deposition fluvial environment. The Kweneng Formation is characterised by massive, poorly bedded quartofeldspathic arkose of coarse to medium grain, some 50 - 80m in thickness.

Boritse Formation

Overlying the Kweneng Formation, the Boritse Formation is characterised by the presence of coals and carbonaceous shales interbedded with fine to very coarse quartz and feldspathic arkoses of relatively limited, but variable, thickness. The total thickness of this unit in the Matsheng area is considerable, up to 150 m.

Kwetla Formation

The Upper Ecca Kwetla Formation is a thick sequence (possibly up to 400 m) of grey (and occasionally redish), generally non-carbonaceous, siltstones and fine sandstones which conformably overlie Boritse strata below. These lithologies indicate a gradual change from an active lagoonal/deltaic depositional environment to one of lower energy and increasing aridity.

Mosolotsane Formation

Unconformably above the Kwetla Formation, (although the junction is often extremely difficult to define), are the yellow/red/brown mudstones with minor intercalations of fine sandstone and siltstones of the Mosolotsane Formation, which mark a transition into an increasingly arid, lacustrine depositional environment.

Ntane Sandstone

The uppermost Karoo unit in the area is the Ntane Sandstone, which usually follows gradationally from the underlying Mosolotsane Formation and which comprises a red/pink, medium, well sorted, largely aeolian, quartz sandstone. The Ntane Sandstone has been recorded only in the two Kalahari Project boreholes located within the area (CKP-8A and CKP-8C1) (Meixner and Peart, 1984)

8.2.5 The Kalahari Sequence

The Kalahari Sequence strata completely obscures the Karoo bedrock in the project area. These strata consist of a mixed sequence of sands, clays and cretes of Cretaceous to Recent age. Boundaries between the various lithologies are commonly gradational and therefore often difficult to recognise. In addition lithologies are often subject to rapid lateral variations.

Loose brown aeolian sands are by far the most common surface deposits throughout the area except in the vicinity of pans where the underlying calcretes and silcretes outcrop. The thickness of these sands generally varies up to about 20 metres but may be greater where banked into large dunes, often located to the south of many of the larger pans. Calcrete and silcrete horizons occur widely at shallow depths or at outcrop in the central Hukuntsi/Lokgwabe/Tshane/Lehututu area. The calcretes vary from a white, rubbly, poorly cemented type to very hard recemented greenish varieties. Marly varieties of calcrete have also been noted, as have considerable thicknesses of silcrete at some localities.

The occurrence of cretes at outcrop only in the central part of the area and in the vicinity of pans elsewhere, may give the impression that calcretes are not widely distributed throughout the Project area. An examination of drilling records for the area show that calcretes are almost universally present throughout the area, even in locations remote from pans. Calcrete seems to be absent at a only few localities. Weathered soft Kalahari sandstones are however commonly present at shallow depths at such locations, and may represent slightly calcretised sands. Cretes occur in thicknesses of only few metres in some locations, up to about 20 metres in the centre of the area.

Clays most commonly occur at the base of the Kalahari sequence although it is virtually impossible, from the drillers logs, to distinguish between possible basal Kalahari clays and weathered

Upper Karoo argillaceous strata. Over the eastern and northern sections of the area these "basal clays" are frequently recorded as being red brown, often interlayered with minor siltstones or sandstones. It is possible that these red brown clays or mudstones in fact represent the Mosolotsane or Kwetla Formation, although this may not be properly resolved until relogging of chip samples is completed.

8.3 Structure

The project area is underlain by a considerable thickness of Karoo strata which are completely obscured by a blanket of Kalahari deposits. The area straddles the Kalahari line, which corresponds to a northerly trending alignment of magnetic and gravity anomalies which roughly parallel longitude 22°E. The line is thought to represent a pre Karoo basin margin (Reeves and Hutchins, 1976) with the Nosop/Ncojane basin deepening rapidly to the west. Pre Karoo basement beneath the Kalahari line, comprised of highly magnetic gabbroic rocks (Tshane Complex), has been encountered at relatively shallow depths within the area, at 750 metres (CKP-8C1) in the south east and 320 metres (CKP-8A) in the central part of the area.

The Zoetfontein Fault, an almost continental scale faultline, trends in a westerly direction across the south east quadrant of the area and appears to be terminated at depth by the Tshane Complex at latitude 24°20' south, some 25 kilometres south of Tshane. Other major faults shown on the Aeromagnetic Survey Interpretation maps trend to the north west. Although these faults are known to affect the Basement strata, it is not known if they reactivated in Post Karoo times and hence also affected the Karoo strata.

Figure 6 A cross section through deep stratigraphic boreholes

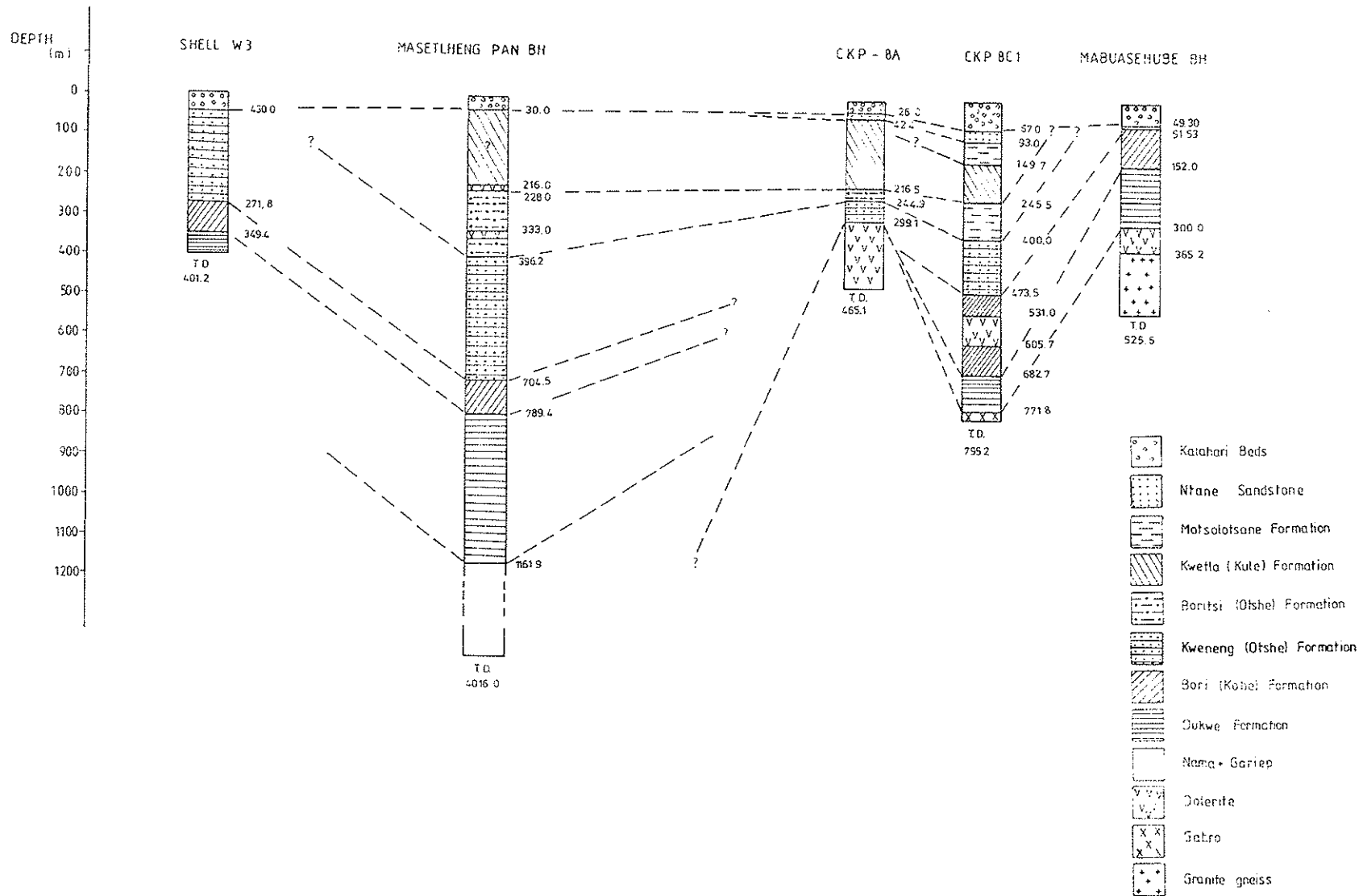
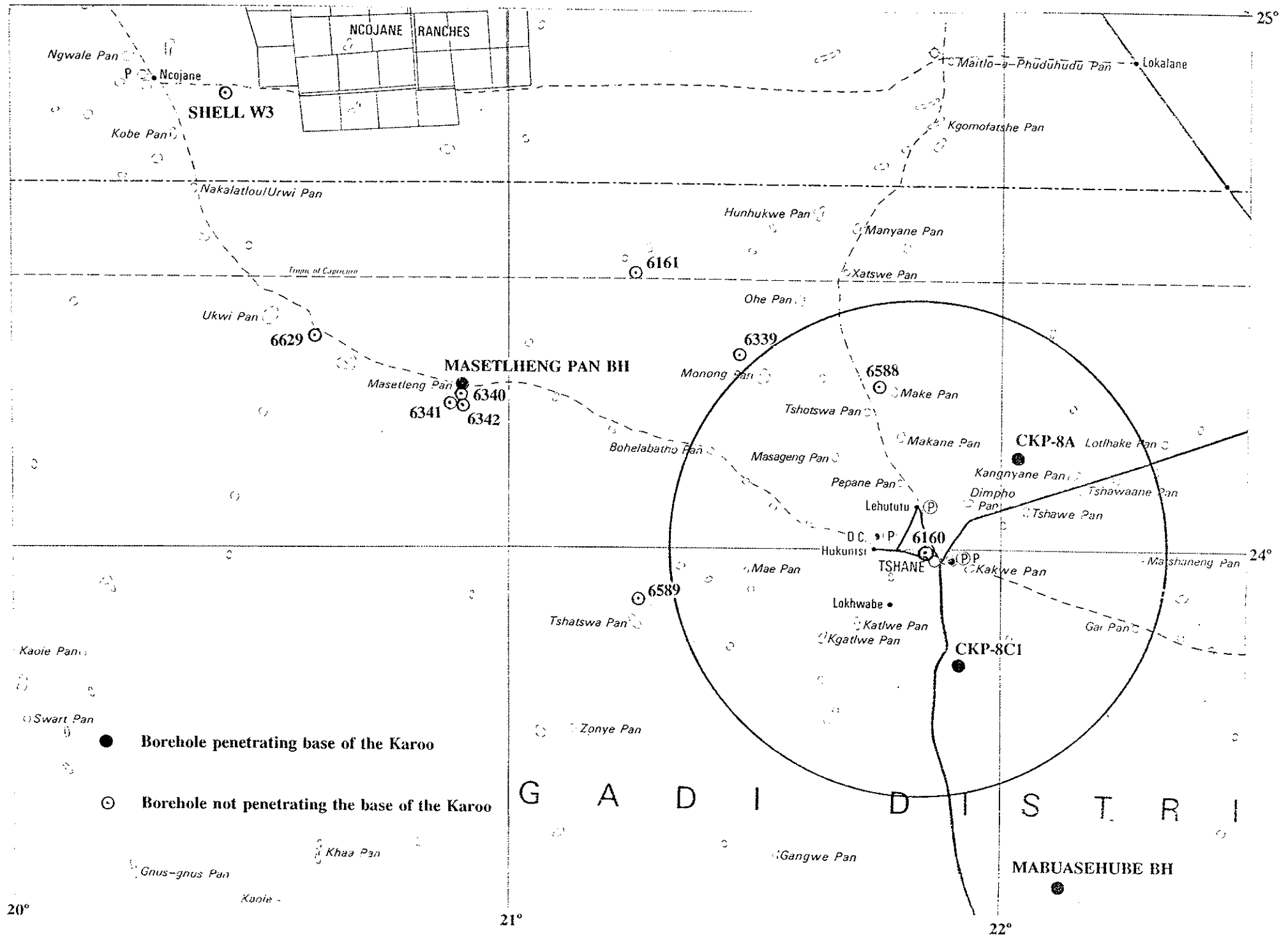


Figure 7 Location of deep boreholes in the Matsheng Area

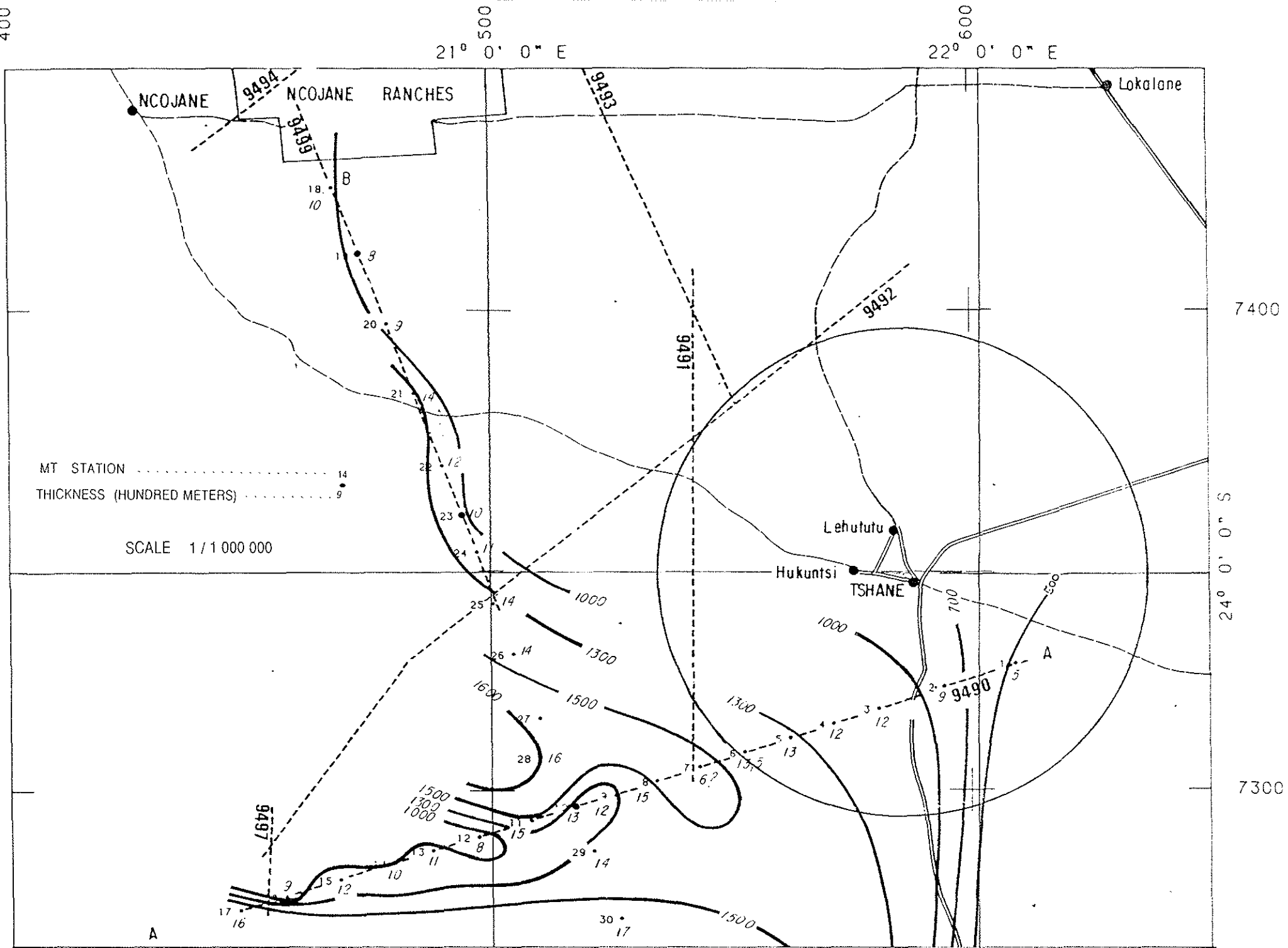


The only major dykes shown on the Aeromagnetic Interpretation, are two located to the west of Lehututu trending north west and a third to the south east of Tshane trending east south east within the Project area. The recent reinterpretation of regional geophysical data (Wellfield Consulting Services, in preparation) indicate that basic sills are very common over the eastern section of the Project area. This is confirmed by mineral exploration boreholes located to the north east of Lehututu.

Field reconnaissance of the Matsheng area permitted the accurate location of the vast majority of boreholes known to have been drilled in the area. It had been anticipated that this would allow the lithological logs, provided by drillers on the Borehole Completion Certificates, to be used to define the subcrop of the various Karoo Formations, (particularly the Ecca) beneath the Kalahari Beds. In particular it was hoped to be able to better define the thickness, depth and distribution of the those Ecca Formations which possess greatest potential as aquifers. The lithological descriptions however proved inadequate for this purpose, only rarely allowing a particular Formation to be defined.

The variation in thickness of the various Middle and lower Karoo strata across the project and adjacent areas is illustrated in a cross section (Figure 6), using the logs of well documented stratigraphic boreholes. It should be noted that the stratigraphy for the Masetlheng Pan borehole is in fact a composite, with the lower section below 396.2 m being from the PCIAC stratigraphic borehole and the upper section from water borehole 6342 also drilled by PCIAC nearby. The borehole locations are shown on Figure 7. From the cross section it can be seen that the various formations thicken in a westward direction. The thinner Ecca at CKP-8A is predominantly the result of the absence of the lower part of the Ecca although some attenuation of thickness has also occurred. The overall combined thickness of the Karoo and Kalahari is illustrated for the western section of the Project area on Figure 8. The thickness is at a minimum above the Tshane Complex intrusion thickening to a maximum of about 1300 metres in the extreme south west of the area. These thicknesses were determined by interpretation of a magnetotelluric survey carried out by *Companie Generale de Geophysique* (1988) on behalf of DGS. Since the interpretation of the aeromagnetic survey indicates a depth to basement of up to 1000 metres over the eastern craton, it seems probable that the full Ecca and Dywka Group sequence are likely to be present in that area.

Figure 8 Thickness of the Karoo Supergroup and Kalahari Sequence



Kalahari sequence thicknesses are at a minimum in the central part of the project area, generally less than 20 metres around Tshane, Lokgwabe and Hukuntsi increasing to about 30 metres around Lehututu. This zone of relatively thin Kalahari strata extends both eastward and north westward from this central zone. Thicknesses increase to the north east but do not generally exceed 50 metres. To the south and west much greater thicknesses are encountered, frequently in excess of 100 metres. The greatest thicknesses are recorded in the south where one PCIAC borehole recorded a thickness of 220 metres although this is not substantiated by other boreholes in the area.

9. GEOPHYSICS

9.1 Regional Geophysical Interpretation

The following data sets have been utilised in the Regional Interpretation of the project area :

- Terra Surveys, 1976 - Reconnaissance Aeromagnetic Survey of Western Botswana
- Poseidon Geophysics, 1991 - Aeromagnetic Survey for De Beers Prospecting
- Botswana Geological Survey - National Gravity Survey of Botswana
- CGG/Geoterrex - Nosop-Ncojane Basin Gravity Survey
- E.J.Ebner Cons. for PetroCanada - Seismic line Gravity Survey
- CGG - Nosop-Ncojane MagnetoTelluric Survey
- Exploration Seismic Services for PetroCanada - Nosop-Ncojane Seismic Survey

The dominant structure within the Project area is the north-south trending "Kalahari Line" first identified by Reeves, 1978. The Kalahari line represents a broad collinear series of deep seated faults and coincident mafic intrusions and represents the edge of the continental craton at mid-Proterozoic time. Drilling has confirmed the existence of gabbroic rocks at depths of 320m and 750m on this trend. These mafic intrusives have apparently been broken and displaced in a left-lateral sense by a series of NNW trending faults of which the Tshane fault is the most obvious. This faulting is considered to be essentially contemporaneous with the formation of the complex, which has been dated as mid-Proterozoic.

The Zoetfontein fault can be identified on the southern margin of the Project area, while it extends to the ENE it appears to be truncated by the Kalahari Line. Elsewhere in Botswana and South Africa the Zoetfontein fault has been shown to be reactivated periodically until as recently as post-Karoo (Letlhakeng-Botlhapatlou). As such it is possible that if reactivation has occurred in this area enhanced groundwater yields due to the creation of secondary permeability by fracturing may occur in the Karoo in this locality.

Additional lineaments with NW and NE trends are also apparent and are clearly much younger than the previously mentioned structures. Dykes can be identified in some of the NW trends however the NE ones appear not to have been infilled.

To the west of the Kalahari Line deposition of sediments of Proterozoic to Nama age has occurred in the Nosop-Ncojane basin. The overlying Karoo sediments increase in thickness to the west of the complex attaining a maximum thickness of 1300m in the south west of the project area. Extensive gravity, seismic and magnetotelluric data is available in this area and constrains this interpretation. To the east of the complex less information is available however gravity data indicates the development of a further basin which may have a thicker sequence of Karoo sediments.

The aeromagnetic data indicates that the Stormberg basalt is not present in this area, however dolerite sills appear to be present at least in the NE quadrant of the project area and may be more extensive.

Should fault zones be considered as drill targets, in the east of the area they can be defined solely by reference to the aeromagnetic data, however in the west upwards of 30 major faults affecting the Karoo strata can be directly identified from the seismic data. These features may be investigated for enhanced groundwater yields, if the Kweneng Formation proves to be a freshwater aquifer.

