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DEPARTMENT OF FISHERIES AND WATER

REPUBLIC OF NAMIBIA

GROUNDWATER INVESTIGATION IN KAVANGO AND BUSHMANLAND NAMIBIA

FINAL REPORT

THE PERMANENT SECRETARY
DEPARTMENT OF FISHERIES AND WATER
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GROUNDWATER
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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF APPENDICIES

1 INTRODUCTION

On 31 May 1990, the Ministry of Agriculture, Fisheries, Water and Rural Development invited consultants to submit quotations for groundwater investigation work in Kavango, Bushmanland and Eastern Hereroland. The requirements and conditions of tender were set out in Tender Number F1/11-9/90. Namibian Groundwater Development Consultants (NGDC), which comprises Namib Hydro Search (Pty) Ltd, C & S Exploration (Pty) Ltd and George, Orr and Carr (Pty) Ltd as the implementation companies, and Groundwater Consulting Services (Pty) Ltd as a consulting company, was formed in response to this.

A quotation was submitted and approved. Thereafter the tender was divided and NGDC was awarded the investigation work in Kavango and Bushmanland (Figure 1). Although the quotation was in respect of Phase 1, work was to consist of two phases.

In summary, Phase 1 was to consist of :

* a desk study of all groundwater resources on record
* a field survey
* progress reports
* a final report

The desk study (Progress Report No 1) required the appraisal of data already available, and was submitted in October 1990. The field survey provided the present status of groundwater conditions based on a field hydrocensus and served to supplement the data presented in the desk study. During the field survey period, consultations were held with the Department of Water Affairs in Windhoek and various government departments in Rundu. Progress Report No 2 was submitted in December 1990, and the field survey was completed by late January 1991.

Information for Phase 1 was managed with the aid of database systems designed specifically for this project. Water samples collected during the survey were analyzed by the laboratory of the Department of Water Affairs.

The results of the survey have now been correlated and assessed and the findings set out in this report. In compliance with the terms of reference, recommendations are submitted for Phase 2 of the investigation. In addition, other aspects deserving attention are discussed. The object of this investigation is to provide a better understanding of one of Namibia's important groundwater reserves.

It should be emphasized that the programme proposed for Phase 2 be flexible and that it be guided by the findings during its execution, in consultation with the Department of Water Affairs.

This final report constitutes a formal proposal from NGDC to undertake the Phase 2 investigation.

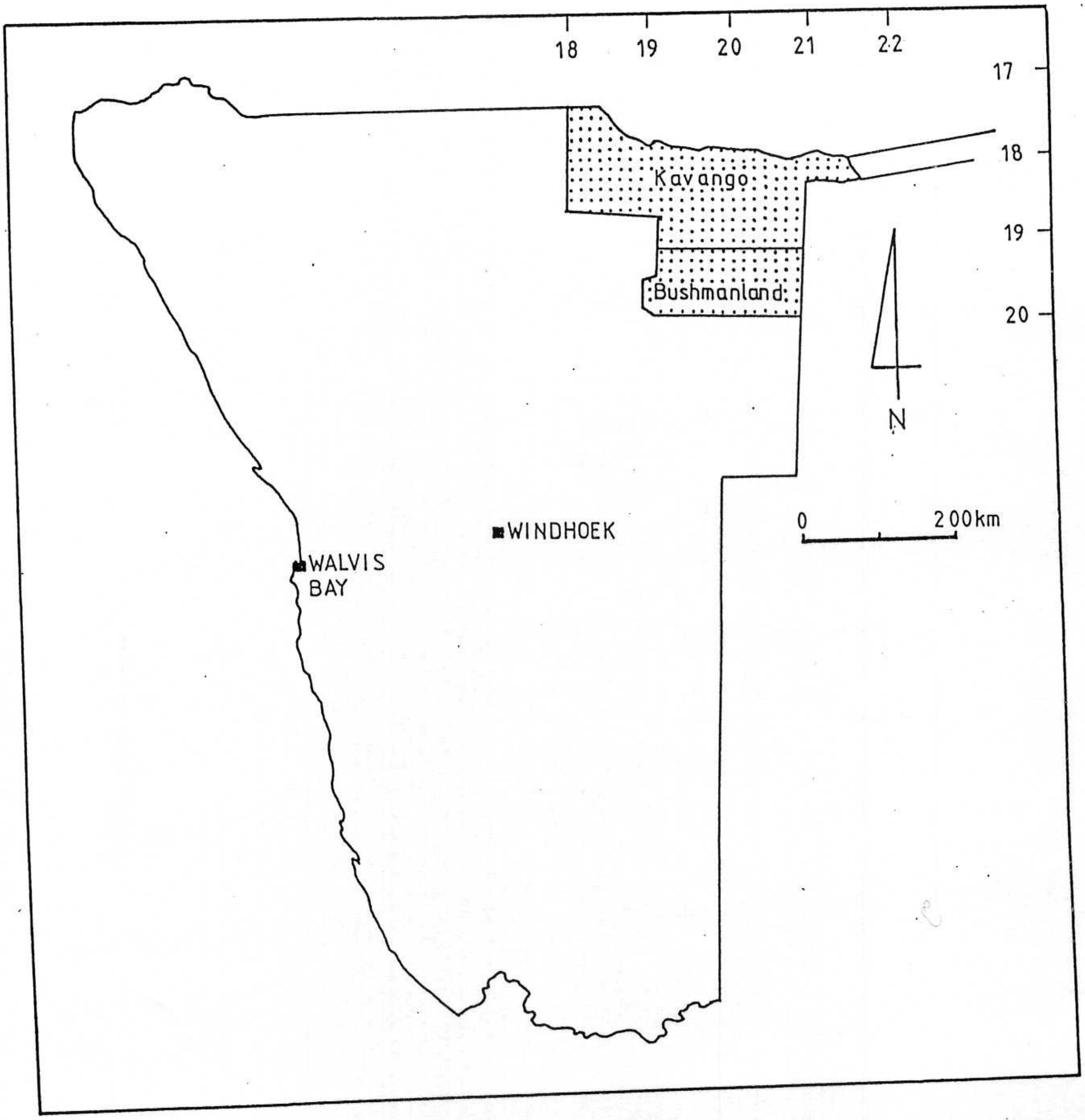


Figure 1 Kavango and Bushmanland, locality plan

2 REGIONAL CHARACTERISTICS

2.1 POPULATION AND ECONOMIC ACTIVITY

2.1.1 KAVANGO

Figure 2 illustrates the distribution of the 5 main tribal groups in Kavango. Population distribution is determined by two factors, namely accessibility to water, and accessibility by road. Predictably the population is largely restricted to a narrow zone adjacent to the Okavango River and to a strip along the main Rundu - Grootfontein highway. Isolated settlements occur throughout other areas but these are very scattered and make up a small part of the overall population. The map showing water point distribution (Figure 9) gives a good indication of the population distribution. Rundu is the administrative and commercial centre of the territory and therefore supports a large urban and peri-urban community.

The Kavango comprise approximately 9% of Namibia's population. Approximately 6% of Kavangos are urbanized, living mainly in Rundu. The rest of the population are traditionally rural and pursue an essentially subsistence type economy. Namibia's largest belt of exploitable natural forest lies to the south of the Okavango River and has formed the basis for a thriving furniture and curio industry which is dominated by the Mbunza tribe. Fishing forms an important part of the livelihood of communities settled along the Okavango River. Throughout the rest of Kavango, with the exception of some uninhabited areas in the south and southeast, cattle farming is the main economic activity. Subsistence crops, which are planted during the early part of the rainy season, include mahangu (pearl millet), maize, sorghum, legumes and melons. Only