9.2 Geophysical Calibration Survey

As called for in the ToR a calibration exercise was conducted in the Matcheng area to investigate the effectiveness of various geophysical techniques to identify zones of shallow perched aquifers and also to investigate the location of some of the deeper boreholes in the area. The intention of the investigation was to determine the most suitable geophysical techniques for groundwater exploration in these localities.

9.2.1 Investigation of Shallow Aquifers

Methodology

The shallow aquifers appear to be associated with pan development, an initial model developed by the Geological Survey (P. A. Gledhill pers com) assumes that downwind of a pan a lens of fresh water is supported on saline, more dense, water below the pan marginal dunes. This fresh water is, in the villages of Lehututu, Hukunsi, Tshane and Lokgwabe, exploited by shallow hand dug wells. From theoretical considerations the freshwater lens should be identifiable by the use of Time Domain Electromagnetic (TDEM) methods. In practise a limited test survey undertaken by the Geophysical Department of the Geological Survey, utilising Geonics Protem EM47 equipment, has shown this to be the case.

To determine whether the fresh water aquifers could in fact be generally identified by geophysical means, the consultant undertook surveys in the areas of Lehututu, Tshane and Lokgwabe. These surveys were conducted along traverses radiating from the pans and were aligned such that wells and boreholes could be utilised to give limited hydrogeological and geological control. Geophysical methods utilised were:

- HLEM - Apex Max-Min I6 , frequency domain EM soundings with a coil separation of 100m and a station interval of 50m.
- TDEM - Zonge GDP-16 and GGT-10 , in-loop transient EM soundings with a transmitter loop size of 25m x 25m and a ferrite cored magnetic antenna, station interval of 200m
- IP/VES - Zonge GDP-16 and GGT-10, galvanic DC and Induced Polarisation soundings in a Schlumberger array with AO to a maximum spacing of 200m

The consultant contracted the field data acquisition to POSEIDON GEOPHYSICS (PTY) LTD who provided the Zonge equipment, while the frequency domain investigations were conducted by the Consultants staff.

In TDEM mode, the Zonge equipment utilised a base repetition frequency of 30Hz and the first observation was taken 0.0304 mS after switching off the transmitter current. The first three (early time) observations were almost always spurious as were measurements beyond 10 mS. These spurious readings are probably a function of the equipment configuration and the geological conditions encountered respectively. While the later observations are not critical for shallow investigations, the early time observations are important for the accurate modelling of the near surface geology. The data was interpreted utilising a program called TEMIX-Z developed by Interpex Ltd , Golden, Colarado.

The Zonge equipment was also configured in the time domain mode to undertake the IP-resistivity soundings, thus chargeability and apparent resistivity was measured. Initially it had been intended that these soundings would also be conducted at 200m intervals along the traverses but, due to the very high electrode contact resistances encountered necessitating the pre-watering of the sites, only a limited number of soundings were conducted on each traverse. The data was interpreted utilising a program called

RESIX-IP developed by Interpex Ltd, which allows the joint inversion of both resistivity and chargeability data.

The HLEM survey data was conducted as a series of parametric soundings and interpreted as a layered earth utilising a program called EMIX-MM developed by Interpex Ltd.

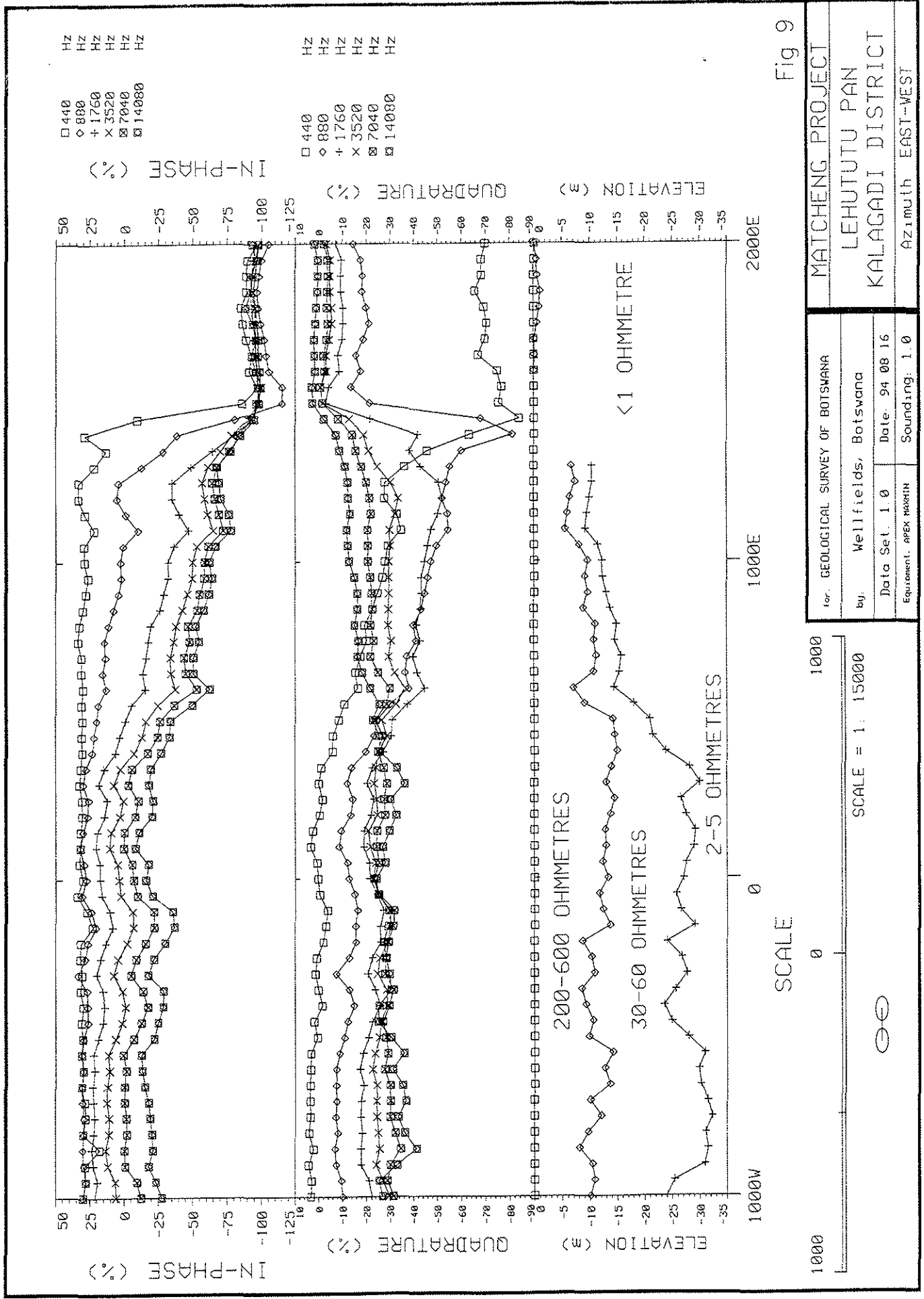


Figure 9 Lehututu Pan Traverse: Interpretation of HLEM data

Fig 9

MATCHENG PROJECT	
LEHUTUTU PAN	
KALAGADI DISTRICT	
AZIMUTH EAST-WEST	
for: GEOLOGICAL SURVEY OF BOTSWANA	
by: Wellfields, Botswana	
Data Set: 1.0	Date: 94 08 16
Equipment: APEx MARKIN	Sounding: 1.0

1000 0 1000 2000

SCALE

SCALE = 1:15000

1000W 0 1000E 2000E

IN-PHASE (%)

QUADRATURE (%)

ELEVATION (M)

200-600 OHMMETRES

30-60 OHMMETRES

2-5 OHMMETRES

< 1 OHMMETRE

Results

The results of the surveys are discussed with specific reference to the Lehututu traverse however the comments are valid for all of the traverses investigated.

HLEM: The Max-Min data is of consistently good quality (Figure 9), except where effected by cultural features as at Tshane (fences) and Lokgwabe (pipelines). The Lehututu data away from the pan can be modelled as a three layer case with resistivities decreasing with depth. The surface layer which shallows towards the pan has resistivities varying between 200 and 600 ohmmeters and is interpreted as unsaturated Kalahari sands probably having variable quantities of silty or clayey material present. The second layer, which is approximately 5m thick towards the pan increasing to approximately 20m thick away from the pan has a resistivity of between 30 and 60 ohmmeters and is interpreted as Kalahari sands probably with a variable clay content and saturated with fresh water, the depth to the interface is consistent with the static water level at locations with either borehole or well control. The third layer has very low resistivities of between 2 and 5 ohmmeters and is interpreted either as saline water or perhaps clay or mudstone.

The above interpretation is compatible with the initial model, however initial modelling has shown that thickness variations in a simple two layer model can equally satisfy the observed model albeit with a generally poorer accuracy. While the interpretation can be constrained in this case by knowledge of the static water level interpretation of a data set without control provided either by direct observation of the static water level or from linear extrapolation along geophysical profiles would be subject to this ambiguity.

TDEM: The TDEM data appears to be unaffected by the cultural features which give rise to strong anomalies in the frequency domain data. The profile data is presented as interpreted sections produced by both forward modelling as a three layer case and by the automatic inversion of the data utilising a maximum

of 15 layers of variable thickness and resistivity (Figures 10 and 11). The pan can clearly be defined as a zone of very low resistivities between 160E and 220E. Dipping away from the pan a low resistivity layer corresponding to either saline water or clays can be identified. Above this layer a higher resistivity zone reflects the presence of the freshwater aquifer. Above this and extending to surface (only evident on the forward modelled profile) is a high resistivity layer reflecting the presence of the unsaturated zone. Unfortunately the section produced by smooth inversion is dominated by the spurious early time readings which have the effect of generating a fictitious conductive zone near surface. These early time observations were discarded for the forward modelling. Evidently the system configuration utilised for this survey is not optimal for the investigation of these very shallow targets, better definition of the static water level is required to accurately determine the thickness of the freshwater aquifer. It is considered that the use of higher base frequencies and air cored receiver coils would improve the data quality at the very early times.

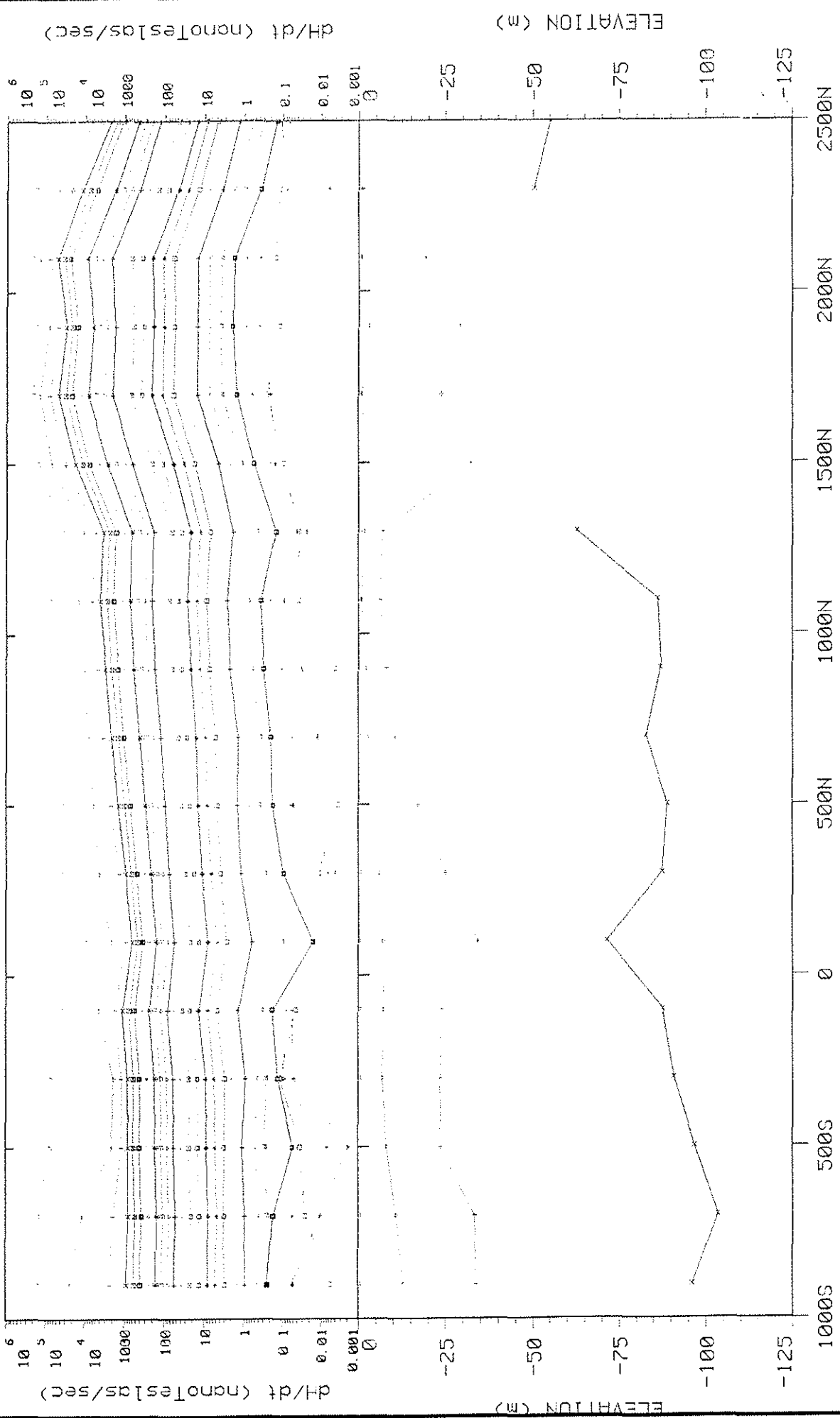
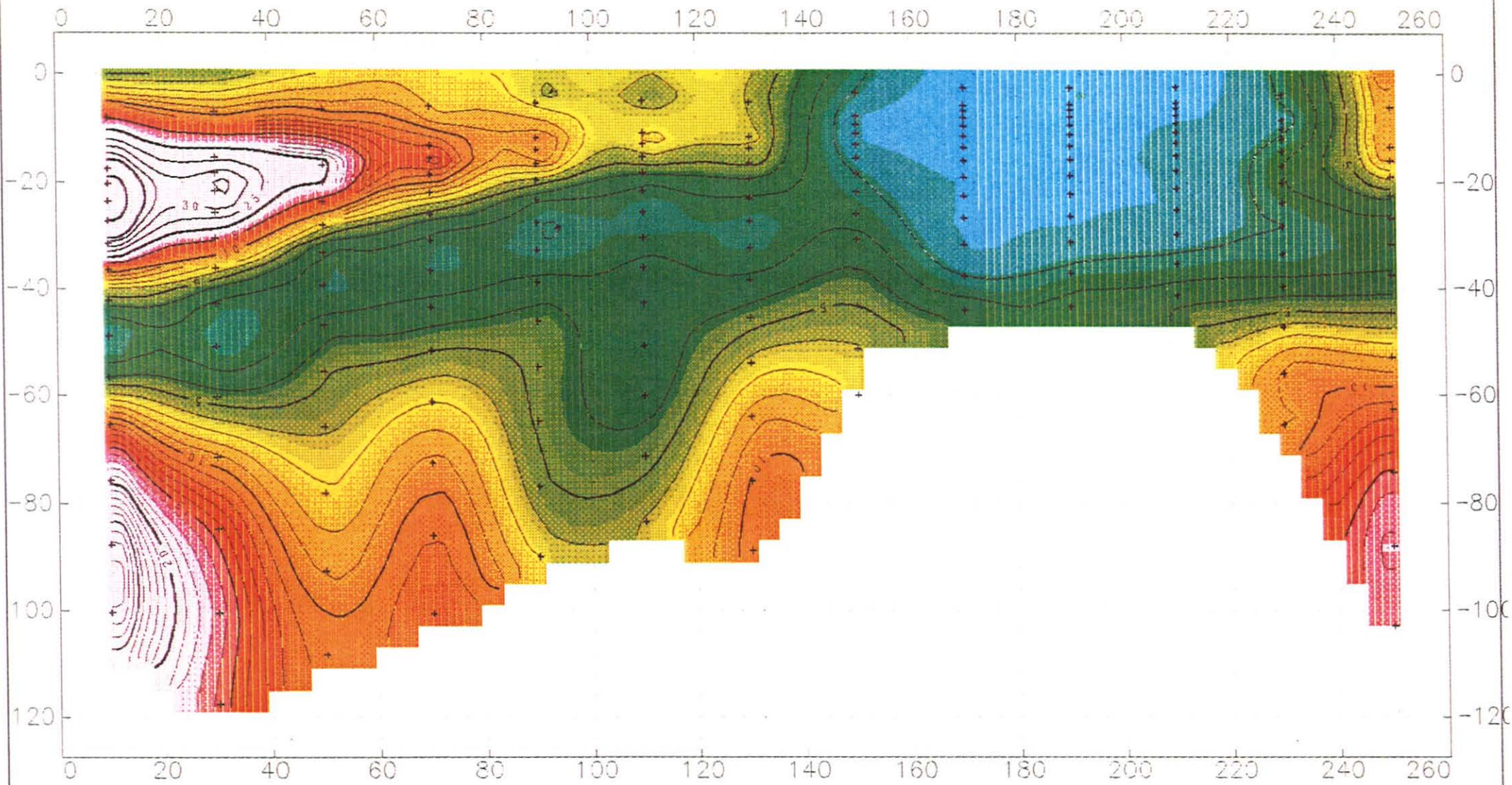


FIG 10

LEHUTUTU PAN	
MATSHENG PROJECT	
TDEM PROFILE	
Azimuth: 90 Scale 1:7874.	
Per. WELLFIELD CONSULTING SERVICES	
by Poseidon Geophysics (Pty) Ltd	
Data Set: LEHUTUTU	Date: AUG 94
Equipment: ZORBE GPR-16	Line: 1



Figure 10 Lehututu Pan Traverse: Interpretation of TDEM data



MATSENG PROJECT

LEHUTUTU PAN TRAVERSE

TDEM SOUNDING DATA - PSEUDO-SECTION FROM SMOOTH INVERSION

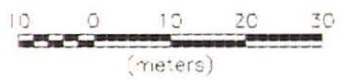


FIG 11

IP/VES: Combined resistivity and induced polarisation Schlumberger soundings conducted over the shallow perched aquifer have results which are consistent with the presence of freshwater over saline water. Apparent resistivities in general have the appearance of a three layered earth with deeper layers having lower resistivities. The water table is however not defined by the resistivity data although the interface with the saline water is. The chargeability curves generally display the sharp increases and negative-going descents characteristic of this method. A clearly defined peak in chargeability is associated with the fresh water while the assumed saline water generally has a low chargeability. The Kalahari sand in the location of the Lehututu traverse is highly resistive towards the surface however at greater depths it evidently has a significant clay component, resulting in the resistivities of the fresh water saturated and unsaturated zones being similar. The zone assumed to be saturated with saline water displays the low resistivities and low chargeabilities characteristic of the method (Roy and Elliott, 1980). The sounding conducted 100m distant from BH6088, (Figure 12) determined depth to fresh water to be approximately 9.5 m while the rest level at drilling was determined as 13.5 m. The thickness of the fresh water aquifer is interpreted as about 15 m, with saline water below. The borehole was terminated prior to the intersection of saline water hence, as with those parameters determined by other methods, exact correlation with geology and hydrogeology is not possible.

While the chargeability resistivity soundings appear to be the most definitive of the geophysical methods utilised in this study to determine the presence of freshwater over saline water, the high contact resistances encountered made the collection of the field data difficult. Careful preparation of the electrodes was required to reduce the contact resistances as such only a maximum of two soundings could be completed in a day.

Figure 12 Lehututu Pan Traverse: Electrical Sounding at 100E

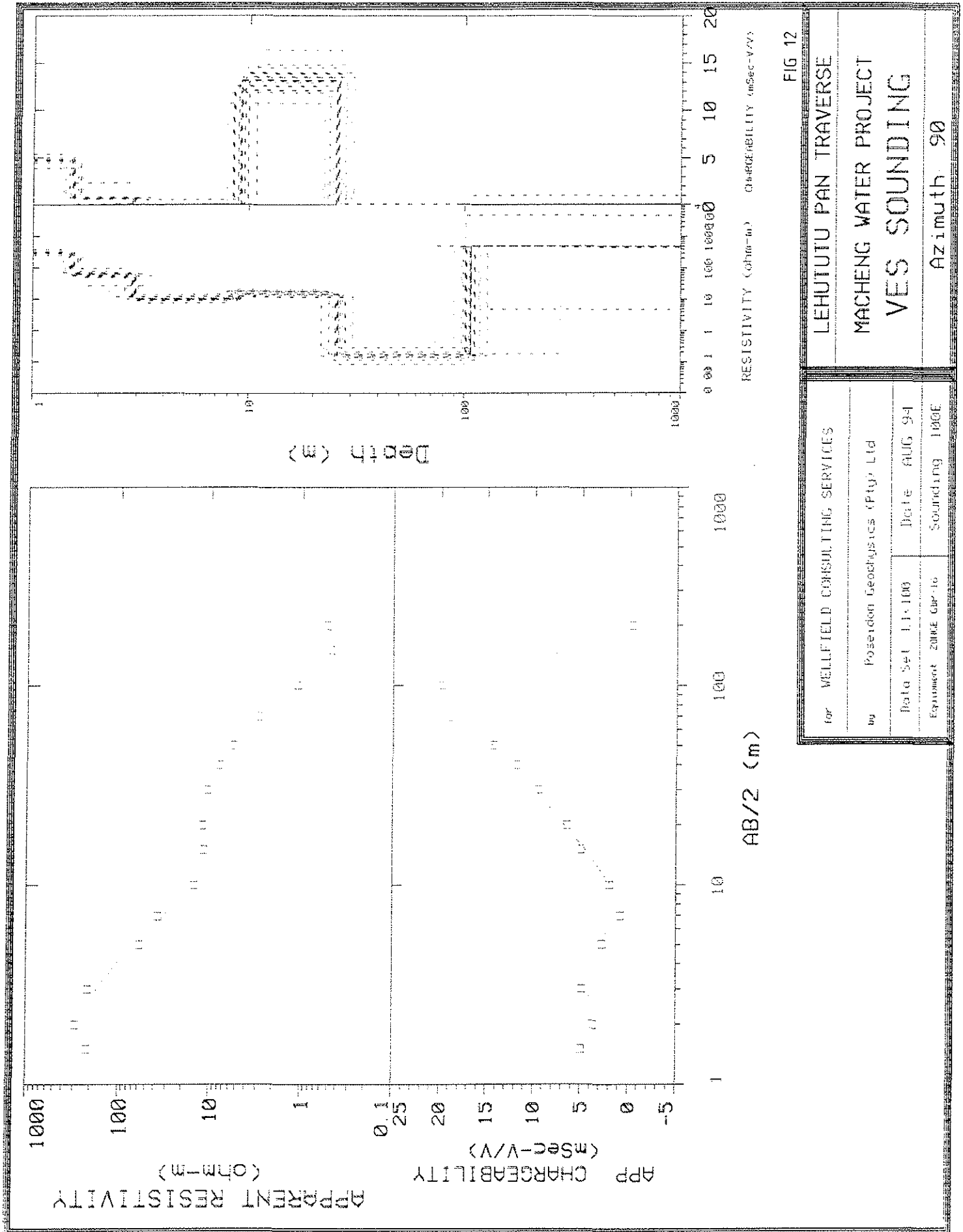


FIG 12

for WELLFIELD CONSULTING SERVICES	
by Poseidon Geophysics (Pty) Ltd	
Date Set 11-100	Date AUG 94
Equipment ZONE Cap-16	Sounding 100E
LEHUTUTU PAN TRAVERSE	
MACHENG WATER PROJECT	
VES SOUNDING	
Azimuth 90	

Comments and Conclusions

The calibration exercise appears to have been successful in confirming the model of a fresh water aquifer located above saline water at a shallow depth and existing to a distance of at least 2kms from the pan margin. Confirmation of the model by drilling is required to enable the extrapolation of these results across the project area. Boreholes should be drilled to intersect the presumed saline water below the fresh water aquifer.

Of the three methods utilised in this investigation, chargeability resistivity soundings appear to provide the most accurate results allowing both definition of the top and thickness of the freshwater zone. Unfortunately the method is rather slow and it is envisaged that this method will be utilised for confirmation of depths and thicknesses derived from interpretation of the electromagnetic data. The TDEM method has been shown to identify the location of the saline water layer although with the equipment utilised for this investigation, the lack of accurate early time observations reduced the accuracy in definition of the fresh water zone. Frequency domain electromagnetic data has been shown to be able to define both the fresh and saline water layers given some a priori information, however without this information the data can be interpreted as a simple two layer case with no definition of the fresh water zone.

9.2.2 Investigations at of Deeper Aquifers

Four boreholes with differing water qualities were investigated to determine whether geophysics could determine any apparent discriminatory feature which could be used to identify a fresh water yielding site. The geologies of each borehole were essentially similar with layers of sandstone, mudstone and shales being identified in the drill logs. The sites were investigated by the use of magnetics and HLEM to determine if they had been located on linear geophysical anomalies, this was proven not to be the case. Each site was then investigated vertically by the use of TDEM and chargeability resistivity Schlumberger soundings to an AO spacing of 1000m. Little correlation could be identified between the models derived from inversion of the two data sets within the limits of equivalence calculated. This may be partly due to the poor quality of some of the electrical soundings, due to the high contact resistances encountered, and it may be also be explained by the fact that TDEM techniques respond best to conductive layers whilst VES respond best to resistive zones. Essentially it has not been

possible to determine conclusively an individual parameter or set of parameters which reflect the presence of fresh water at depth.

9.2.3 Investigation of a Calcrete Ridge

In discussion with the Remote Sensing Expert the apparent coincidence of north westerly trending calcrete ridges with aeromagnetic lineaments was commented on. It was considered that the ridges may have been formed over zones in the bed rock having enhanced permeability, corresponding to faulting or dyke emplacement. A ridge at Hukuntsi was investigated utilising ground magnetics and HLEM to determine whether a dyke or fault was located below it.

The magnetic data was featureless, however the HLEM data reflects the presence of a sub-vertical conductor probably caused by a fault immediately below the ridge, (Figure 13). It is considered that boreholes sited on faults and fractures may provide higher yields as such in areas having a fresh water aquifer present the ridges may provide easily definable drilling targets.

9.2.4 Recommendations

As a result of the investigations carried out certain conclusions and recommendations can be drawn with regard to both investigatory drilling to confirm the shallow aquifer model and for the design of an effective geophysical exploration programme.

Of prime importance is the confirmation of the validity of the shallow aquifer model and the conclusions drawn from the geophysical results over this aquifer. It is considered that a number of boreholes should be drilled located on the geophysical traverses to confirm the exact geology, depth and thickness of the freshwater layer and the presence of saline water at depth. In addition the calcrete ridge should be investigated by drilling to confirm whether there is associated faulting and whether yields are enhanced.

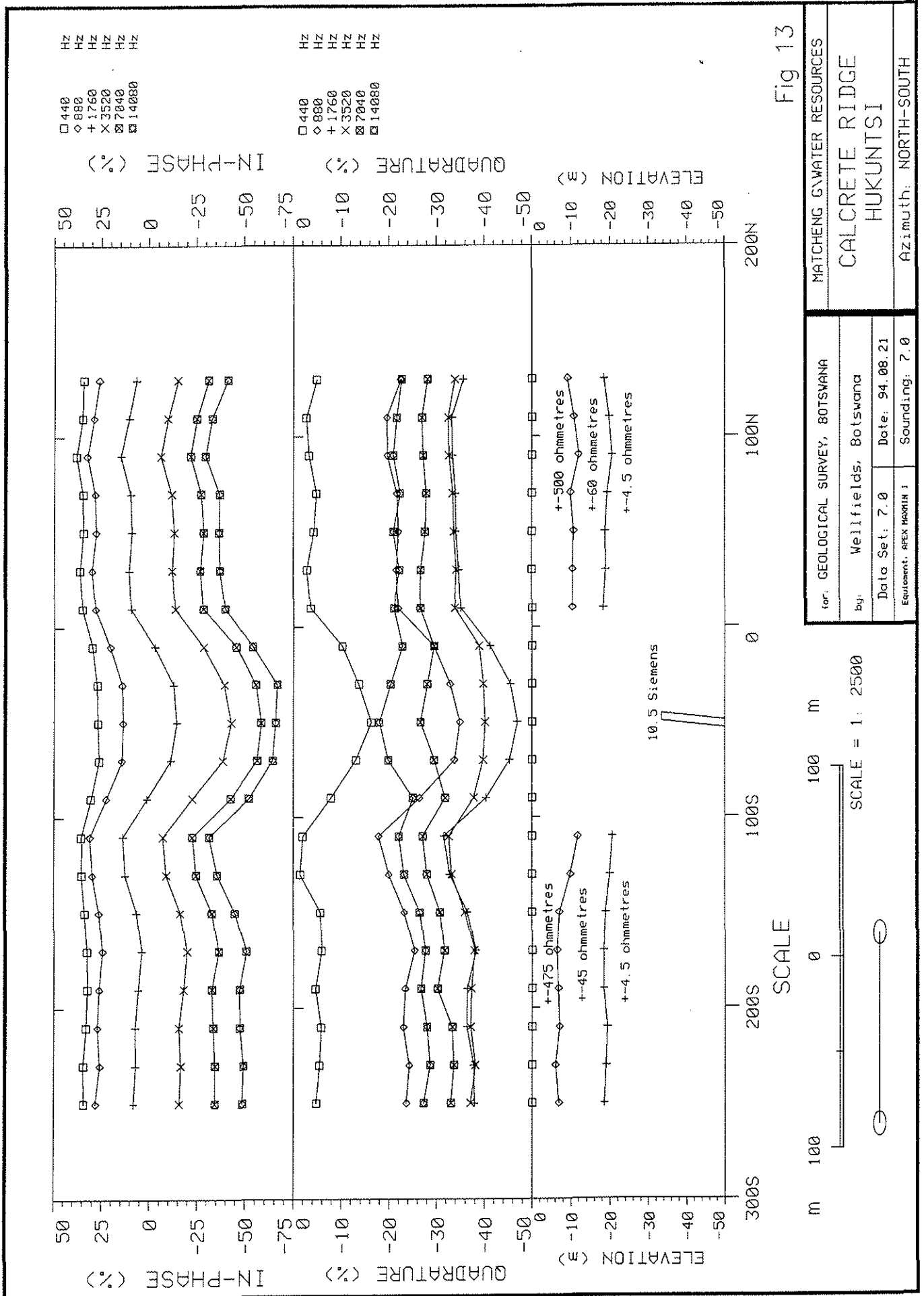


Fig 13

MATCHENG GWATER RESOURCES	
CALCRETE RIDGE HUKUNTSI	
for: GEOLOGICAL SURVEY, BOTSWANA	Azimuth: NORTH-SOUTH
by: Wellfields, Botswana	
Date Set: 7.0	Date: 94.08.21
Equipment: APEX MOXIM I	Sounding: 7.0

Figure 13 Hukuntsi Calcrete Ridge: Interpretation of HLEM data

If, as is expected, the shallow aquifer model is proven correct by exploratory drilling, the most important question remaining to be answered is with regard to the lateral extent of the fresh water perched aquifer; are they localised around pans or laterally extensive? It is recommended that initial investigations are aimed at solving this problem. To this end it is considered that a traverse be made between Lehututu Pan and Lokgwabe Pan to ascertain whether the boundaries of the perched aquifer can be detected. If no boundaries are detected and this is confirmed by exploratory drilling it will be necessary to determine the lateral extent of the aquifer away from the central villages by conducting traverses along the major roads and tracks in the area. Should, it be shown however, that the perched aquifers are of limited extent the boundaries to the aquifers associated with the central pans must first be established, prior to the investigation of outlying pans.

With respect to the siting of the deep holes to investigate the potential of the Kweneng Formation it is not considered that geophysical techniques would be sufficiently discriminatory to infer the presence of fresh or saline water at considerable depths. If faulting is to be targeted in these deep holes in an attempt to improve yields, it is however considered that the holes should be approximately sited with reference to the regional data available and the exact location of the fault on the ground defined by reference to ground magnetic and HLEM data.

10 HYDROGEOLOGY

10.1 Previous Work and Information Sources

Only two directly relevant hydrogeological reports are available for the project area. Details of a series of deep boreholes, (some of which are located in the area), drilled in an attempt to obtain fresh water from the Ecca, were provided by Groundwater Consulting Services (1991) but included only limited information regarding aquifer parameters. Geoflux (Pty) Ltd (1994) concentrated primarily on the hydrogeology of the Kalahari sequence in the central part of the Project area and included analyses of aquifer tests carried out on boreholes penetrating both the Kalahari and Ecca.

The Kgalagadi Water Point Survey (Knight Piesold, 1991) provides basic information regarding water sources but, since the survey was aimed primarily at identifying water sources and the ownership of water rights, the information was of limited hydrogeological value.

Other work (Wellfield Consulting Services, 1993 and Boocock and van Stratten, 1962) provide valuable insights into the hydrogeology of strata similar to those beneath the Project area, in locations to the east along the line of the Ghanzi road.

The Borehole Completion Certificates also represent a large potential source of hydrogeological data but this data needs to be viewed with some caution, as basic items of data are often not recorded, or recorded in an incomplete and potentially misleading manner.

10.2 Groundwater Occurrence

Groundwater can potentially occur in virtually all of the geological units present beneath the Project area but it is improbable that many constitute viable aquifers, either in terms of sustainable yields or potable water quality.

Very little is known regarding the hydrogeological characteristics of the deeper Karoo, (particularly the lower part of the Ecca and Dwyka), the pre-Karoo and basement strata. These horizons have only been penetrated by deep stratigraphic boreholes from which no water related data has been recorded. Their hydrogeological characteristics can only be assessed in the light of their lithologies and aquifer potential in other parts of Botswana.

The upper part of the Karoo and Kalahari strata are penetrated by many water boreholes in the Project area but, lacking detailed studies, their

hydrogeological characteristics remain uncertain in many respects. It is possible however to use the limited information available for these strata, within the area, in combination with additional data from other better known areas, to assess the aquifer potential of various units.

10.3 Aquifer Distribution and Properties

10.3.1 Basement

No direct evidence is available regarding the hydrogeological characteristics of the basement strata in the Matsheng area but elsewhere in Botswana similar strata do not form viable aquifers. The lithologies of the basement strata and their considerable depth of burial beneath the Project area it make highly unlikely that these strata form a viable aquifer unit.

10.3.2 Pre-Karoo

The pre-Karoo strata, consisting of the Nama and Gariep Groups have only been penetrated in a single stratigraphic borehole. Stokes and McMaster (1990) indicate that the constituent arkosic sandstones are well indurated and non porous. These strata are not therefore likely to form aquifer units.

10.3.3 The Dwyka Group

The Dukwi Formation does not form an viable aquifer elsewhere in Botswana and in view of the massive argillaceous nature of the Formation in the area, it is not likely to constitute an aquifer unit.

10.3.4 The Ecca Group

The Ecca Group is, due to its varied lithology, likely to constitute a complex multilayered aquifer, in which the argillaceous horizons form aquicludes or aquitards between the argillaceous strata, some of which may form aquifer units. This view is supported by multiple water strikes, (often over a considerable depth interval), recorded in many water boreholes penetrating the Ecca. Aquifer units within the Ecca are likely to be generally confined, although if a unit is in hydraulic continuity with the overlying Kalahari aquifer, unconfined conditions may exist.

Bori Formation

Although predominantly argillaceous in nature, the presence of fine well cemented sandstones, particularly towards the top of the

Formation, may indicate a slightly better aquifer potential compared to the underlying (Dukwi) strata. The Formation is not however likely to form a viable aquifer unit unless appreciable secondary (fracture) permeability is present. There are no records regarding hydrogeological characteristics of this Formation in the Matsheng area, but it does not form a viable aquifer unit elsewhere in Botswana.

Kweneng Formation

The Kweneng Formation, characterised by massive, often poorly cemented, quartzofeldspathic arkose, has the greatest aquifer potential. The Formation would be expected to possess a high primary (intergranular) permeability, undoubtedly enhanced by secondary permeability attributable to fractures. It is considered doubtful that any of the water boreholes, even those drilled specifically to obtain fresh water from the deeper horizons of the Eccca, (Groundwater Consulting Services, 1991), penetrate the base of the Boritse Formation, into the Kweneng Formation. Thus in the absence of evidence to the contrary, parallels may be drawn between the Kweneng strata in the Matsheng area and very similar Middle Eccca lithologies which constitute important fresh water aquifers in other areas (including Jwaneng and Dukwi areas, Kang, Kokong and to the east of the Ghanzi road, some 50 to 100 kilometres to the east of the Project area).

Boritse Formation

The overlying Boritse Formation, comprised of coals and carbonaceous shales, with limited fine to coarse arkoses of is also thought to constitute an aquifer unit but of a lesser importance than the underlying Kweneng Formation.

The sandstone horizons of the Boritse Formation appear generally to be better cemented than those of the Kweneng Formation, and, in consequence, overall permeability is likely to be much reduced and more dependant on the degree of fracturing present. The presence of numerous of argillaceous horizons will cause the aquifer unit as a whole to have a multilayered nature. Numerous boreholes penetrate the Formation together with the overlying Kwetla Formation without penetrating the base of the Formation. It is therefore considered that the limited information, concerning water levels and aquifer properties, available for the Eccca relates specifically to this Formation and the overlying Kwetla Formation.

Kwetla Formation

The thick sequence of well cemented siltstones with occasional fine sandstones may provide minor aquifer horizons, but the Formation as a whole, is unlikely to possess great aquifer potential. Boreholes thought to penetrate the Kwetla commonly have low yields or are effectively dry.

Aquifer Properties of the Eccca Group

Piezometric levels for the Eccca in the central part of the area are relatively shallow, generally less than 30 metres, with water strikes also being relatively shallow at less than 50 metres. Elsewhere water levels are generally in excess of 80 m below surface (Map 4). In some areas, for example to the NE of Tshane, water levels in boreholes of similar depth often have similar water levels although it is not possible to discern any particular piezometric level gradient direction from the data available.

Very little reliable aquifer test data is available for the Eccca within the Project area. That which is available is thought only to relate to the Kweneng and Boritse Formations. Transmissivity and specific capacity values, from analyses of aquifer test data for three boreholes, (5448, 6481 and 5968). (Geoflux, 1994). It should be noted that there is some doubt whether the main aquifer in 5448 at Lokgwabe is in fact Eccca or Kalahari. On balance however the Eccca seems more probable. An examination of the data plots provided by Geoflux indicates that the discharge rates, for boreholes 5448 and 6481, were stable throughout the test period and that the analysis methods were appropriate. Transmissivity values obtained from these two tests were about 1 m²/d. Much higher values of about 20 m²/d were obtained from the third data set for borehole 5968 at Lehututu. However an examination of this data indicates that the discharge rate was unstable and the transmissivity values obtained from the analysis are of doubtful accuracy. Transmissivity values may, in any case, be expected to vary markedly between different aquifer horizons within this upper section of the Eccca.

Groundwater Chemistry of the Eccca Group

Variation of pH, conductivity and alkalinity across the Project area have been assessed. The frequency distribution of conductivity, measured at the wellhead, for Karoo and Kalahari water samples is shown in Table 7. Although some samples have low conductivities, a relatively large proportion are classified as very

saline or brine. In addition many more boreholes, for which no conductivity values are available, were noted as being saline or very saline by drillers on the Borehole Completion Certificate. Most of these boreholes were abandoned never having been equipped. Conductivities for Ecca water samples together with those for Kalahari samples are shown on Map 3.

		Kalahari	Ecca
Fresh	<1400 μ S	22	8
Brackish	1400-4000 μ S	8	3
Mod Saline	4000-14000 μ S	0	3
Very Saline	14000-40000 μ S	4	7
Brine	>40000 μ S	0	3

TABLE 7 Frequency Distribution of Conductivity for Karoo and Kalahari water samples

In the central area, conductivities for the Ecca are generally similar to those in the Kalahari and the main producing Ecca aquifer horizon is relatively shallow (<60m or so). The main exception (BH 5968) has a conductivity of over 15000 μ S. This borehole originally drilled to 87 m depth was backfilled to 70 m probably indicating that saline water was encountered. This suggests the presence of saline water at depth beneath the central fresh water Ecca aquifer horizon.

The range of pH values is similar to those measured for the Kalahari, samples in general ranging from 6.87 to 8.4. The recorded alkalinity values were slightly higher than for the Kalahari samples, but most were still within the 200 to 800 mg/l (as HCO₃) range.

The similarity of water type (calcium bicarbonate) for Kalahari and Karoo groundwaters in the central area, suggests there could be hydraulic continuity between the two aquifers, resulting in recharge to the Upper Karoo via the Kalahari.

It is interesting to note a marked change in water quality between east and west Hukuntsi. Several boreholes were drilled by Water Affairs in the 1980s to the west of Hukuntsi Pan. These all proved to be saline, with recorded conductivities between 22000 and 103000 μ S. To the east of the pan, conductivities are less than 2000 μ S. The boreholes also differ from those to the east of the pan, in that the main producing aquifer was much deeper (boreholes 4433, 4398 and 4267 had main water strikes at 74, 89

and 100m respectively), compared to east of the pan where major water strikes were generally less than 50m. The marked difference in conductivity values and water strike depths between the two groups of boreholes suggests the presence of a major structural feature, possibly a fault.

Although not generally considered potable, water of usable quality extends from the central area to the ENE, roughly along the line of the main road to Kang. This lower conductivity "corridor" appears to be relatively narrow, with significantly higher conductivities recorded at boreholes located to the north and south. The extent of the "corridor" towards Kang can only be guessed at. Conductivity at Borehole 4251 (Map 3) was less than $6000\mu\text{S}$, whilst drillers records indicate boreholes on Lothlake Pan were saline. BH 3969 (approximately 5km east of Lothlake Pan, and 40km west of Kang) is, however, of usable quality, (although recorded by the drillers as being saline), as it is used for livestock watering. Fresh water boreholes are again encountered at Kang.

Apart from a relatively limited number of boreholes penetrating the Ecça in the central and eastern part of the Project area, most other Ecça boreholes in the Project area are dry or excessively saline. Many of these boreholes penetrate to depths ranging between 200 and 400m, the greatest depths tending to be in the west. Despite this, rumours of fresh water existing at depth in the Ecça persist. This belief seems to have been reinforced by water dowers, despite their very poor success rate.