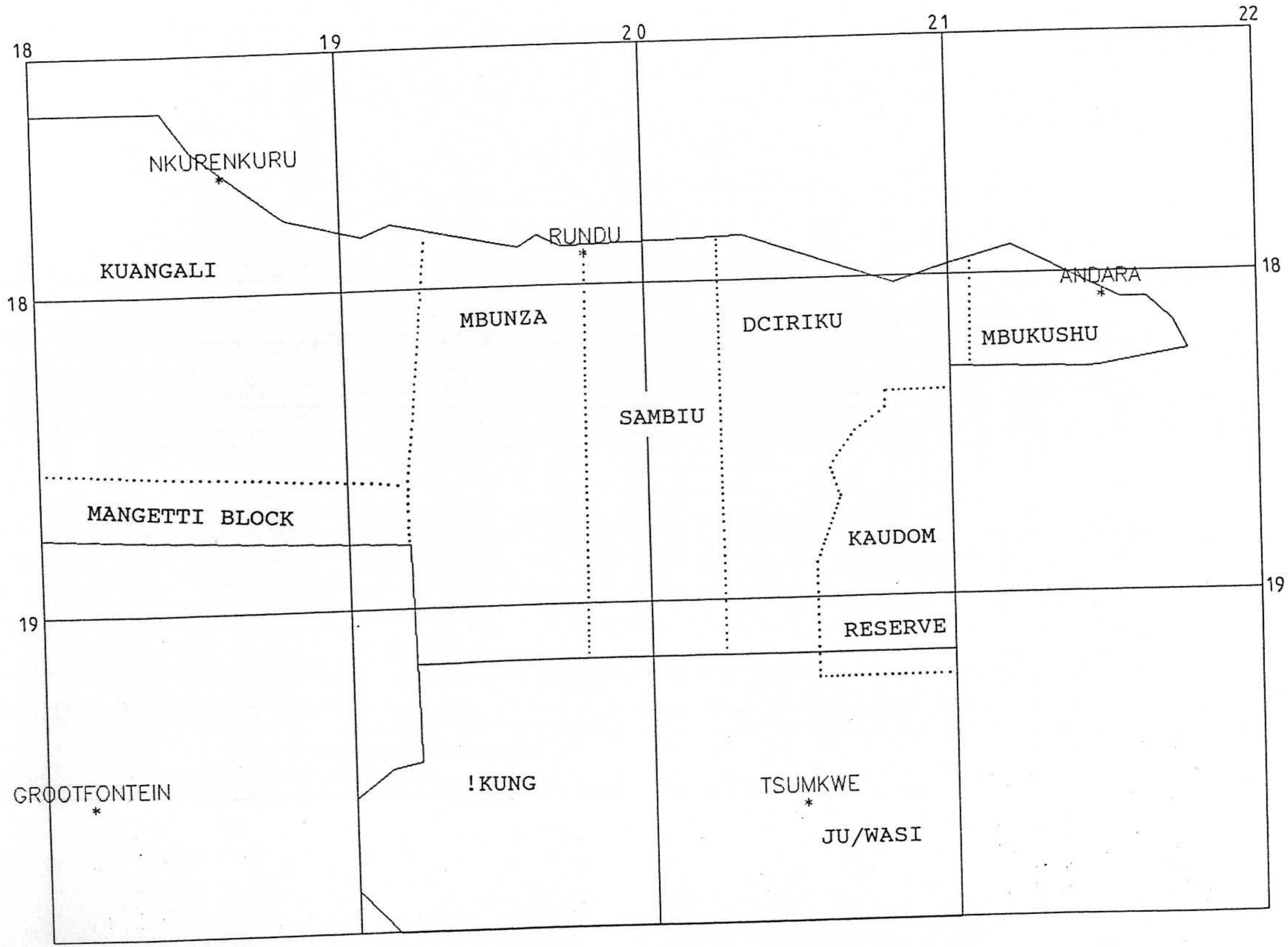


Figure 2 Tribal distributions in Kavango and Bushmanland

a handful of the farmers practise any serious cash crop farming.