Bath (1980), using ^{14}C data obtained from the Ecça in the Ncojane area, suggested that, under certain conditions, low salinity may persist in Ecça waters of considerable age. In 1989 Petro-Canada drilled three water supply boreholes near Masetleng Pan some 88km NW of Hukuntsi (Figure 7). One of these boreholes struck useable quantities of fresh water at 408m in black, sandy, shales most probably of the Boritsi Formation. Encouraged by this result, the Department of Water Affairs undertook the drilling of 6 deep boreholes under the Consolidated Emergency Programme in 1989/90, in the villages of Monong (BH 6339), Make (BH 6588), Tshane (BH 6160), Ncaang (BH 6161), Ukwi (BH 6629), and Zutshwa (BH 6589) (Geotechnical Consulting Services, 1991). The latter three sites are outside the project area but the results are of interest, as a guide to the prospect of obtaining deep potable water.

It is interesting to note that the original Petro-Canada borehole drilled at Masetleng Pan, although initially fresh, is rumoured to

have become increasingly saline with use over a relatively short period of time (*Pers. Comm. L. Heiden*).

Ncaang borehole (total depth (TD) 336m) was saline (total dissolved solids (TDS) 10 000mg/l) whilst that at Zutshwa (TD 432m) was very low yielding and saline (TDS 55, 554 mg/l). The Tshane borehole (TD 420m) had an initial TDS of only 8400 mg/l, but this increased during 4.5 hours of borehole development to 18 034 mg/l. An initial TDS of 4100 mg/l, was recorded for the Make borehole (TD 370 m) but again this increased to 10,500 mg/l over a 12 hour period of air lift development. Monong (TD 390m) had an initial TDS of 2200 mg/l, but this again increased to a laboratory measured value of 25 550 mg/l during 9 hours of air flushing.

The Ukwi borehole (TD 212 m) appears to have been initially more successful in providing usable water having a reported TDS of 1411 mg/l on completion. The borehole would appear to have later become saline, as the Kgalagadi District Development Plan 1989-1995 (Kgalagadi District Council, 1989) records that a desalination system had been installed at the village.

It was claimed that all boreholes penetrated the Kweneng Formation (Geotechnical Consulting Services, 1991), but the reported lithologies make it unlikely that the boreholes actually passed the base of the overlying Boritsi Formation.

From the above, and other data available for the project area, it would appear that the quality of the water in the Ecca formations penetrated by boreholes to date is, with the exception of the central and narrow eastern zone, fairly uniformly saline. There is, however, no substantial evidence to suggest that any of these water boreholes did, in fact, penetrate the Kweneng Formation.

10.3.5 Lebung Group

Mosolotsane Formation

An examination of the records of boreholes which penetrated red clay strata, thought to represent the Mosolotsane Formation, indicate that these strata are generally dry. At only two locations, were water strikes recorded in these red clays. In both cases yields were extremely low and the water quality highly saline. At a third location fresh water was struck in a sandstone horizon at 110 m bgl, sandwiched between red clays above and red shales below. The yield was again very low, (0.8 m³/hr). Drilling continued to a second water strike at 125 metre which yielded 1.5 m³/hr of highly

saline water. In consequence the Mosolotsane Formation is not considered to constitute an aquifer within the Project area.

Ntane Sandstone

The Natane Sandstone, forms a major aquifer over considerable areas of Botswana and was originally considered to be a major potential drilling target within the Project Area. The sandstone has however only been definitely identified in the two Kalahari Project boreholes CKP-8A and CKP-8C (Meixner and Peart, 1984). Even in these two boreholes Ntane Sandstone thicknesses were limited and it is highly probable that, due to their elevated position in the stratigraphic column, they were unsaturated. It is therefore improbable that the Ntane does in fact form an aquifer of any major importance within the Matsheng Project Area. There is a slight possibility that the Formation forms an aquifer unit in the extreme south east, particularly if grabben structures are present, but again this seems unlikely.

10.3.6 Kalahari Sequence

The Kalahari shallow fresh water aquifer is restricted to the central village quadrangle area (Lokgwabe/Hukuntsi/Lehututu/Tshane villages). The aquifer constitutes that largest known fresh water groundwater resource in the Matsheng area and in consequence represents an important target for groundwater exploration. The aquifer would appear to be unconfined.

Drillers logs for the central area, show the aquifer lithology to be quite variable, in some localities consisting of cretes and calcareous sandstones, in others, loosely consolidated sands. The upper unconsolidated brown aeolean sands do not however seem to form part of the aquifer horizon at any location. The rapid lateral and vertical lithological variation of the aquifer is illustrated in Figure 14, a cross section through five boreholes located in a line, (at about 400 m intervals), along the main road to the south of Lehututu. It may be noted, that despite the reported lithological variations, the water strikes are at very similar depths and the water table gradient is gentle and south trending.

Within the central area boreholes and wells penetrating the Kalahari shallow aquifer are clustered in groups in and around the four main villages. In consequence virtually no information is available between the villages or immediately outside the quadrangle formed by the villages. It is therefore not possible to define the lateral continuity of the Kalahari aquifer and hence

extends between the villages or if the fresh water aquifer is patchy being limited to a small area around the main pans.

Outside of the central zone most boreholes penetrate through the Kalahari into the underlying strata without recording a water strike, indicating that the Kalahari is predominantly dry. Wells constructed on the margins of pans outside the central area are almost invariably saline. The base of the aquifer is almost invariably formed by an aquiclude consisting of argillaceous material. This horizon is variously reported by drillers to consist of clays (often red brown in colour, mudstones or shales. As discussed in 8.2.5 it is uncertain whether this horizon is in fact basal Kalahari, Mosolotsane or Kwetla Formations. These basal "clays" occasionally show variations in level over very short distances, suggesting a buried Karoo topography. Such a feature is probably present at the southern end of the cross section (Figure 14).

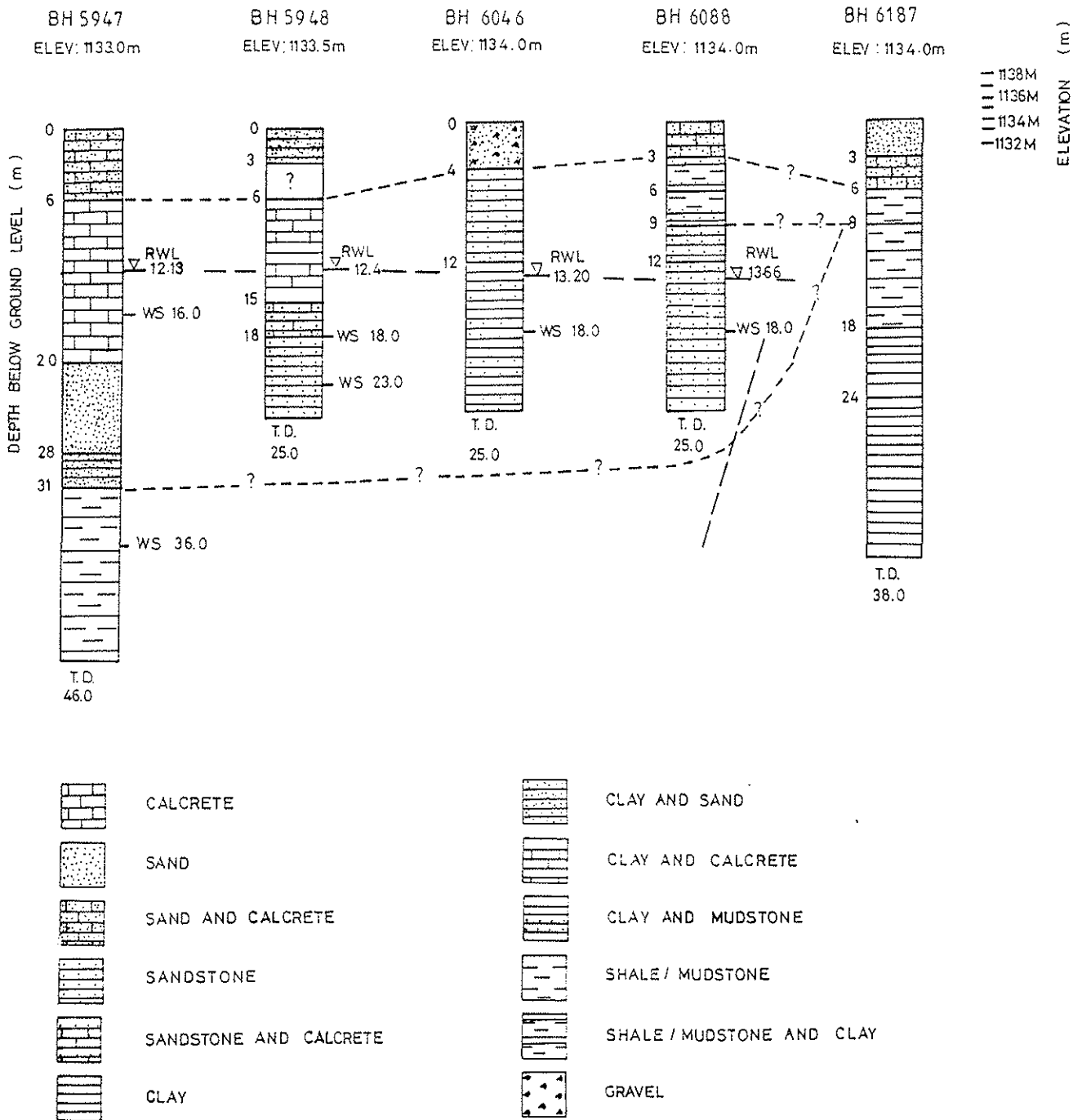


Figure 14 Cross section through boreholes penetrating the Kalahari to the south of Lehututu

Aquifer Properties

Rest water levels for the Kalahari aquifer are shallow generally ranging from 10 to 20 m below surface. Rest water elevations are available for many of the boreholes and some wells in the central part of the area but the densely clustered nature of the data points precludes the construction of water table contours. A general south eastward trend in water table gradient (about 1123 MOD at Pepane Pan, about 1120 MOD at Lehututu, 1115 MOD at Hukuntsi, 1105 MOD at Tshane and 1100 MOD at Lokgwabe), can however be discerned.

An examination of drilling records show that water strike depths are also shallow commonly within 3 m of the final rest water level, perhaps suggesting a very slight degree of confinement in some localities. Saturated aquifer thicknesses are commonly of the order of only 10 to 20 m in the central area.

Borehole yields bear little relationship to borehole diameters. Yields are generally low ranging up to about 6 m³/hr. Although higher yields have been recorded, others are so low as to be effectively unusable.

A summary of aquifer test results analysed by Geoflux (1994) is provided in Table 8. In general transmissivity values vary between 5 to 20 m²/hr, the only higher values being obtained from the test data for borehole 5947 at Lehututu. The values obtained from this test are however considered unreliable since the discharge rate was not constant. Analysis of data for borehole 6482 at Tshane provided such lower values. It is interesting to note that both the drawdown and recovery data in this case gave consistently low values, despite the fact that the pumping water level reached to the pump suction. The variation in transmissivity values is probably a reflection of lithological variations of the Kalahari aquifers combined with the often limited saturated thickness.

BH No.	Locality	Depth (m)	Water strike (m)	SWL (m)	Discharge (m ³ /hr)	Drawdown (m)	T-Value		Comment
							Pumping	Recovery	
6484	Tshane	22	11.0	10.24	6.0	4.74	15.5	7.32	Constant Q-good test
6482	Tshane	66	21.0	12.57	3.0	sunction 37.62	0.66	0.55	Dewatered aquifer pumped to sunction
6046	Lehututu	25	18.0	13.34	1.05	0.97	10.5 32.9	8.0	Constant Q
5948	Lehututu	25	18.0/ 22.0	12.14	1.30	0.59	22	15.4	Yield decreased data not good
6088	Lehututu	25	18.0	13.40	4.03	5.82	5.9 7.7	5.4	Pumping data plot not good. Recovery okay
5947	Lehututu	42	16.0/ 36.0	12.60	6.70	1.08	86.5?	116.3?	Yield decreased

TABLE 8 A Summary of Aquifer Test Results from Kalahari Boreholes (after Geoflux, 1994)

Groundwater Chemistry

Virtually all of the water samples obtained from wells and boreholes penetrating the Kalahari aquifer were from within the central village area. The only two exceptions were Ohe Pan (WCS 69) and BH 5128 at Zutswa (WCS 46).

Water quality of the Kalahari aquifer is generally potable. Of the 34 samples for which wellhead analyses are available, only four showed conductivities greater than 3500 μ S. Within the central area, water abstracted at Tshane and Lokgwabe villages has particularly low conductivity (< 1000 μ S), although none of the samples from the villages exceeded 3500 μ S. The anomalous samples mentioned above all have conductivities in excess of 14000 μ S (samples WCS46, WCS69, WCS94, and WCS80). (It is notable that these four sample points are all on non-vegetated pans outside the central area).

The frequency distribution of conductivity for both Kalahari and Karoo samples is given in Table 7. The high number of "fresh" samples from the Kalahari aquifer is immediately obvious. None

of the samples fall into the "moderately saline" or "brine" category, although the four samples mentioned above are classified "very saline".

The majority of pH values are in the range 6.91 to 8.1, with only two being greater than 9 (WCS46 and WCS80). Again the majority of alkalinity values were within a fairly narrow range (48 to 462 mg/l HCO₃), with only three samples (WCS94, WCS80, and WCS120) greater than 1000 mg/l as HCO₃. Fresh waters are predominantly of calcium bicarbonate type.

11 A CONCEPTUAL HYDROGEOLOGICAL MODEL

11.1 General

A diagrammatic representation of a conceptual model of the hydrogeology of the Matsheng area is presented in Figure 15. The model, which has been formulated gradually, as data has been collected and assessed, attempts to take account of all hydrogeological information currently available. Some aspects of the model are admittedly rather conjectural, given the sparsity of data in some areas. Even in this respect, the model is of value, as it serves to highlight aspects that need to be resolved during the drilling programme. Some relatively minor features, (such as calcrete ridges), have been omitted from the representation rather than make the model over complex.

It should be stressed that the conceptual model of the hydrogeology is only a first step and incorporates many assumptions which are based on occasionally sparse, and in some cases possibly inaccurate, information. The model will undoubtedly change and evolve further in response to additional data, obtained during the remainder of the project programme, particularly the results obtained from geophysics surveys, drilling and aquifer testing programmes.

11.2 The Aquifer Units

The Shallow Kalahari Aquifer

The aquifer lithology is, from available evidence, very variable ranging from cretes to slightly cemented sands and sandstones. To simplify the diagram these strata are represented almost solely by calcretes.

The basal aquiclude of the Kalahari aquifer is formed by red brown clays, (assumed possibly to be Mosolotsane Formation), over at least part of the area. Elsewhere the base is also formed by clays or shales but, from the available information, it is not possible to determine if these are Kalahari or Ecca. On balance it seems more probable that these clays and shales are Ecca. The "topographic" Ecca high, shown in the model is an attempt to portray the situation to the south of Lehututu where the Kalahari aquifer is effectively truncated by such a feature. It is however probable that the feature may be of very localised lateral extent and may not have a major effect on the lateral continuity of the Kalahari aquifer. Due to the clustering of borehole data in the four village locations and almost complete absence of information for areas in between, it has not been possible to determine the lateral continuity of the shallow Kalahari fresh water aquifer in the central part of the project area. No attempt has been

made to show this uncertainty on the diagram but the situation will need to be resolved early in the next phase of the project. In some areas, particularly the north, the Kalahari appears to be completely dry, whilst in many southern and western areas the only groundwater encountered is highly saline. These conditions have also been included in the conceptual model.

The Mosolotsane Formation has been included in the model since although it is commonly dry, limited amounts of fresh or saline water have occasionally been obtained from it. It should however be recognised that these deposits may in fact represent basal Kalahari clays or possibly Kwetla Formation, a matter which hopefully can be resolved during future investigations. The Ntane Sandstone has not been included in the model since as indicated in 10.3.5, it is considered unlikely that these strata form an aquifer unit within the Project area. There is a slight possibility that the Ntane Sandstone could form an aquifer in the extreme southeast and, if this proves to be the case on further investigation, the initial conceptual model will need to be modified accordingly.

Only the upper part of the Karoo strata have been portrayed, as the Bori Formation and Dukwe Group are not thought to constitute significant aquifers in the Matsheng Area. The Ecca multilayered aquifer has been very much simplified in the diagrammatic model. An upper Ecca fresh water aquifer has been included, with recharge occurring through a "window" in the basal Kalahari aquiclude. This aquifer horizon is however considered to be of limited extent. Aquifer horizons lower in the Kwetla and Boritse Formations are likely to be of limited thickness and according to available evidence largely saline. A possible mechanism to account for the presence of brackish groundwater has been included.

The Kweneng Formation has also been portrayed but the aquifer characteristics and groundwater quality of these strata are almost totally unknown. It is probable that high yields may be available from the Kweneng but, in view of the remoteness of the area from any potential recharge zone, groundwater is likely to be "fossil" and possibly of poor quality. The situation is however highly uncertain and needs to be properly resolved by exploratory drilling.

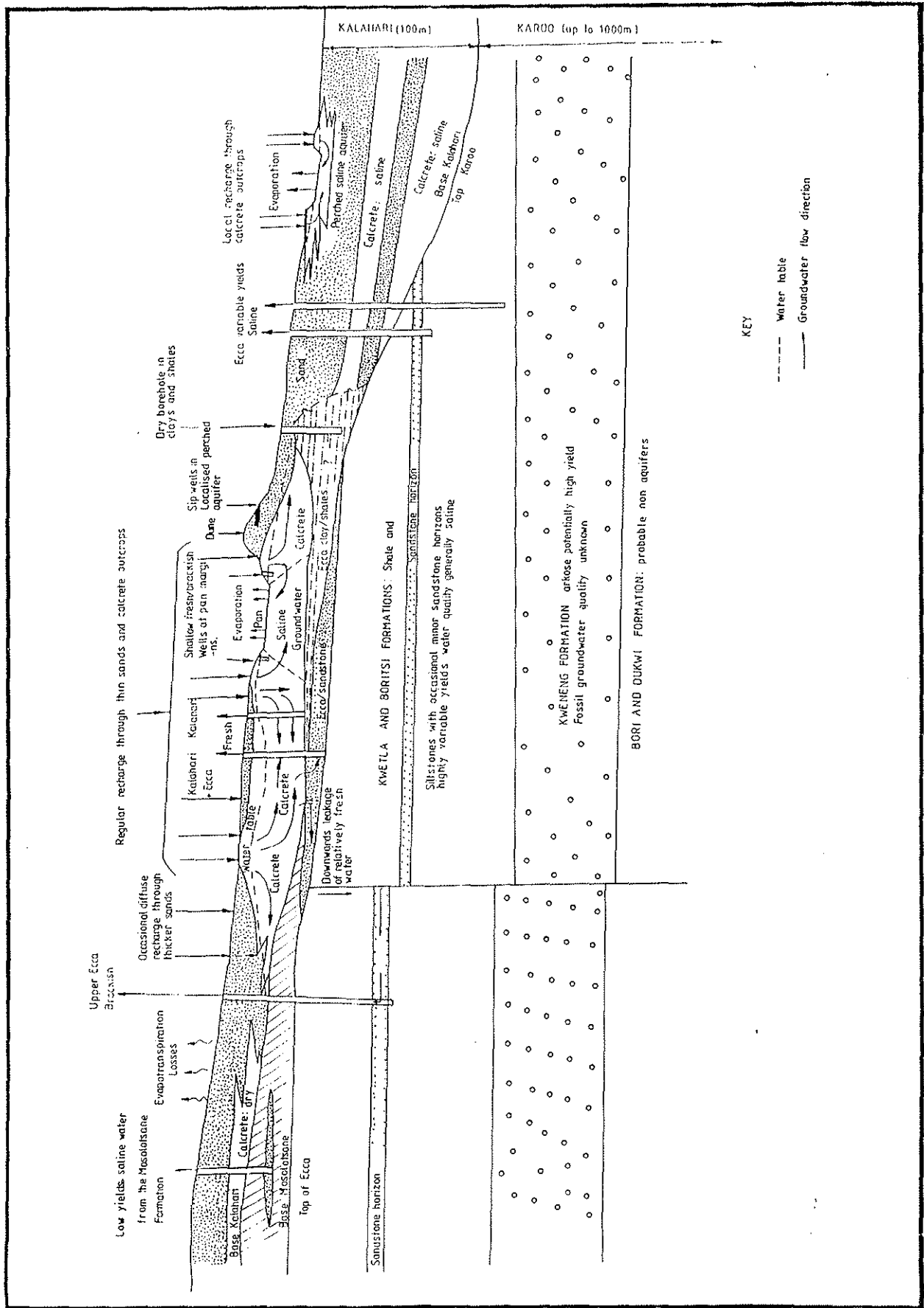


Figure 15 A Conceptual Hydrogeological Model

11.3 Recharge

Recharge has been assumed to occur only through calcrete outcrops and relatively thin Kalahari sand deposits. In the absence of any Karoo outcrop or near surface subcrop it has been assumed that recharge to the fresh water Ecca aquifer horizon in the centre of the area, is entirely via the overlying Kalahari. This assumption would seem reasonable in view of the similarity of rest water levels and groundwater chemistry (10.3.4). There is no evidence currently available to suggest that any inflow of groundwater occurs from outside the project area. Groundwater movement in the shallow Kalahari aquifer is thought to be from potential recharge zones down gradient towards the south east. Water levels near pans are lower than groundwater levels in the general vicinity, indicating that pans form points of discharge. Although there are currently no surface phenomenon associated with this groundwater discharge, it may occur by evaporation through the pan surface, thereby causing high salinity levels beneath the pan. During wetter periods in the past, when the water table have been higher, there may have been springs and seeps at the pan margins, such as tradition says existed at the margin of Tshane Pan near the Police Station.

12. FIELD INVESTIGATION PHASE

The Field Investigation Phase is the second phase of the programme and will constitute the bulk of the project activity. Work includes the examination of hydrogeologically significant features by ground geophysical surveys, investigation of such features by exploratory drilling, and subsequent evaluation of aquifer potential by controlled testing. Such work, together with a number of subsidiary but contributory activities such as hydrochemical analyses and recharge studies should then provide adequate and reliable information with which to develop and refine the conceptual model. The data may also permit the development of numerical aquifer models for the shallow aquifers, from which a groundwater resources assessment can be derived.

In order to allow flexibility and to optimise the use of contract drilling facilities, geophysical survey work should not be restricted only to the very early stages of the Field Investigation Phase. Geophysical input will be programmed during the later part of the drilling programme to redirect the programme on the basis of earlier results if so required. The employment of additional geophysics would clearly be in very close consultation with the Client and as such would also serve to crystalize ideas as to how future contract works should proceed. The programming of this geophysics could most effectively be discussed at the time of the submission of the Mid Project Review Report, due for submission during Month 8 of the programme.

12.1 Geophysics and Exploratory Drilling

The detailed assessment of all available hydrogeological and hydrochemical data for the Project area and formulation of a very basic conceptual model, as required in the ToR and RTP, has served to highlight a number of areas for which relevant data is not available. These area need to be addressed as a matter of priority, early in the Field Investigation Phase.

12.1.1 Karoo Aquifer Units

As outlined in 10.3.4 the presence of the Kweneng Formation, a potentially high yielding aquifer, unit, has only been proven in stratigraphic boreholes. No information is available from these boreholes regarding aquifer properties or water quality for the Formation. The overlying Boritse and Kwetla Formations can be shown to generally only contain limited quantities of saline water and the Lower Karoo strata are not likely to form aquifers. The Kweneng Formation therefore represents the only potential aquifer unit widely distributed across the Project area which may be capable of providing usable groundwater. It is therefore essential that the Formation be investigated by means of drilling deep

exploratory boreholes. Provision was made for the drilling of deep boreholes in the ToR and RTP. Apart from providing essential hydrogeological data, the boreholes will greatly extend knowledge of the overall stratigraphy of the area. These boreholes will be sited following detailed discussions with the Client and taking regard of all relevant information, particularly the findings of the Regional Geophysical Interpretation (9.1) It is considered unlikely that extensive geophysics will be required to carry out the siting, unless it is necessary to determine the presence of any linear features (faults or dykes) near the site.

12.1.2 Kalahari Aquifer

Virtually all of the hydrogeological data for the shallow Kalahari is concentrated around the four villages, with little or no data available elsewhere. In consequence the presence of the aquifer close to the four pans is well documented but considerable uncertainty remains regarding the lateral extent of the aquifer between or surrounding these localities. Definition of the spacial distribution is essential before any resource evaluation of the Kalahari aquifer can be carried out. It is therefore recommended that the required geophysical surveys (specified in 9.2.4) and conjunctive exploratory drilling be carried out as a matter of priority at the beginning of the Field Investigation.

The Revised Technical and Financial Proposals envisaged that geophysical inputs to the exploratory drilling programme for the shallow aquifer would be on a site specific basis. The recommended reorientation of geophysical surveys would require use of techniques identified as being appropriate during the calibration survey (9.2.1), to carry out traverses across the central area, where there is a potential shallow aquifer. Possible financial implications attendant upon this reorientation of geophysical activities will be discussed in detail with the Client before operations proceed.

It is not anticipated that this reorientation of geophysical activities, to carry out traverses, will have any substantial effect on the exploratory drilling programme since the surveys can still be utilised to site exploratory boreholes to investigate the shallow aquifer. The recommendations contained in 9.2.3 and 9.2.4 regarding the drilling of exploratory boreholes to investigate particular features found during the calibration survey and to provide data to further confirm the geophysical model, is considered entirely consistent with the objectives contained in the ToR and RTP. Neither is it anticipated that this reorientation of activities would in any way

detract from the other objectives specified for the exploratory drilling, namely the assessment of aquifer properties through the gathering of lithological and basic hydrogeological data together with that from aquifer testing.

It is also recommended that some investigation be carried out at locations with a potential for shallow groundwater, as indicated by the Botanical Survey. In this context, the area located in the extreme south east of the Project area is of particular interest, as shallow groundwater at this location could be associated with the Ntane Sandstone rather than the Kalahari Sequence.

12.2 Drilling and Aquifer Testing Operations

It is anticipated that the supervision of the drilling and aquifer testing by the Consultant will proceed as specified in the ToR and RTP.

A questionnaire based on the Uniform Rates Agreement was circulated to all Tender Board registered drilling and test pumping contractors early in Month 4 (September), with a deadline for provision of the required information at the end of the same month. Following a detailed assessment of the data received and discussion with the Client, it is anticipated that the Pre Mobilisation Meeting will be held with the selected drilling contractor within the first week or so of Month 5 (October). Mobilisation and commencement of exploratory drilling operations should then occur in the middle of the month as specified in the RTP.

REFERENCES

- | | | |
|----------------------------------|---------|--|
| Bhalotra Y.P.R. | 1987(a) | Climate of Botswana, Part II: Elements of climate: 1 Rainfall. Dept. of Meteorological Services, Gaborone. |
| Bhalotra Y.P.R. | 1987(b) | Climate of Botswana, Part II Elements of climate: 2 Sunshine and Solar Radiation and Evaporation Dept of Meteorological Services, Gaborone. |
| Bhalotra Y.P.R. | 1987(c) | Climate of Botswana. Part II Elements of Climate: 4. Surface winds and atmospheric pressure. Dept Meteorological Services, Gaborone. |
| Boocock and Van Stratten | 1962 | A note on the development of potable water supplies at depth in the central Kalahari. Internal Report, Department of Geological Survey. |
| Central Statistics Office | 1992 | Population of towns, villages and associated localities in Central Statistics Office, August 1991, Gaborone. |
| Compagnie General de Geophysique | 1988 | Report on the interpretation of geophysical surveys in western Botswana. Nosop/Ncojane Basins. Report for Department of Geological Survey. |
| Geoflux (Pty) Ltd | 1994 | Integrated rural village water supply programme, siting of boreholes and supervision of drilling, construction and pump test works in Hukuntsi, Lehututu and Tshane. Inception Report for Department of Water Affairs, |

		Ministry of Mineral Resources and Water Affairs.
Geotechnical Consulting Services	1991	Supervision of drilling and construction of boreholes in Monong, Make, Zutshwa, Tshane, Ncaang and Ukwi villages of Kgalagadi District. Final Report for Department of Water Affairs, Ministry of Mineral Resources and Water Affairs.
Jessen, N and Bujak Davies Group	1988	Lithologic descriptions and palynological dating of surface samples from the Ncojane-Nosop Basin, Botswana Petro-Canada International Assistance Corporation report for DGS.
Kgalagadi District Council	1989	Kgalagadi District Development Plan 1989-1995. Kgalagadi District Council, Tsabong.
Kgalagadi DLUPU	1991	Kgalagadi Land use Plan, Kgalagadi District Council, Tsabong.
Leridon J and Ardrieux P.	1988	Report on the interpretation of geophysical surveys in western Botswana Nosop/Ncojane Basins Compagnie General de Geophysique report for DGS.
Meixner, N.M. and Peart, R.J.	1984	The Kalahari Drilling Project Bill. Geol. Surv. Botswana 27. Department of Geological Survey.
Peart and Bruns S.	1982	A Hydrogeophysical Survey to locate promising sites for shallow wells in the vicinity of Hukuntsi, Kgalagadi District. DGS Report No RSP/18/82. Department of Geological Survey.

Reeves, C.V.	1978	Reconnaissance Aeromagnetic Survey of Botswana 1975-77, Final Interpretation Report. Geol. Surv. Botswana.
Reeves, C.V.	1979	The reconnaissance aeromagnetic survey of Botswana its contribution to the geology of the Kalahari in Bull. Geol. Surv. Botswana 22.
Reeves, C.V. and Hutchins, D.G.	1976	The National Gravity Survey of Botswana 1972-3. Bull. Geol. Surv. Botswana 5.
Roy K.K. and Elliot H.M.	1980	Resistivity IP Survey for delineating saline water and fresh water zones. Geoexploration 18, P145-162.
Smith, R.A.	1984	The lithostratigraphy of the Karoo Supergroup in Botswana. Bull. Geol. Surv. Botswana 26.
Stoakes F.A. and McMaster D.W.	1990	Final Technical Report Botswana Project: Interpretation of the results of stratigraphic well Mabeltheng Pan-1 in the Nosop-Ncojane Basin of Southwest Botswana. Petro-Canada International Assistance Corporation report for DGS.
Tshimako, B.	1991	The Tribal Grazing Land Policy (TGLP) Ranches Performance to Date. MOA, Botswana.
Van der Mass, H.A	1993	Kgalagadi District CFDA: Matsheng Villages. Socio-economic and Biophysical baseline survey. Division of Applied Research, Planning and Statistics, MLGLH, Botswana.

Wasilenkoff J.M.	1988	Exploration results of the Kalahari Geophysical Project 1987-1988, Botswana, Africa Petro-Canada International Assistance Corporation report for DGS.
Wellfield Consulting Services	1985	Report on Borehole Siting in 9 villages. Report for Department of Water Affairs.
Wellfield Consulting Services	1994	Matsheng Area Groundwater Investigation: Inception Report. Report for Department of Geological Survey.
Wellfield Consulting Services	1994	Transkalahari Road Groundwater Investigation Project: Final Report. Prepared for Department of Water Affairs.
Wellfield Consulting Services	in prep.	Matsheng Area Groundwater Investigation: Regional Aeromagnetic and gravity interpretation. Technical Report T6, for Department of Geological Survey.
Wellfield Consulting Services	in prep.	Matsheng Area Groundwater Investigation: interpretation of satellite imagery and photomosaics. Technical Report T2, for Department of Geological Survey.

APPENDIX 1

Ground Control Points

Ground Control Points: Matsheng Area

No	LOCATION	SITE DESCRIPTION
1	LEHUTUTU PAN	NE corner of pan near wells
1B	LEHUTUTU PAN	NE tip of spit in pan
2	LEHUTUTU-KANG/TSHANE X-RDS	Jctn of Lehututu & old Tshane/Kang roads
3	TSHAWE PAN	Northern tip of pan, near roads camp
4	KANGNYANE PAN	Point nearest pan on old Kang road
5	TSATSONYA PAN	To east of Tshawaane Pan
6	LEHUTUTU VILLAGE	Cross roads at centre
7	PEPANE PAN	At point LEHUTUTU-MAKE rd enters pan
8	MAKANE PAN	On RHS road at point closest to pan
8A	TSHOTSWA PAN	At point where road enters from south
9	MAKE PAN	At point where road enters from south
10	MONONG PAN	At point where NE/SW cutline crosses NE margin
11	MONONG PAN	Western point on pan
12	HUKUNTSI VILLAGE	Cross roads at centre
13	MONONG PAN	Where NE/SW cutline crosses SW margin
14	SW OF MONONG PAN	Intersec NE/SW cutline passing thru pan with N/S cutline cutting Bohelabatho Pan
15	SE OF LOKGWABE	Junction road from LOKGWABE with TSHANE/TSABONG road
16	TSHANE TO TSABONG ROAD	Junction between road and E/W cutline
17	TSHANE VILLAGE	LOKGWABE/HUKUNTSI/TSABONG cross roads
18	MATSHANENG PAN	Northern edge, where road enters from north
19	GAI PAN	Northern point of pan
20	MAHUDITLHAKE PAN	Where road from GAI PAN enters pan
21A	KAKWE PAN	Where road crosses western edge
21B	KAKWE PAN	Where road crosses eastern edge
22	NGWABORWA PAN	Upper centre point on pan margin
23	MASAGENG PAN	Where MONONG/HUKUNTSI road cuts NW pan margin
24	LOKGWABE	On road close to borehole
25	BOHELABATHO PAN	Where HUKUNTSI/NCOJANE road crosses N/S cutline
26	HUKUNTSI	North end of air strip
27	HUKUNTSI	South end of air strip

Ground Control Points: Matsheng Area

No	Lat_deg	Lat_min	Lat_sec	Long_deg	Long_min	Long_sec	UTM_N	UTM_E	Air Photo Scale	Run No	Photo No
1	23	55	34.020	21	50	40.920	7353916.10	585968.71	20000	4	50
1B	23	55	42.840	21	50	26.280	7353647.28	585553.16	20000	4	50
2	23	56	2.220	21	56	4.920	7352991.13	595123.18	20000	7	23
3	23	54	51.000	22	3	21.300	7355094.56	607476.50	50000	9	284
4	23	52	18.660	22	8	39.060	7359709.93	616499.40	50000	9	286
5	23	50	40.920	22	14	11.880	7362636.86	625939.75	50000	8	313
6	23	54	54.120	21	49	47.160	7355152.21	584456.05	50000	8	313
7	23	52	45.420	21	48	13.200	7359125.50	581821.86	20000	4	50
8	23	47	47.700	21	47	31.260	7368288.03	580686.86	50000	8	304
8A	23	44	45.960	21	43	47.700	7373910.92	574388.87	50000	7	87
9	23	42	29.280	21	47	31.080	7378080.39	580736.29	50000	6	132
10	23	40	20.820	21	31	42.900	7382155.14	553899.92	50000	6	132
11	23	39	38.160	21	30	51.720	7384025.82	552456.94	50000	6	3
12	23	59	54.225	21	46	48.780	7345951.59	579361.42	50000	5	214
13	23	41	8.040	21	30	42.060	7380709.31	552171.35	20000	2	81
14	23	45	17.880	21	24	54.600	7373058.38	542308.02	50000	6	3
15	24	13	9.780	21	51	11.100	7321392.55	586505.98	Unable to locate on 1:50000 photos	10	165
16	24	34	15.000	21	54	18.840	7282495.21	591666.53	50000	17	250
17	24	1	12.720	21	52	11.040	7343484.21	588452.34	50000	5	37
18	24	8	0.840	22	17	33.180	7330601.09	631341.58	20000	10	137
19	24	7	56.040	22	16	41.100	7330762.28	629872.71	50000	11	25
20	24	10	31.380	22	26	6.240	7325829.72	645777.81	To east of air photo coverage		
21A	24	1	37.320	21	56	1.140	7342686.03	594948.05	50000	10	128
21B	24	1	32.160	21	56	57.780	7342833.98	596549.20	50000	10	128
22	24	4	16.500	21	52	43.740	7337826.41	589340.88	50000	10	128
23	23	49	42.120	21	39	52.680	7364835.86	567692.71	50000	7	84
24	24	6	12.780	21	46	54.360	7334308.64	579454.35	20000	2	88
25	23	49	2.400	21	24	57.960	7366153.84	542382.88	50000	7	78
26	23	58	57.580	21	45	39.080	7347704.41	577401.39	20000	2	81
27	23	59	36.060	21	45	23.100	7346523.44	576943.46	20000	2	81

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WRPRT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
6457	587492.48	TSHANE	D.W.A.	DISTRICT COUNCIL	122.00	14.00	-9.00	-9		COMPLETION RECORDS
30	7343789.05	1	28/09/89	1	-9.00	-9.00	1.00			0
	1116.50	1		6	10.20	-9.00				1
6481	617034.68	TSHANE	D.W.A.	NGWAMOTSOKO BROTHERS	260.00	246.00	-9.00	-9	COMPLETION RECORDS	COMPLETION RECORDS
49	7328537.13	1	04/08/89	1	-9.00	252.00	17.00			86
	1140.00	1		1	85.15	-9.00				4
6482	587096.95	TSHANE	D.W.A.	DISTRICT COUNCIL	66.00	21.00	4.20	816	COMPLETION RECORDS	COMPLETION RECORDS
137	7343791.46	1	19/08/89	1	13.14	23.00	6.00			22
	1150.00	1		1	12.00	-9.00				1
6484	587687.99	TSHANE	D.W.A.	DISTRICT COUNCIL	22.00	11.00	5.80	836	COMPLETION RECORDS	COMPLETION RECORDS
136	7343418.79	1	18/11/89	1	10.79	-9.00	8.00			7
	1116.50	1		1	10.00	-9.00				1
6496	587661.43	TSHANE	D.W.A.	DISTRICT COUNCIL	80.00	38.00	-9.00	-9		COMPLETION RECORDS
31	7343695.75	1	07/11/89	3	-9.00	-9.00	-9.00			17
	1150.00	1		6	34.12	-9.00				4
6498	525490.38	ZUTSWA	D.W.A.	DISTRICT COUNCIL	68.00	68.00	-9.00	-9		COMPLETION RECORDS
41	7333147.35	1	28/02/90	3	-9.00	-9.00	1.00			23
	1150.00	1		6	63.00	-9.00				1
6589	529213.35	ZUTSWA	TGB (DWA?)	DISTRICT COUNCIL	432.00	-9.00	-9.00	-9		COMPLETION RECORDS
111	7331571.82	1	/ /	3	-9.00	-9.00	-9.00			0
	1155.00	1		6	-9.00	-9.00				

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
5128	525684.26	ZUTSWA	D.W.A?	DISTRICT COUNCIL	21.00	4.00	-9.00	19999		
46	7331086.58	1	/ /	1	-9.00	10.00	8.00			21
	1140.00	1		2	-9.00	15.00				1
5127	525033.91	ZUTSWA	D.W.A.	DISTRICT COUNCIL	23.00	18.00	-9.00	-9	COMPLETION RECORDS	COMPLETION RECORDS
42	7330411.17	1	15/01/86	4	-9.00	-9.00	-9.00		CHEMISTRY DATABASE	23
	1150.00	1		6	14.68	-9.00				1
5282	579143.16	HUKUNTSI	D.W.A.	DISTRICT COUNCIL	106.00	-9.00	-9.00	-9		COMPLETION RECORDS
2	7346236.51	1	21/08/90	4	-9.00	-9.00	-9.00			53
	1150.00	1		6	-9.00	-9.00				
6559	529491.46	ZUTSWA	D.W.A.	DISTRICT COUNCIL	-9.00	-9.00	-9.00	-9		
110	7329572.31	1	/ /	3	-9.00	-9.00	-9.00			0
	1155.00	1		6	-9.00	-9.00				
T951	525005.20	ZUTSWA	D.W.A.?	DISTRICT COUNCIL	0.00	0.00	0.00	0		
40	7330134.45	1	/ /	1	0.00	0.00	0.00			0
	1150.00	1		3	0.00	0.00				
T954	550532.09	MONONG	D.W.A.?	DISTRICT COUNCIL	0.00	0.00	0.00	0		
73	7382192.45	1	01/01/94	3	0.00	0.00	0.00			0
	1100.00	1		6	0.00	0.00				
T952	527950.79	ZUTSWA	D.W.A.	DISTRICT COUNCIL	0.00	0.00	0.00	0		
57	7335449.19	1	/ /	3	0.00	0.00	0.00			0
	1155.00	1		6	0.00	0.00				

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
25316	557934.05	HUKUNTSI	BB MOAPARE DR	ITEKENG SYNDICATE (M. MAUTL	147.00	-9.00	-9.00	-9		
97	7321304.33	1	25/06/85	4	-9.00	-9.00	-9.00			0
	1111.00	1		6	-9.00	-9.00				4
25338	539226.95	ZUTSWE	MOAPARE DRILL	BOIPOPO SYNDICATE	152.00	-9.00	-9.00	-9		
160	7329179.76	1	21/08/85	3	-9.00	-9.00	-9.00			0
	1053.00	1		6	-9.00	-9.00				
25596	588337.20	TSHANE	JADA (LOBATSE	IPELEGENG SYNDICATE	105.00	90.00	10.80	981		
33	7343322.53	1	01/01/70	1	9.10	-9.00	-9.00			0
	1106.50	1		1	-9.00	-9.00				4
26132	580775.45	HUKUNTSI	MOAPARE'S DRI	B.B. MOAPARE	108.00	14.00	-9.00	-9		
157	7345058.72	1	28/04/89	7	-9.00	54.00	-9.00			2
	1137.00	1		6	-9.00	-9.00				5
24850	600509.46	HUKUNTSI	MOAPARE DRILL	B.B. MOAPARE	243.00	225.00	-9.00	-9		COMPLETION RECORDS
158	7322635.08	1	04/11/84	3	87.50	237.00	3.00			34
	-9.00	1		6	87.50	-9.00				4
27310	568279.10	LOKWABE	CENDEX	BOITEKO SYNDICATE	158.00	132.00	-9.00	-9		COMPLETION RECORD
92	7314030.85	1	26/08/92	3	-9.00	142.00	10.00			53
	1111.00	1		6	-9.00	-9.00				4
26543	588425.00	TSHANE		J.K. LEBURU	100.00	80.00	-9.00	-9		
36	7343814.08	1	01/01/62	8	15.10	-9.00	2.00			0
	1150.00	1		1	-9.00	-9.00				4

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
7412	526483.79	ZUTSWA	PULA GROUNDWA	DEPARTMENT OF WATER AFFAIRS	160.00	101.00	-9.00	-9		COMPLETION RECORD
45	7320905.89	1	10/09/93	1	-9.00	148.00	15.00			53
	1155.00	1		1	70.00	150.00				4
7413	526174.40	ZUTSWA	P.G.W.	D.W.A (COUNCIL?)	300.00	106.00	-9.00	-9		COMPLETION RECORD
43	7321367.77	1	25/09/93	3	-9.00	-9.00	1.00			100
	1160.00	1		6	-9.00	-9.00				4
72259	612931.19	TSHANE	CENDEX	MICHAEL PEGO	96.00	75.00	-9.00	-9		COMPLETION RECORD
64	7345025.83	1	07/08/92	4	-9.00	-9.00	9.00			32
	1140.00	1		6	72.00	-9.00				4
72258	613709.49	TSHANE	CENDEX	M. PEGO	158.00	134.00	1.10	19999		COMPLETION RECORD
63	7346957.41	1	13/08/92	1	-9.00	-9.00	7.00			53
	1107.00	1		1	74.00	-9.00				4
3741	583690.61	LEHUTUTU	DWA	DISTRICT COUNCIL	82.74	-9.00	-9.00	-9		COMPLETION RECORDS
22	7355590.91	1	05/09/81	3	-9.00	-9.00	-9.00			0
	1150.00	1		6	14.30	-9.00				3
6086	553319.94	MONONG		DISTRICT COUNCIL	-9.00	-9.00	-9.00	-9		
102	7385442.18	1	/ /	3	-9.00	-9.00	-9.00			-9
	1147.00	1		6	-9.00	-9.00				
6559	529491.46	ZUTSWA	D.W.A.	DISTRICT COUNCIL	-9.00	-9.00	-9.00	-9		
110	7329572.31	1	/ /	3	-9.00	-9.00	-9.00			0
	1155.00	1		6	-9.00	-9.00				

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_VLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_VLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
T962	579630.18	HUKUNTSI		UNKNOWN	0.00	0.00	0.00	0		
164	7347433.25	1	/ /	7	0.00	0.00	0.00			0
	1060.00	1		6	0.00	0.00				
T961	577517.42	HUKUNTSI	D.W.A?	DISTRICT COUNCIL	0.00	0.00	0.00	0		JESSEN ET AL, 1988
151	7348675.01	1	/ /	3	0.00	0.00	0.00			0
	1099.00	1			0.00	0.00				
6559	529491.46	ZUTSWA	D.W.A.	DISTRICT COUNCIL	0.00	0.00	0.00	0		
110	7329572.31	1	/ /	3	0.00	0.00	0.00			0
	1155.00	1		6	0.00	0.00				

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
7070	613160.57	LEHUTUTU	AAR WATER	DE BEERS PROSPECTING	296.00	-9.00	-9.00	-9		COMPLETION RECORD
129	7377903.35	1	19/07/91	4	91.70	-9.00	-9.00			-9
	1143.50	2		6	-9.00	-9.00				4
T953	542086.60	TSHANE	PETRO-CANADA	PETRO-CANADA	300.00	0.00	0.00	0		
58	7303861.25	1	/ /	7	0.00	0.00	0.00			0
	1025.00	2		6	0.00	0.00				
T955	567179.50	OHE	PETRO-CANADA	PETRO-CANADA	0.00	0.00	0.00	0		
89	7392642.43	1	/ /	4	0.00	0.00	0.00			0
	1222.00	2		6	0.00	0.00				
T956	576717.08	LOKGWABE	PETRO-CANADA	PETRO-CANADA	0.00	0.00	0.00	0		
93	7315556.12	1	/ /	7	0.00	0.00	0.00			0
	1160.00	2		6	0.00	0.00				
T957	598110.88	TSHANE	PETRO-CANADA	PETRO-CANADA	0.00	0.00	0.00	0		
99	7322559.60	1	/ /	7	0.00	0.00	0.00			0
	1100.00	2		6	0.00	0.00				
T958	542509.44	LOKGWABE	PETRO-CANADA	PETRO-CANADA	0.00	0.00	0.00	0		
113	7303952.24	1	/ /	4	0.00	0.00	0.00			0
	1025.00	2		6	0.00	0.00				
T959	612623.14	TSHANE	DE BEERS	DE BEERS	0.00	0.00	0.00	0		RELINQUISHMENT RPT
127	7356193.20	1	01/01/92	6	0.00	0.00	0.00			0
	0.00	2		6	0.00	0.00				

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
T960	612623.14	TSHANE	DE BEERS	DE BEERS	0.00	0.00	0.00	0		RELINQUISHMENT RPT
128	7356193.20	1	01/01/92	5	0.00	0.00	0.00			0
	0.00	2		6	0.00	0.00				
T963	516411.55			PETRO-CANADA	280.00	0.00	0.00	0		JESSEN ET AL, 1988
165	7293888.88	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T964	526103.80			PETRO-CANADA	95.00	0.00	0.00	0		JESSEN ET AL, 1988
166	7359992.87	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T965	542308.12			PETRO-CANADA	300.00	0.00	0.00	0		JESSEN ET AL, 1988
167	7373058.38	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T966	541922.77			PETRO-CANADA	195.00	0.00	0.00	0		JESSEN ET AL, 1988
168	7363215.26	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T967	541770.42			PETRO-CANADA	0.00	0.00	0.00	0		JESSEN ET AL, 1988
169	7311243.17	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T968	562909.20			PETRO-CANADA	300.00	0.00	0.00	0		JESSEN ET AL, 1988
170	7311041.79	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
T969	593503.02			PETRO-CANADA	187.00	0.00	0.00	0		JESSEN ET AL, 1988
171	7321145.15	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T970	608886.66			PETRO-CANADA	300.00	0.00	0.00	0		JESSEN ET AL, 1988
172	7326048.93	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T971	594763.73			GEOL SURVEY	795.23	0.00	0.00	0		MEIXNER ET AL, 1984
173	7319844.99	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				
T972	605243.02			GEOL SURVEY	465.13	0.00	0.00	0		MEIXNER ET AL, 1984
174	7364061.18	1	/ /		0.00	0.00	0.00			0
	0.00	2			0.00	0.00				

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
24676	618645.37	HUKUNTSI		LESEDI MOTHIBAMELE	128.00	107.00	1.80	11250		
60	7349162.75	1	08/08/83	1	-9.00	118.00	-9.00			3
	1087.00	1		1	70.00	-9.00				4
27260	584591.08	LEHUTUTU	CENDEX	K.E. NGWAMOTSOKO	60.00	24.00	-9.00	-9		COMPLETION RECORD
115	7354847.53	1	04/08/92	3	-9.00	-9.00	1.00			20
	1071.00	1		6	18.00	-9.00				1
27257	608523.69	TSHANE	CENDEX	K. LEBURU	122.00	94.00	10.80	17450		COMPLETION RECORD
65	7352595.39	1	05/08/92	1	-9.00	102.00	7.00			41
	1118.00	1		1	83.00	-9.00				4
473	588479.98	TSHANE		DISTRICT COUNCIL	108.20	24.38	1.85	1786		COMPLETION RECORDS
32	7343567.69	1	17/05/53	1	-9.00	34.75	3.00		CHEMISTRY DATABASE	0
	1114.50	1		1	22.86	-9.00				5
1521	579325.40	LOKGWABE		DISTRICT COUNCIL	33.83	22.86	-9.00	-9		COMPLETION RECORDS
66	7333256.92	1	10/06/63	7	-9.00	-9.00	2.00		CHEMISTRY DATABASE	11
	1114.50	1		6	12.19	-9.00				1
4188	615566.53	TSHANE	RIVERS DRILLI	NGWAMOTSOKO SYNDICATE	200.00	-9.00	-9.00	-9		COMPLETION RECORDS
48	7328487.62	1	01/11/82	4	-9.00	-9.00	-9.00			59
	1140.00	1		6	-9.00	-9.00				
5448	578227.43	LOKGWABE	D.W.A.	DISTRICT COUNCIL	108.00	33.00	3.60	760	COMPLETION RECORDS	COMPLETION RECORDS
39	7333816.58	1	09/08/86	1	-9.00	42.00	6.00			72
	1110.00	1		1	-9.00	-9.00				4

BH_NO	UTM_E	LOCALITY	DRILLER	OWNER	DEPTH	WSL1	MEAS_YLD	COND	PUMP_TEST	LITHOLOGY
WCS_NO	UTM_N	TYPE_WTRPT	DATE	STATUS	MEAS_RWL	WSL2	GS_YLD		CHEM	NO_SAMPLES
	ELEVATION	CATAGORY		EQUIPMENT	GS_RWL	WSL3				MAIN AQUIFER
27350	606861.93	LEHUTUTU		MARANG SYNDICATE	120.00	88.00	-9.00	2310		COMPLETION RECORD
54	7357252.10	1	25/12/92	1	-9.00	-9.00	3.00			30
	1122.50	1		1	60.00	-9.00				4
27359	567835.48	HUKUNTSI	CENDEX	BAMO SYNDICATE (MR BAUMAKE)	176.00	-9.00	-9.00	-9		COMPLETION RECORD
161	7363178.24	1	11/02/93	6	-9.00	-9.00	-9.00			58
	1100.00	1		6	-9.00	-9.00				
26809	591977.08	LEHUTUTU	VAN DYKE (CEN P. MOLOSIWA)		153.00	110.00	-9.00	-9		COMPLETION RECORD
98	7369134.07	1	08/04/91	4	85.00	125.00	3.00			0
	1196.00	1		6	105.00	-9.00				5
6630	542509.58	MONONG	TGB? VAN DYKE	DISTRICT COUNCIL	393.00	281.00	-9.00	-9		COMPLETION RECORD
75	7380034.75	1	28/12/90	3	-9.00	371.00	4.00			132
	1150.00	1		6	281.00	-9.00				4
6753	546082.45	MONONG	T.G.B.	LUTHERN WORLD FEDERATION	110.00	-9.00	-9.00	-9		COMPLETION RECORD
104	7372489.69	1	22/09/90	5	-9.00	-9.00	-9.00			74
	1208.00	1		6	-9.00	-9.00				
6754	547330.75	MONONG	T.G.B	LUTHERN WORLD FEDERATION	300.00	125.00	-9.00	-9		COMPLETION RECORD
105	7373346.72	1	25/09/90	3	-9.00	-9.00	10.00			100
	1208.00	1		6	-9.00	-9.00				4
3835	562928.91	OHE	D.W.A.	DISTRICT COUNCIL	280.00	170.00	-9.00	-9		COMPLETION RECORD
132	7399580.50	1	30/05/82	6	-9.00	228.00	-9.00			73
	-9.00	1		6	-9.00	-9.00				4

APPENDIX 3

Well Inventory

Explanation of Well Inventory

WCS_No WCS site number
 WCS numbers greater than 500 denote Knight-Pieshold wells that were not located in the field

KP_No Knight-Pieshold reference number

UTM_E UTM easting

UTM_N UTM northing

ELEVATION Elevation (m AOD)

TYPE_WTRPT	2	Dam
	3	Haffir dam
	4	Hand dug well
	5	Sip well

STATUS	1	Equipped
	2	Not equipped
	3	Sealed
	4	Abandoned
	5	Dry
	6	Collapsed
	7	Filled
	8	Other

EQUIPMENT	1	Diesel engine
	2	Windmill
	3	Hand
	4	Solar
	5	Draught
	6	Other

DEPTH Recorded depth (m bgl)

MEAS_RWL Measured RWL (m bgl)

MEAS_YLD Measured yield (m³/hr)

COND Conductivity value (uS)

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
5	577819.45 7347043.38 4 1121.00	HUKUNTSI	K. NGWAMOTSOKO 1 1	-9.00 7.81	3.60	867
6	577904.05 7347012.17 4 1150.00	HUKUNTSI	MUNTSU 1 6	-9.00 6.75	1.00	746
34	588364.88 7343230.09 4 1140.00	TSHANE	KEREEMANG FAMILY 1 3	-9.00 8.65	-9.00	916
35	588536.10 7343505.83 4 1140.00	TSHANE	VARIOUS - SEE REC FORM 2 3	-9.00 6.00	-9.00	0
38	577023.93 7346248.06 4 1155.00	HUKUNTSI	VARIOUS - SEE REC FORM 6	-9.00 -9.00	-9.00	0
47	578765.71 7334151.92 4 1150.00	LOKGWABE	VARIOUS	-9.00 -9.00	-9.00	0
56 94	576744.66 7346864.65 4 1155.00	HUKUNTSI	AMOS MOTLHANE 1 3	-9.00 7.00	-9.00	0

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
59 114	576690.77 7347357.01 4 1122.50	HUKUNTSI	W.K. VILJOEN 1 1	-9.00 -9.00	0.70	846
69	560851.36 OHE 7397836.43 4 1150.00		SYNDICATE 2 3	-9.00 8.30	-9.00	19500
70	560681.35 OHE 7397867.89 4 -9.00		SYNDICATE 6 6	-9.00 -9.00	-9.00	0
71	560256.64 OHE 7398023.40 4 1174.00		SYNDICATE 6 6	-9.00 -9.00	-9.00	0
72	560086.24 OHE 7397962.60 4 1150.00		SYNDICATE 4 6	-9.00 8.00	-9.00	0
77 709	574570.86 TSHOTSWA PAN 7374616.08 4 1160.00		M Tlhankane 6 6	-9.00 -9.00	-9.00	0
78 219	581393.78 PEPANE PAN 7359448.39 4 1111.00		SETLKANA MOTSIWA 2 4	-9.00 7.00	-9.00	0

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
79 229	581311.53 7359910.17 4 1132.00	PEPANE PAN	KGATHI MOILWA 2 3	-9.00 8.60	-9.00	0
80 206	581564.52 7359631.95 4 1131.50	PEPANE PAN	BENFEET THIITE 2 3	-9.00 7.54	-9.00	14440
90 120	579303.33 7334364.23 4 1110.50	LOKGWABE	KELOPILE KEBADIRENG 1 2	-9.00 10.50	1.00	830
91 132	579415.74 7334271.33 4 1112.00	LOKGWABE	KUBASE LESHUPE 1 2	-9.00 5.00	1.00	0
94 372	573099.49 7330337.75 4 1188.00	LOKGWABE	NTSHWARELANG MOKGWATHISE 2 3	-9.00 9.87	-9.00	18880
95 146	573953.98 7326396.69 4 1113.00	LOKGWABE	Lokgwabe Community 2 6	-9.00 15.93	0.40	0
96	578399.87 7334369.22 4 1045.00	LOKGWABE	JANE KEBARENG 1 2	-9.00 11.98	-9.00	727

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
106	579415.74 7334271.33 4 1112.00	LOKGWABE		-9.00 11.59	-9.00	759
			1 2			
112	526329.78 7329117.22 7 1155.00	ZUTSWA	ZUTSWA SALT MINE	-9.00 -9.00	-9.00	0
			1 6			
114 945	584873.27 7354753.60 4 1131.00	LEHUTUTU	KEAMOGORETSE DITHOBOLO	-9.00 13.98	1.50	2530
			1 1			
116 73	576882.81 7346279.57 4 1150.00	HUKUNTSI	ANDIRISI KALANTE	-9.00 7.00	1.50	2030
			1 3			
117	576882.81 7346279.57 4 1124.50	HUKUNTSI	PATHIAS SENTO	-9.00 7.00	1.50	1801
			1 2			
119 196	586084.80 7354039.04 4 1121.00	LEHUTUTU	LEKUTLANE MAAPATSANE	-9.00 6.63	-9.00	937
			2 3			
120	585120.81 7353583.45 4 1121.50	LEHUTUTU	THINA MABOTE	-9.00 4.60	-9.00	1863
			2 3			

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
125	578793.77	LOKGWABE	MOKWENE GADILEFE	-9.00	1.00	610
373	7334121.01	4	1	9.20		
	1107.50		2			
126	576769.29	HUKUNTSI	KEMOYAONE MMESETSI	-9.00	0.70	3340
104	7346187.92	4	1	5.80		
	1121.50		1			
130	584591.08	LEHUTUTU	K.E. NGWAMOTSOKO	-9.00	0.40	0
181	7354847.53	4	2	11.89		
	1071.00		6			
138	577536.20	HUKUNTSI	J.K. MOLATELELE	-9.00	6.00	950
	7346921.90	4	1	7.01		
	1040.00		3			
142	579682.60	HUKUNTSI	SANITAS / GUS NILSSON	-9.00	-9.00	0
107	7346694.84	4	5	-9.00		
	1137.00		3			
152	579485.48	HUKUNTSI	KDC	-9.00	-9.00	0
78	7346818.96	4	4	13.40		
	1141.00		6			
153	580217.08	HUKUNTSI	UNKNOWN	-9.00	-9.00	0
	7346261.30	4	4	14.36		
	1135.00		6			

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
156	579661.66 7378771.51 1105.00	MAKE 4		-9.00 2.96	-9.00	0
			6			
159	576518.92 7346927.36 -9.00	HUKUNTSI 4	MR PHOLOGOLO	-9.00 3.25	-9.00	2125
			2 3			
162	636693.24 7368411.64 1119.50	LOTHLAKE PAN 4	UNKNOWN	-9.00 -9.00	-9.00	0
			5 6			
163	525005.20 7330134.45 1150.00	ZUTSWA 4	UNKNOWN	-9.00 -9.00	-9.00	0
			5 6			
500 066	546271.43 7308584.28 1094.00	Kaekae pan 3	Ipolokeng Synd Chmn Gadijewe L	-9.00 -9.00	-9.00	0
			1 0			
501 068	576625.87 7345788.88 1124.00	Hukuntsi 4	Etshane Ore kang & Kgatlo Motlh	-9.00 -9.00	0.40	0
			2 3			
502 081	576738.23 7345665.26 1141.00	Hukuntsi 4	Pothego Mogolele	-9.00 -9.00	0.00	0
			7 0			

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
503 105	576851.42 7345695.40 1125.00	Hukuntsi 4	Matshabane Mautle 2 3	-9.00 -9.00	0.50	0
504 113	537584.92 7327215.99 1100.00	Diolwane Pan 4	Kgomotso Sinye 2 3	-9.00 -9.00	-9.00	0
505 115	538877.69 7304793.10 1130.00	Kanghane pan 3	Ithuseng Synd Chmn S.Mogolele 1 0	-9.00 -9.00	-9.00	0
506 117	578300.97 7331786.33 1111.00	Lokgwabe 3	Lokgwabe Community 2 0	-9.00 -9.00	-9.00	0
507 118-11	579613.89 7334362.49 1093.00	Lokgwabe 4	Gaetsalwe Kgogobi 2 3	-9.00 -9.00	0.40	0
509 121	578202.74 7334462.57 1100.00	Lokgwabe 4	Hendrik Keadireng 2 3	-9.00 -9.00	0.40	0
510 122-12	578795.47 7334428.55 1093.00	Lokgwabe 4	S.Kgotlhane 4 1	-9.00 -9.00	1.50	0

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
513	579613.89	Lokgwabe	Tsietso Legakabe	-9.00	0.40	0
125	7334362.49	4	2	-9.00		
	1093.00		3			
514	578285.92	Lokgwabe	Monologa Legakabe	-9.00	0.40	0
126	7334185.32	4	2	-9.00		
	1097.00		3			
515	578795.47	Lokgwabe	Setsho Legakabe	-9.00	-9.00	0
127-31	7334428.55	4	8	-9.00		
	1093.00		0			
516	579613.89	Lokgwabe	Gaoetwe Mosweu	-9.00	0.40	0
133-13	7334362.49	4	2	-9.00		
	1093.00		3			
518	579613.89	Lokgwabe	Kalobai Motlhalawadira	-9.00	0.40	0
141	7334362.49	4	2	-9.00		
	1093.00		3			
519	578670.41	Lokgwarane	Mapense Moagele	-9.00	0.40	0
142	7337350.97	4	2	-9.00		
	1105.00		3			
520	578795.47	Lokgwabe	Moshemele Tselaesele	-9.00	0.40	0
143-44	7334428.55	4	2	-9.00		
	1093.00		3			

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
521	579781.39	Lokgwabe	Lokgwabe Community	-9.00	-9.00	0
145-14	7334023.25	4	6	-9.00		
	1125.00		0			
522	578670.41	Lokgwabe	Not known	-9.00	-9.00	0
147	7337350.97	4	6	-9.00		
	1105.00		0			
523	579613.89	Lokgwabe	Mogalane Batshape	-9.00	0.40	0
148	7334362.49	4	2	-9.00		
	1093.00		3			
524	579697.56	Lokgwabe	Lebutshwane Gabaitshe	-9.00	0.40	0
149	7334177.50	4	2	-9.00		
	1136.00		3			
525	578795.47	Lokgwabe	L.Hiri+Khudube Khudube	-9.00	0.80	0
150-52	7334428.55	4	2	-9.00		
	1093.00		3			
526	579613.89	Lokgwabe	Dugmore Kgogobi	-9.00	0.40	0
153-54	7334362.49	4	2	-9.00		
	1093.00		3			
527	579866.61	Lokgwabe	Mosikwane Kgogobi	-9.00	0.40	0
155	7334115.04	4	2	-9.00		
	1132.00		3			

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
528 157	578427.93 7334338.31 4 1196.00	Lokgwabe	Mokwena Keadireng 2 3	-9.00 -9.00	0.40	0
529 158	588988.57 7343564.54 4 1114.00	Tshane	Benjamin Bok 2 3	-9.00 -9.00	0.40	0
530 159-62	588395.22 7343568.22 4 1114.00	Tshane	Kaekule Etshane 2 3	-9.00 -9.00	0.40	0
531 163	588168.61 7343477.35 4 1122.00	Tshane	Moses Mosalaesi 2 3	-9.00 -9.00	0.20	0
532 164	588395.22 7343568.22 4 1114.00	Tshane	Morobise Morobise 2 3	-9.00 -9.00	0.40	0
533 165-67	588281.65 7343476.65 4 1122.00	Tshane	Ramotlhane Motlhane 2 3	-9.00 -9.00	0.20	0
534 169-70	588613.26 7337723.30 3 1103.00	Ngwaborwa Pan	Ramokgethe Mothibi 1 0	-9.00 -9.00	-9.00	0

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
537	524497.77	Zutswa	Kgalagadi District Council	-9.00	-9.00	0
310	7330473.61	4	4	-9.00		
	1107.00		0			
538	549417.29	Mazakahazakha	RAD Community	-9.00	-9.00	0
547	7338005.00	5	2	-9.00		
	1133.00		0			
539	524498.35	Zutswa	Zutswa Community	-9.00	-9.00	0
548	7330811.89	5	2	-9.00		
	1101.00		0			
542	524585.15	Zutswa	Kgalagadi District Council	-9.00	-9.00	0
716	7332041.85	4	6	-9.00		
	1107.00		0			
543	525599.64	Zutswa	Zutswa community	-9.00	-9.00	0
718	7331117.48	3	2	-9.00		
	1159.00		0			
547	589064.15	Nqwaborwa Pan	Lekalake Malgas	-9.00	-9.00	0
943	7337566.71	3		-9.00		
	1093.00		0			
548	588365.45	Tshane	Legeru Mosianele	-9.00	0.50	0
944	7343322.36	4	4	-9.00		
	-9.00		3			

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
549 980	573476.36 7326798.99 3 1113.00	Motheisi Pan	Mongologa Legakabe	-9.00 -9.00	-9.00	0
550 992	567797.18 7313479.58 5 1092.00	Ngoleshadi Pan	RAD Community	-9.00 -9.00	-9.00	0
551 036	576603.20 7346834.65 4 1121.00	Hukuntsi	Job Montsho	-9.00 -9.00	0.40	0
552 063	636097.41 7368263.46 3 1136.00	Lotlhake Pan	Lotlhake Community (now @ Inal	-9.00 -9.00	-9.00	0
553 064	636182.03 7368231.90 5 1136.00	Lotlhake Pan	Lotlhake Community	-9.00 -9.00	-9.00	0
554 067	576604.03 7346988.42 4 1127.00	Hukuntsi	Zion Montsho	-9.00 -9.00	1.00	0
555 069	576603.20 7346834.65 4 1121.00	Hukuntsi	Mophutolodi Lekaukau	-9.00 -9.00	0.40	0

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
556	576463.88	Hukuntsi	Kebotseng Letlhotlho	-9.00	0.40	0
070	7347204.45	4	2	-9.00		
	1170.00		3			
557	576576.59	Hukuntsi	Dikiti Kelekolwane	-9.00	0.40	0
072	7347142.34	4	2	-9.00		
	1118.00		3			
558	576603.20	Hukuntsi	Medupe Kalantle	-9.00	0.00	0
074-75	7346834.65	4	5	-9.00		
	1121.00		3			
559	577170.51	Hukuntsi	Hukuntsi Community	-9.00	0.40	0
076	7347231.42	4	2	-9.00		
	1146.00		3			
560	576629.82	Hukuntsi	Keakopa Chaune	-9.00	0.40	0
077	7346526.96	4	2	-9.00		
	1124.00		3			
561	576686.33	Hukuntsi	Charles T. Thlage	-9.00	-9.00	0
080	7346526.66	4	1	-9.00		
	1140.00		0			
562	577000.46	Hukuntsi	Kemoyaone Mmesetsi	-9.00	1.00	0
082	7347140.07	4	2	-9.00		
	1150.00		3			

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
563	577197.61	Hukuntsi	Lazarus Sento	-9.00	-9.00	0
083	7347015.99	4	2	-9.00		
	1125.00		3			
564	576887.76	Hukuntsi	George Lekaukau	-9.00	1.00	0
084	7347202.18	4	2	-9.00		
	1136.00		3			
565	576603.20	Hukuntsi	Mabogwe Baumake	-9.00	0.40	0
085-88	7346834.65	4	2	-9.00		
	1121.00		3			
566	566808.81	Bohise	Abel Baumake and group	-9.00	-9.00	0
089	7361399.34	3	2	-9.00		
	1098.00		0			
567	567903.26	Bohise	Tidemalo Synd Chmn Pego Baumak	-9.00	-9.00	0
090	7359549.02	3	2	-9.00		
	1098.00		0			
568	576293.84	Hukuntsi	Hukuntsi Community	-9.00	-9.00	0
091	7347113.09	3	2	-9.00		
	1110.00		0			
569	576743.17	Hukuntsi	Boy Moapare	-9.00	0.40	0
092	7346587.87	4	2	-9.00		
	1119.00		3			

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
570 093,09	576603.20 7346834.65 4 1121.00	Hukuntsi	Matlho Mounakwa 4 3	-9.00 -9.00	0.40	0
571 102	577114.65 7347354.74 4 1075.00	Hukuntsi	Amos Moncho 4 1	-9.00 -9.00	2.00	0
572 103	576603.20 7346834.65 4 1121.00	Hukuntsi	Etiogile Mounakwa 2 3	-9.00 -9.00	0.40	0
573 106	576971.87 7347078.71 4 1131.00	Hukuntsi	Lekaukau family Syndicate 4 1	-9.00 -9.00	2.00	0
574 108-11	576603.20 7346834.65 4 1121.00	Hukuntsi	Mosikeemang Nkwane 2 3	-9.00 -9.00	0.40	0
575 111	576802.16 7347048.87 4 1107.00	Hukuntsi	Lazarus Sento 2 3	-9.00 -9.00	2.00	0
576 112	576518.60 7346865.86 4 1127.00	Hukuntsi	Tlhapi Sento 7 0	-9.00 -9.00	-9.00	0

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
577	576916.35	Hukuntsi	Hukuntsi Community	-9.00	1.00	0
156	7347263.54	4	2	-9.00		
	1146.00		3			
578	616048.02	Kgainyane	Ramothibi Mothibi	-9.00	-9.00	0
168	7360072.20	3	2	-9.00		
	1154.00		0			
579	591945.66	Tshane	Tshane Community	-9.00	-9.00	0
171	7346498.40	3	2	-9.00		
	1258.00		0			
580	585039.64	Lehututu	Ramenwane Modige	-9.00	0.40	0
172-80	7354199.03	4	2	-9.00		
	1106.00		3			
581	585521.19	Lehututu/Lecha	Mokhe Thuku	-9.00	1.00	0
182-97	7354349.95	4	2	-9.00		
	1120.00		3			
582	580745.35	Phepane	Thomame Moleta	-9.00	0.40	0
198-22	7359821.09	4	2	-9.00		
	1120.00		3			
583	562067.95	Ohe	Setshela Boruilwe	-9.00	-9.00	0
306	7397185.54	4	4	-9.00		
	1139.00		0			

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
584	573044.49	Tshotswa	Tshotswa village	-9.00	-9.00	0
308	7375115.90	5		-9.00		
	1164.00		0			
585	551960.55	Monong Pan	Moletlhe Mabote	-9.00	-9.00	0
311	7385600.85	4	4	-9.00		
	-9.00		0			
586	553535.18	Monong Pan	Not known	-9.00	-9.00	0
312	7382335.47	4	4	-9.00		
	-9.00		0			
587	560201.56	Ohe	Maragaole Sekgoma	-9.00	-9.00	0
313-16	7398423.40	4	4	-9.00		
	1187.00		0			
588	558743.98	Ohe	Gabogatswe Leswape	-9.00	-9.00	0
317	7395600.17	4	4	-9.00		
	1159.00		0			
589	559975.08	Ohe	Molefele Tshipe	-9.00	-9.00	0
318	7398516.50	4	4	-9.00		
	1160.00		0			
590	610471.66	Kukame Pan	RAD Community	-9.00	-9.00	0
336	7359593.14	5		-9.00		
	-9.00		3			

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
591 370-71	576575.77 7346988.57 4 1127.00	Hukuntsi	Pego Baumake 3	-9.00 -9.00	0.40	0
592 374	580745.35 7359821.09 4 1120.00	Phepane	Joseph Phute 3	-9.00 -9.00	0.40	0
593 375	579693.19 7379355.65 4 0.00	Make Pan	Kgosi Leshope 4 0	-9.00 -9.00	-9.00	0
594 519	558829.16 7395630.58 4 1159.00	Ohe	Gabogatswe Leswape 4 0	-9.00 -9.00	-9.00	0
595 520	558635.13 7396738.41 3 1154.00	Ohe	Kakutle Koloti 0	-9.00 -9.00	-9.00	0
596 521	560343.48 7398453.56 4 1187.00	Ohe	Kebonye Sekgoma 4 0	-9.00 -9.00	-9.00	0
597 522	560286.13 7398300.04 4 1159.00	Ohe	Dibanatlho Tshipe 4 0	-9.00 -9.00	-9.00	0

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
598 523	562067.95 7397185.54 1139.00	Ohe 5	Ohe community 0	-9.00 -9.00	-9.00	0
599 525-28	559861.53 7398486.29 1161.00	Ohe 4	Mabalose Ditshweng 2 0	-9.00 -9.00	-9.00	0
600 529	560286.64 7398423.05 -9.00	Ohe 4	Molefele Tshipe 2 0	-9.00 -9.00	-9.00	0
601 530	579124.25 7378897.46 1180.00	Make 4	Kgosi Leshope 2 0	-9.00 -9.00	-9.00	0
602 531-32	579095.59 7378836.11 1180.00	Make 4	Kgosi Leshope 2 0	-9.00 -9.00	-9.00	0
603 533-34	579124.25 7378897.46 1180.00	Make 4	Kgosi Leshope 2 0	-9.00 -9.00	-9.00	0
605 535	573694.75 7374928.09 1145.00	Tshotswa 3	Tshotswa Community 2 0	-9.00 -9.00	-9.00	0

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
606 536	580517.40 7379873.92 1086.00	Make 3	Make Community 2 0	-9.00 -9.00	-9.00	0
607 537	579889.24 7378954.78 1180.00	Make 4	Kgosi Leshope 2 0	-9.00 -9.00	-9.00	0
608 538	559996.13 7396732.90 1168.00	Ohe pan 3	Ohe Community 2 0	-9.00 -9.00	-9.00	0
609 539-40	558635.13 7396738.41 1154.00	Ohe 3	Kebonyeng Sekgoma 2 0	-9.00 -9.00	-9.00	0
611 542	554719.44 7380885.72 1249.00	Monong Pan 4	Not known 4 0	-9.00 -9.00	-9.00	0
612 544	581787.20 7409451.31 1166.00	Tshowa Pan 4	Headman at Make 4 0	-9.00 -9.00	-9.00	0
614 552	566996.07 7365181.21 1180.00	Kgame Pan 3	Elijah Maboe 0	-9.00 -9.00	-9.00	0

WCS_NO KP_NO	UTM_E UTM_N ELEVATION	LOCALITY TYPE_WTRPT	OWNER STATUS EQUIPMENT	DEPTH MEAS_RWL	MEAS_YLD	COND
615 553	588682.01 7376443.44 1160.00	Motsolo pan 3	Kekgabelle Mahupu 0	-9.00 -9.00	-9.00	0
616 555	580745.35 7359821.09 1120.00	Phepane 3	Lehututu Community 2 0	-9.00 -9.00	-9.00	0
617 556	585521.19 7354349.95 1120.00	Lehututu 3	Lehututu Community 2 0	-9.00 -9.00	-9.00	0
618 558	573268.36 7368994.86 1158.00	Tshotswane 3	Phatswa Mokgwetsi 0	-9.00 -9.00	-9.00	0
619 559	585551.96 7369081.22 1141.00	Dikabaneng 3	Letlotlo Letlotlo 2 0	-9.00 -9.00	-9.00	0
620 678	580202.95 7384488.67 -9.00	Molongwane 3	Tshenelo Modiga 0	-9.00 -9.00	-9.00	0
621 682	573581.50 7374928.67 1145.00	Tshotswa Pan 3	Tshotswa Community 2 0	-9.00 -9.00	-9.00	0

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
622	553309.25	Monong	Tlhokomolomo Sehularo	-9.00	-9.00	0
683-89	7382520.81	3	2	-9.00		
	1138.00		0			
626	571968.20	Tshotswane	RAD Community	-9.00	-9.00	0
694	7369339.67	5	2	-9.00		
	1164.00		0			
627	570438.72	Mothebethise P	Mokganene Mokganene	-9.00	-9.00	0
695	7369101.17	4		-9.00		
	1160.00		0			
628	573242.53	Tshotswa	Tshotswa village	-9.00	-9.00	0
696	7375084.15	5	2	-9.00		
	1164.00		0			
635	604387.57	Gomogwe Pan	Lekolori Mapatsane	-9.00	-9.00	0
711	7370987.49	4	4	-9.00		
	1146.00		3			
636	549583.22	Kwakai Pan	RAD Community	-9.00	-9.00	0
719	7361530.35	5	2	-9.00		
	1135.00		0			
637	546508.55	Bohelabatho Pa	RAD Community	-9.00	-9.00	0
720	7364154.53	5	2	-9.00		
	1133.00		0			

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
638	556039.14	Tshau Tshau Pa	RAD Community	-9.00	-9.00	0
721	7356001.96	5	2	-9.00		
	1089.00		0			
639	563878.39	Hunhukwe pan	Boswe Sekgoma	-9.00	-9.00	0
728	7415782.41	4	4	-9.00		
	1201.00		3			
640	564730.22	Setshwe pan	Mabakgomo Serame	-9.00	-9.00	0
734	7396466.72	4	4	-9.00		
	-9.00		0			
641	586198.63	Lehututu	Ngakaefe Mogapele	-9.00	0.30	0
942	7354165.37	4	2	-9.00		
	1130.00		3			
642	584901.54	Lehututu	F.J Stegling	-9.00	0.90	0
945-46	7354753.43	4	1	-9.00		
	1136.00		1			
643	581450.69	Phepane	Lesone Leswape	-9.00	0.40	0
947	7359509.58	4	2	-9.00		
	1168.00		3			
644	580365.95	Hukuntsi	Brendan Moapare	-9.00	-9.00	0
959	7347613.67	4	4	-9.00		
	-9.00		0			

WCS_NO	UTM_E	LOCALITY	OWNER	DEPTH	MEAS_YLD	COND
KP_NO	UTM_N	TYPE_WTRPT	STATUS	MEAS_RWL		
	ELEVATION		EQUIPMENT			
645	577818.28	Hukuntsi	Moapare Mosiwa + Community	-9.00	-9.00	0
960	7346828.11	4	4	-9.00		
	1140.00		3			
646	553309.25	Monong Communi	Monong Community	-9.00	-9.00	0
981	7382520.81	3	2	-9.00		
	1138.00		0			
647	573382.54	Tshotswa Pan	Tshane Tlhankane	-9.00	-9.00	0
982	7374775.91	4	2	-9.00		
	1145.00		3			
648	573467.94	Tshotswa Pan	Tshane Tlhankane	-9.00	-9.00	0
983	7374867.74	4	2	-9.00		
	1145.00		3			
651	573892.63	Tshotswa Pan	Tshane Tlhankane	-9.00	-9.00	0
986	7374865.58	4	2	-9.00		
	1145.00		3			
652	573467.94	Tshotswa Pan	Tshane Tlhankane	-9.00	-9.00	0
987	7374867.74	4	2	-9.00		
	1145.00		3			
654	570326.57	Mothebethise	RAD Community	-9.00	-9.00	0
993	7369316.99	5	2	-9.00		
	1128.00		0			

APPENDIX 4

Hydrochemistry Inventory

Explanation of Hydrochemistry Table

BH_No	GS borehole number
WCS_No	WCS site number
STRT_PUM	Time since start of pumping (hours)
FLD_pH	Field measured pH value
LAB_pH	Lab measured pH value
FLD_EC	Field measured conductivity (uS)
LAB_EC	Lab measured conductivity (uS)
TDS	Total dissolved solids (mg/l)
FLD_DO	Field measured dissolved oxygen (%)

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_PH LAB_PH	FLD_EC LAB_EC	FLD_DO (%) TDS	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)					
						HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn
4 2649	HUKUNTSI	18/12/83 -9.0	-9.00 7.20	-9 982	-9.0 629	-9	-9	52.0	-9.0	150.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
4 2649	HUKUNTSI	09/03/84 -9.0	-9.00 7.50	-9 1306	-9.0 836	351	0	138.0	12.0	250.0	-9.00	-9.00	-9.00	-9.0	-9.0	204.2	-9.0	-9.00	-9.00
4 2649	HUKUNTSI	12/03/84 -9.0	-9.00 7.30	-9 1334	-9.0 853	371	0	99.0	13.0	210.0	-9.00	-9.00	-9.00	-9.0	-9.0	200.2	-9.0	-9.00	-9.00
4 2649	HUKUNTSI	18/12/83 -9.0	-9.00 7.73	-9 1064	-9.0 704	310	12	86.0	16.0	165.2	0.30	0.71	0.50	84.0	7.0	78.0	33.0	-9.00	-9.00
4 2649	HUKUNTSI	/ / -9.0	-9.00 7.10	-9 1080	-9.0 700	445	-9	98.0	13.0	73.0	-9.00	1.20	-9.00	107.0	7.5	63.0	37.0	-9.00	-9.00
5	HUKUNTSI	12/07/94 -9.0	7.02 -9.00	867 -9	-9.0 -9	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
6	HUKUNTSI	12/07/94 -9.0	7.43 -9.00	746 -9	-9.0 -9	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
7 5283	HUKUNTSI	25/02/86 -9.0	-9.00 7.50	-9 1891	-9.0 986	302	0	310.0	12.0	46.0	-9.00	1.05	-9.00	102.0	228.0	56.0	63.0	0.01	0.01
7 5283	HUKUNTSI	17/03/86 -9.0	-9.00 7.98	-9 989	-9.0 1044	280	0	128.0	7.0	42.0	-9.00	0.88	-9.00	80.0	6.8	48.1	31.6	1.42	0.01

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH	FLD_EC	FLD_DO (%)	MAJOR ANIONS (mg/l)							MAJOR CATIONS (mg/l)						
			LAB_pH	LAB_EC		HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn
			TDS																
7 5283	HUKUNTSI	19/03/86 -9.0	-9.0 8.22	-9 984	-9.0	285	0	115.0	8.0	45.0	-9.00	-9.00	-9.00	-9.0	4.4	44.1	41.3	0.05	0.01
7 5283	HUKUNTSI	27/04/88 -9.0	-9.0 8.76	-9 750 650	-9.0	293	0	110.0	11.0	46.8	-9.00	-9.00	-9.00	83.0	4.2	64.0	19.9	0.02	0.10
7 5283	HUKUNTSI	02/11/88 -9.0	-9.0 8.16	792 797 530	-9.0	205	25	85.0	26.0	51.0	-9.00	0.70	-9.00	90.0	4.2	41.0	20.0	0.00	0.00
7 5283	HUKUNTSI	13/03/91 -9.0	6.88 8.05	826 844 587	-9.0	255	17	80.0	16.0	41.0	-9.00	0.79	-9.00	78.0	7.5	60.2	16.7	-9.00	-9.00
7 5283	HUKUNTSI	16/06/93 -9.0	-9.0 7.59	-9 846 532	-9.0	290	24	72.0	25.5	50.0	-9.00	1.58	-9.00	75.0	4.0	64.9	30.6	0.08	-9.00
7 5283	HUKUNTSI	04/08/94 -9.0	7.26 -9.00	0 -9 -9	70.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
8 5846	HUKUNTSI	09/03/88 -9.0	-9.0 7.35	-9 743 488	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
8 5846	HUKUNTSI	13/03/90 -9.0	7.14 7.89	845 839 584	-9.0	260	12	94.0	15.0	27.0	-9.00	1.00	-9.00	82.0	4.6	46.2	21.4	-9.00	-9.00
8 5846	HUKUNTSI	16/06/93 -9.0	-9.0 7.78	-9 895 590	-9.0	298	0	108.0	23.0	32.0	-9.00	1.58	-9.00	87.0	4.5	53.7	33.1	-9.00	-9.00

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)						
			LAB_pH	LAB_EC	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn	
			TDS																	
13 4617	HUKUNTSI	02/11/88	-9.00	673	-9.0	231	20	29.0	24.0	105.0	-9.00	0.82	-9.00	50.0	4.9	87.0	21.0	0.00	0.00	
			-9.0	8.09	700															
				526																
13 4617	HUKUNTSI	02/05/89	-9.00	-9	-9.0	-9	-9	-9.0	12.8	117.0	-9.00	0.41	-9.00	68.0	5.1	58.0	20.0	0.22	0.00	
			-9.0	-9.00	-9															
				-9																
14 2827	HUKUNTSI	/ /	-9.00	-9	-9.0	249	-9	60.0	14.0	112.0	-9.00	1.50	-9.00	107.0	3.6	35.0	9.0	-9.00	-9.00	
			-9.0	7.50	780															
				476																
14 2827	HUKUNTSI	/ /	-9.00	-9	-9.0	328	-9	68.0	16.0	-9.0	-9.00	1.00	-9.00	112.0	3.6	44.0	12.0	-9.00	-9.00	
			-9.0	7.70	760															
				612																
15 5793	HUKUNTSI	08/05/88	-9.00	-9	-9.0	305	0	145.0	0.1	46.8	-9.00	-9.00	-9.00	96.0	5.4	63.0	13.6	0.04	0.10	
			-9.0	7.90	891															
				618																
18 6088	LEHUTUTU	05/09/88	-9.00	-9	-9.0	462	0	116.0	49.0	65.0	-9.00	0.74	-9.00	155.0	7.4	74.0	24.0	0.01	0.01	
			-9.0	7.09	1128															
				802																
18 6088	LEHUTUTU	04/08/94	7.32	1217	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
				-9																
19 6046	LEHUTUTU	15/10/88	-9.00	-9	-9.0	329	0	159.0	13.0	79.0	-9.00	1.20	-9.00	120.0	8.0	94.0	23.0	0.00	0.00	
			-9.0	7.36	1094															
				668																
19 6046	LEHUTUTU	29/04/93	-9.00	-9	-9.0	254	14	203.4	46.5	84.2	-9.00	0.79	-9.00	250.0	10.4	25.2	17.7	-9.00	-9.00	
			7.5	8.31	1371															
				780																

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_ph	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)					
			LAB_ph	LAB_EC TDS	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn
19 6046	LEHUTUTU	02/05/93 47.0	-9.0 8.12	-9 1652	-9.0 960	154	12	330.3	44.0	81.1	-9.00	0.79	-9.00	180.0	9.4	75.9	18.7	-9.00	-9.00
19 6046	LEHUTUTU	07/06/93 -9.0	-9.0 7.51	1294 1465	-9.0 868	443	0	185.0	47.3	73.1	-9.00	1.58	-9.00	200.0	10.0	72.1	28.7	-9.00	-9.00
19 6046	LEHUTUTU	03/08/94 -9.0	7.03 -9.00	1714 -9	-9.0 -9	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
20 5948	LEHUTUTU	13/10/88 -9.0	-9.0 7.54	-9 1206	-9.0 810	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
20 5948	LEHUTUTU	07/05/93 24.0	-9.0 8.02	-9 1426	-9.0 840	352	5	186.0	25.9	76.1	-9.00	0.79	-9.00	140.0	5.7	91.8	27.4	-9.00	-9.00
20 5948	HUKUNTSI	05/05/93 10.0	-9.0 8.12	-9 1205	-9.0 672	226	13	186.0	30.5	82.5	-9.00	1.00	-9.00	130.0	6.0	86.7	28.0	-9.00	-9.00
20 5948	LEHUTUTU	07/06/93 -9.0	-9.0 7.86	1296 1353	-9.0 918	417	0	175.0	30.5	72.7	-9.00	1.58	-9.00	129.0	5.8	49.7	53.5	0.08	-9.00
20 5948	LEHUTUTU	15/10/88 -9.0	-9.0 7.15	-9 1290	-9.0 776	386	0	173.0	30.2	80.7	0.30	1.11	0.50	135.0	9.4	44.0	53.0	-9.00	-9.00
20 5948	LEHUTUTU	03/08/94 -9.0	6.91 -9.00	1436 -9	-9.0 -9	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_PH	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)						
			LAB_PH	LAB_EC	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn	
			TDS																	
21 5947	LEHUTUTU	03/08/94	7.08	2320	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9	-9															
			-9																	
22 3741	LEHUTUTU	/ /	-9.00	-9	-9.0	-9	-9	196.0	-9.0	50.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	7.50	1265															
			-9																	
22 3741	LEHUTUTU	/ /	-9.00	-9	-9.0	-9	-9	204.0	-9.0	45.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	7.50	1258															
			-9																	
22 3741	LEHUTUTU	21/11/81	-9.00	-9	-9.0	-9	-9	106.0	-9.0	150.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	7.60	1365															
			-9																	
22 3741	LEHUTUTU	23/11/81	-9.00	-9	-9.0	-9	-9	110.0	-9.0	215.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	7.60	1390															
			-9																	
23 4237	LEHUTUTU	27/02/84	-9.00	-9	-9.0	398	0	937.0	63.0	66.0	-9.00	-9.00	-9.00	-9.0	-9.0	184.2	-9.0	-9.00	-9.00	
			-9.0	7.70	2431															
				1556																
23 4237	LEHUTUTU	29/02/84	-9.00	-9	-9.0	407	0	951.0	66.0	68.0	-9.00	-9.00	-9.00	-9.0	-9.0	212.3	-9.0	-9.00	-9.00	
			-9.0	7.70	2466															
				1578																
24 5967	LEHUTUTU	14/11/88	-9.00	-9	-9.0	373	0	85.0	35.0	173.0	-9.00	1.30	-9.00	92.0	16.0	75.0	39.0	0.01	0.01	
			-9.0	7.66	930															
				618																
25 5968	LEHUTUTU	07/07/88	-9.00	-9	-9.0	293	0	3758.0	186.0	245.0	-9.00	0.57	-9.00	1300.0	20.0	448.0	378.0	0.00	0.00	
			-9.0	7.35	10360															
				7332																

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_PH	FLD_EC	FLD_DO (%)	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)					
			LAB_PH	LAB_EC		TDS	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe
25 5968	LEHUTUTU	07/07/88 -9.0	-9.0 7.61	-9 10810 7180	-9.0	505	0	3899.0	284.0	211.0	-9.00	0.62	-9.00	1700.0	20.0	520.0	326.0	0.05	0.10
25 5968	LEHUTUTU	08/10/88 -9.0	-9.0 7.31	-9 11719 8542	-9.0	120	0	4849.0	379.0	83.0	-9.00	0.48	-9.00	1600.0	42.0	1124.0	456.0	0.00	0.00
25 5968	LEHUTUTU	29/01/90 -9.0	-9.0 7.20	-9 17593 17974	-9.0	331	0	7077.0	3.7	6.7	-9.00	0.17	-9.00	1850.0	46.0	1302.0	862.0	1.27	-9.00
25 5968	LEHUTUTU	31/01/90 -9.0	-9.0 7.54	-9 15463 15344	-9.0	343	0	5840.0	346.0	39.0	-9.00	0.19	-9.00	1700.0	35.0	1048.0	712.0	-9.00	-9.00
26 1505	LEHUTUTU	/ / -9.0	-9.0 7.55	0 -9 5660	0.0	305	0	2755.0	144.0	-9.0	-9.00	2.00	-9.00	800.0	16.0	509.0	301.0	-9.00	0.00
27 499	LEHUTUTU	04/02/86 -9.0	7.35 6.98	942 1333 937	-9.0	805	0	177.0	24.0	360.0	-9.00	1.00	-9.00	49.0	3.9	136.0	102.0	0.01	0.01
27 499	LEHUTUTU	02/11/88 -9.0	-9.0 7.95	1047 1090 844	-9.0	366	0	111.0	38.0	176.0	-9.00	0.56	-9.00	40.0	4.6	164.0	46.0	0.00	0.00
27 499	MOOLOGESYNDICA	06/10/75 -9.0	-9.0 7.30	-9 6700 4212	-9.0	426	0	1858.0	206.0	-9.0	-9.00	0.60	-9.00	440.0	5.5	440.0	340.0	-9.00	-9.00
30 6457	TSHANE	15/07/89 -9.0	-9.0 7.76	-9 1481 1004	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)						
			LAB_pH	LAB_EC	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn	
			TDS																	
32 473	TSHANE	/ /	-9.00	-9	-9.0	401	0	295.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	77.0	34.0	-9.00	-9.00	
			-9.0	7.55	-9															
				1037																
32 473	TSHANE	14/07/94	6.96	1786	72.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
				-9																
33 25596	TSHANE	14/07/94	6.94	981	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
				-9																
34	TSHANE	15/07/94	7.32	916	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
				-9																
39 5448	LOKWABE	07/08/86	-9.00	-9	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
				478																
39 5448	LOKWABE	07/12/86	-9.00	-9	-9.0	241	0	62.0	56.0	43.0	-9.00	0.56	-9.00	93.0	1.4	24.4	22.9	0.01	0.10	
			-9.0	7.90	806															
				554																
39 5448	LOKWABE	09/12/86	-9.00	-9	-9.0	276	0	64.0	54.0	32.0	-9.00	0.56	-9.00	93.0	2.0	32.0	30.0	0.01	0.10	
			-9.0	7.70	862															
				530																
39 5448	LOKWARE	07/08/86	-9.00	-9	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
				478																
39 5448	LOKWABE	12/03/91	7.01	763	-9.0	282	14	44.0	21.0	54.0	-9.00	1.00	-9.00	64.0	3.1	64.2	13.9	-9.00	-9.00	
			-9.0	734	517															
				734	517															

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)					
			LAB_pH	LAB_EC	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn
			TDS																
45 7412	ZUTSHWA	17/09/93	-9.00	-9	-9.0	1232	252	11029.0	9151.8	6.4	-9.00	10.00	-9.00	13250.0	45.0	3.8	4.8	0.50	0.02
			12.0	8.65	64570														
					41120														
45 7412	ZUTSHWA	18/09/93	-9.00	-9	-9.0	1133	294	10733.6	9283.4	3.8	-9.00	10.00	-9.00	13000.0	42.5	4.0	4.9	0.40	0.00
			36.0	8.64	64893														
					41120														
45 7412	ZUTSHWA	18/09/93	-9.00	-9	-9.0	1201	298	11078.3	9464.5	2.6	-9.00	10.00	-9.00	13600.0	42.0	4.0	5.1	0.43	-9.00
			24.0	8.80	67475														
					41360														
45 7412	ZUTSHWA	19/09/93	-9.00	-9	-9.0	1172	287	10979.8	9513.9	3.6	-9.00	10.00	-9.00	13500.0	45.0	4.1	5.1	0.40	-9.00
			48.0	8.87	67260														
					40800														
45 7412	ZUTSHWA	20/09/93	-9.00	-9	-9.0	1160	317	10930.5	9530.0	3.2	-9.00	10.00	-9.00	13000.0	40.0	4.0	5.2	0.50	-9.00
			72.0	8.85	69090														
					41320														
45 7412	ZUTSHWAA	17/09/93	-9.00	-9	-9.0	1312	365	11233.0	10616.0	1.5	-9.00	10.00	-9.00	14500.0	49.0	1.8	2.1	0.02	-9.00
			0.2	6.91	73318														
					44020														
45 7412	ZUTSHWAA	19/09/93	-9.00	-9	-9.0	1127	321	13049.0	9415.1	2.9	-9.00	10.00	-9.00	14000.0	48.0	3.2	4.1	0.06	-9.00
			60.0	8.79	67342														
					42960														
46 5128	ZUTSHWA	19/01/86	-9.00	-9	-9.0	3732	0	84066.0	9600.0	0.0	-9.00	3.60	-9.00	57600.0	160.0	20.0	24.3	0.01	0.01
			-9.0	8.60	370049														
					236831														
46 5128	ZUTSHWA	20/01/86	-9.00	-9	-9.0	9634	0	87987.0	6130.0	0.0	-9.00	7.10	-9.00	45000.0	240.0	560.0	19.5	0.75	0.01
			-9.0	8.90	314312														
					201160														

WCS_NO BH_NO	LOCALITY	DATE	FLD_ph	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)					
		STRT_PUMP	LAB_ph	LAB_EC	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn
			TDS																
63 27258	TSHANE	26/07/94	6.99	19999	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
			-9.0	-9.00	-9														
					-9														
65 27257	TSHANE	04/08/94	7.60	17450	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
			-9.0	-9.00	-9														
					-9														
66 1521	LOKWABE	02/11/88	-9.00	-9	-9.0	238	33	29.0	15.0	55.0	-9.00	0.98	-9.00	50.0	24.0	28.0	28.0	0.00	0.00
			-9.0	8.02	673														
					482														
66 1521	LOKWABE	12/03/91	6.85	678	-9.0	285	19	28.0	14.0	35.0	-9.00	1.00	-9.00	50.0	30.0	56.8	16.1	0.03	-9.00
			-9.0	7.76	686														
					463														
66 1521	LOKWABE	/ /	-9.00	0	-9.0	360	-9	71.0	25.0	-9.0	-9.00	1.60	-9.00	60.0	33.0	46.0	41.0	-9.00	-9.00
			-9.0	7.70	650														
					544														
67 4251	KANG	18/05/83	-9.00	-9	-9.0	-9	-9	1460.0	-9.0	40.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
			-9.0	8.20	7510														
					4810														
67 4251	KANG	19/05/83	-9.00	-9	-9.0	-9	-9	1635.0	-9.0	40.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
			-9.0	7.60	7740														
					4950														
67 4251	TSHANE	25/07/94	7.48	5840	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
			-9.0	-9.00	-9														
					-9														
68 3969	LOTHAKE	01/11/82	-9.00	-9	-9.0	398	38	3191.0	2885.0	0.5	0.30	2.16	-9.00	3050.0	47.0	73.0	53.0	-9.00	-9.00
			-9.0	8.20	13650														
					8984														

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH LAB_pH	FLD_EC LAB_EC TDS	FLD_DO (%)	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)					
						HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn
74 6339	MONONG	21/06/91 -9.0	-9.00 7.84	-9 32870 21072	-9.0	-9	-9	-9.0	-9.0	26.1	-9.00	0.63	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
74 6339	MONONG	21/06/91 -9.0	-9.00 7.79	-9 32977 21094	-9.0	-9	-9	-9.0	-9.0	23.0	-9.00	0.63	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
74 6339	MONONG	09/11/91 24.0	-9.00 7.42	-9 2585 1321	-9.0	84	0	575.0	63.0	0.0	-9.00	0.20	-9.00	420.0	1.9	4.2	1.4	0.37	-9.00
74 6339	MONONG	09/11/91 -9.0	-9.00 7.68	-9 14654 10400	-9.0	340	13	3075.0	3323.0	0.0	-9.00	0.40	-9.00	3200.0	15.0	176.0	54.0	0.50	-9.00
74 6339	MONONG	25/09/92 -9.0	-9.00 6.59	-9 2410 1308	-9.0	46	0	559.4	193.4	0.0	-9.00	0.25	-9.00	411.3	1.7	11.8	2.3	0.06	-9.00
75 6630	MONONG	28/12/90 -9.0	-9.00 7.52	-9 33891 21204	-9.0	-9	-9	-9.0	-9.0	8.9	-9.00	0.40	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
75 6630	MONONG	28/12/90 -9.0	-9.00 7.53	-9 32640 20594	-9.0	-9	-9	-9.0	-9.0	0.0	-9.00	0.40	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
75 6630	MONONG	28/12/90 -9.0	-9.00 7.52	-9 33891 21204	-9.0	-9	-9	-9.0	-9.0	8.9	-9.00	0.40	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
75 6630	MONONG	28/12/90 -9.0	-9.00 7.53	-9 32640 20594	-9.0	-9	-9	-9.0	-9.0	0.0	-9.00	0.40	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH	FLD_EC	FLD_DO (%)	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)					
			LAB_pH	LAB_EC TDS		HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn
86 6186	HUNHUKWE	30/11/88 -9.0	-9.0 7.96	-9 13873 9530	-9.0	1171	72	3820.0	967.0	0.0	-9.00	0.84	-9.00	3400.0	110.0	40.0	20.0	0.01	0.01
87 6257	HUNHUKWE	12/03/89 -9.0	-9.0 8.25	-9 2606 1544	-9.0	744	56	291.0	123.0	31.0	-9.00	1.20	-9.00	486.0	16.0	35.0	4.2	0.14	0.00
87 6257	HUNHUKWE	14/06/89 -9.0	-9.0 8.73	-9 2350 1590	-9.0	909	48	365.0	145.0	12.0	-9.00	1.80	-9.00	625.0	13.0	4.4	3.7	0.23	0.00
87 6257	HUNHUKWE	14/06/89 -9.0	-9.0 8.64	-9 2350 1555	-9.0	896	37	333.0	114.0	16.0	-9.00	1.90	-9.00	605.0	13.0	4.3	3.6	0.52	0.00
87 6257	HUNHUKWE	14/03/91 -9.0	7.94 8.35	2470 2667 1696	0.0	772	50	326.0	130.0	42.0	-9.00	1.58	-9.00	590.0	10.0	3.7	23.1	0.76	-9.00
87 6257	HUNHUKWE	11/06/93 -9.0	-9.0 7.84	2226 2766 1596	-9.0	686	14	347.0	172.0	39.4	-9.00	2.00	-9.00	515.0	12.6	6.4	9.7	-9.00	-9.00
88 5668	HUNHUKWE	21/09/89 -9.0	-9.0 8.91	-9 2350 1820	-9.0	671	62	320.0	194.0	8.1	-9.00	1.30	-9.00	609.0	13.0	4.9	3.5	0.06	0.00
90	LOKGWABE	29/07/94 -9.0	7.26 -9.00	830 -9 -9	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00
94	LOKGWABE	17/08/94 -9.0	7.98 -9.00	18880 -9 -9	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)							MAJOR CATIONS (mg/l)							
			LAB_pH	LAB_EC	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn	
			TDS																	
135 3585	OHE	29/10/81	-9.00	-9	-9.0	-9	-9	350.0	-9.0	0.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	8.10	11350															
					7200															
136 6484	TSHANE	18/11/89	-9.00	-9	-9.0	314	0	37.0	15.0	116.0	-9.00	0.56	-9.00	52.0	5.7	85.0	27.0	-9.00	-9.00	
			-9.0	6.98	816															
					596															
136 6484	TSHANE	01/12/89	-9.00	-9	-9.0	324	0	46.0	11.5	21.9	-9.00	0.52	-9.00	54.0	4.8	99.0	1.6	0.43	0.00	
			-9.0	7.05	880															
					610															
136 6484	TSHANE	01/12/89	-9.00	-9	-9.0	302	9	40.0	9.9	0.6	-9.00	0.58	-9.00	56.0	4.7	72.0	1.8	0.32	0.00	
			-9.0	7.36	888															
					598															
136 6484	TSHANE	09/08/94	7.03	836	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
					-9															
137 6482	TSHANE	18/08/89	-9.00	-9	-9.0	-9	-9	-9.0	-9.0	56.3	-9.00	0.52	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	6.77	816															
					578															
137 6482	TSHANE	08/12/89	-9.00	-9	-9.0	162	14	46.0	17.7	157.0	-9.00	0.48	-9.00	70.0	4.5	35.0	36.0	2.57	0.13	
			-9.0	7.66	735															
					510															
137 6482	TSHANE	14/12/89	-9.00	0	-9.0	243	14	50.0	16.9	149.0	-9.00	0.44	-9.00	74.0	4.5	36.0	39.0	0.06	0.09	
			-9.0	7.55	867															
					584															
137 6482	TSHANE	09/08/94	7.36	816	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9.00	-9															
					-9															

WCS_NO BH_NO	LOCALITY	DATE STRT_PUMP	FLD_pH	FLD_EC	FLD_DO	MAJOR ANIONS (mg/l)								MAJOR CATIONS (mg/l)						
			LAB_pH	LAB_EC	(%)	HCO3	CO3	CL	SO4	NO3	NO2	F	Br	Na	K	Ca	Mg	Fe	Mn	
			TDS																	
138	HUKUNTSI	09/08/94	7.53	950	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
			-9.0	-9	-9															
			-9.00	-9	-9.0															
143	HUNHUKWE	10/10/88	-9.00	-9	-9.0	71	0	2233.0	3182.0	0.0	-9.00	0.46	-9.00	1900.0	20.0	660.0	148.0	0.00	0.00	
6043		-9.0	7.54	10199																
				8556																
143	HUNHUKWE	18/10/88	-9.00	-9	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
6043		-9.0	-9.00	10579																
				8916																
143	HUNHUKWE	01/11/88	-9.00	-9	-9.0	39	0	2154.0	3243.0	0.0	-9.00	0.35	-9.00	2000.0	25.0	676.0	116.0	0.01	0.01	
6043		-9.0	6.15	10010																
				8730																
143	HUNHUKWE	11/05/89	-9.00	-9	-9.0	74	0	2358.0	3411.0	0.1	-9.00	0.21	-9.00	2100.0	17.0	971.0	84.0	1.19	0.00	
6043		-9.0	7.15	10720																
				8958																
143	HUNHUKWE	13/05/89	-9.00	-9	-9.0	217	10	1136.0	2164.0	23.9	-9.00	0.19	-9.00	1060.0	12.0	500.4	28.0	0.01	0.00	
6043		-9.0	7.42	6550																
				5236																
143	HUNHUKWE	12/08/94	7.71	10000	-9.0	-9	-9	-9.0	-9.0	-9.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
6043		-9.0	-9.00	-9																
				-9																
144	CROWN LANDS	/ /	-9.00	-9	-9.0	753	64	441.0	187.0	-9.0	-9.00	1.00	-9.00	690.0	16.0	4.0	3.0	-9.00	-9.00	
1485		-9.0	8.90	-9																
				1776																
146	HUKUNTSI	04/04/83	-9.00	-9	-9.0	-9	-9	6138.0	-9.0	0.0	-9.00	-9.00	-9.00	-9.0	-9.0	-9.0	-9.0	-9.00	-9.00	
4267		-9.0	7.70	22890																
				14650																