Statistics quoted from the former Directorate : Development Co-ordination, indicate that more than 55% of the population of Kavango is less than 18 years of age, and that only 15-20% of the total are economically active. These figures, although low, are in keeping with the developing third world character of the region.

2.1.2 BUSHMANLAND

The rural population were found, during the field survey, to total 3609. This, when added to an approximate 400 reportedly living in Tsumkwe, gives a total of around 4000 people in Bushmanland. The population of Bushmanland may be divided evenly into two major groups, the Ju/wasi of the east and the !kung of the west. Little or no social contact is maintained between the groups who differ both in general appearance and lifestyle.

In the east the people have pursued the more traditional hunter-gatherer existence and it has only been during the last two decades that a gradual but distinct move has been made towards a more sedentary, agricultural and market oriented livelihood. The institutions which have assumed an important role in this process are the Ju/wa Bushman Development Foundation (JBDF) and the former San Affairs Committee of the Directorate : Development Co-ordination. One of the main strategies employed has been the establishment of water points (boreholes with hand-pumps) in traditional living and hunting areas (n!oresi) where communities have been able to settle and conduct small scale farming and gardening along with traditional and other economic activities (eg. curio manufacture). These efforts have by and large been successful in tackling some of the social and economic problems of the area.

A greater degree of subsistence farming activity has characterised the western populace for some time. This relates to their origins in Kavango and Caprivi West where sustained interaction with other population groups has led to the development of mixed race people and has influenced strongly their way of life. Many of their number were resettled in western Bushmanland from other areas during the pre-independence period and as a result have not been established in the territory for very long. Nevertheless they have settled in permanent villages characterised by formal pole-and-thatch housing more typical of the Kavango than of eastern Bushmanland, where the bee-hive shaped, grass and stick structures suited to a more traditional, nomadic lifestyle, predominate.

The numbers of stock in Bushmanland total 865 cattle and 420 goats according to field survey figures. These are in agreement with figures quoted for the desk study where it was reported that there were 760 head of cattle (excluding those held at the breeding stations) according to a survey of early 1989. Of these cattle the major proportion are kept by the Ju/wa people in the east. Among the difficulties encountered by the Bushmen farmers are stock losses due to predators [1] and the presence of large areas where poison-leaf abounds.

[1] It is of interest to note that a certain Tsamxao Toma of Gautscha Pan lost another 2 cattle, from his herd of 70, due to lion attack, during our survey of SE Bushmanland, during January 1991. This brings his total losses to ±100 over the decade he has been farming.

2.2 PHYSIOGRAPHY AND CLIMATE

2.2.1 KAVANGO

Kavango is a relatively flat, sand covered region which slopes gently to the north, towards the Okavango River (Figure 3). In certain places permanent dunes provide the only positive relief features in the region. This essentially flat surface varies from 1200 m elevation in the central southern part, adjacent to the Grootfontein District, to 1150 m in the northwestern corner and to 1000 m in the northeast at Andara on the Caprivi West boundary. The south-north regional gradient is thus of the order of 0.8 m/km or 0.08%. As a result of this and the permeable nature of the sandy soils, very little surface drainage takes place. Generally, rainfall never exceeds the absorption capacity of these soils. Deep horizontal soil drainage does occur after heavy rains in the vicinity of well-defined omiramba. The east flowing Okavango River, which drains from Angola in the north, is the only perennial watercourse in the region. Almost no water from the Omuramba Omatako reaches the Okavango River. Surface waters present at the confluences of deep omiramba and the Okavango River are largely the result of lateral flooding by the Okavango River itself, for instance at the confluence of the Omuramba Omatako.

In the southwest of the territory no omiramba are developed and drainage is mainly via shallow depressions into numerous pans.

In general the Kavango region lies within the tropical summer rainfall zone and conditions may be described as semi-arid, warm, with a moisture deficiency in all seasons (classified as "hot steppe" according to the Koppen System). The temperature averages 22,5° C with diurnal

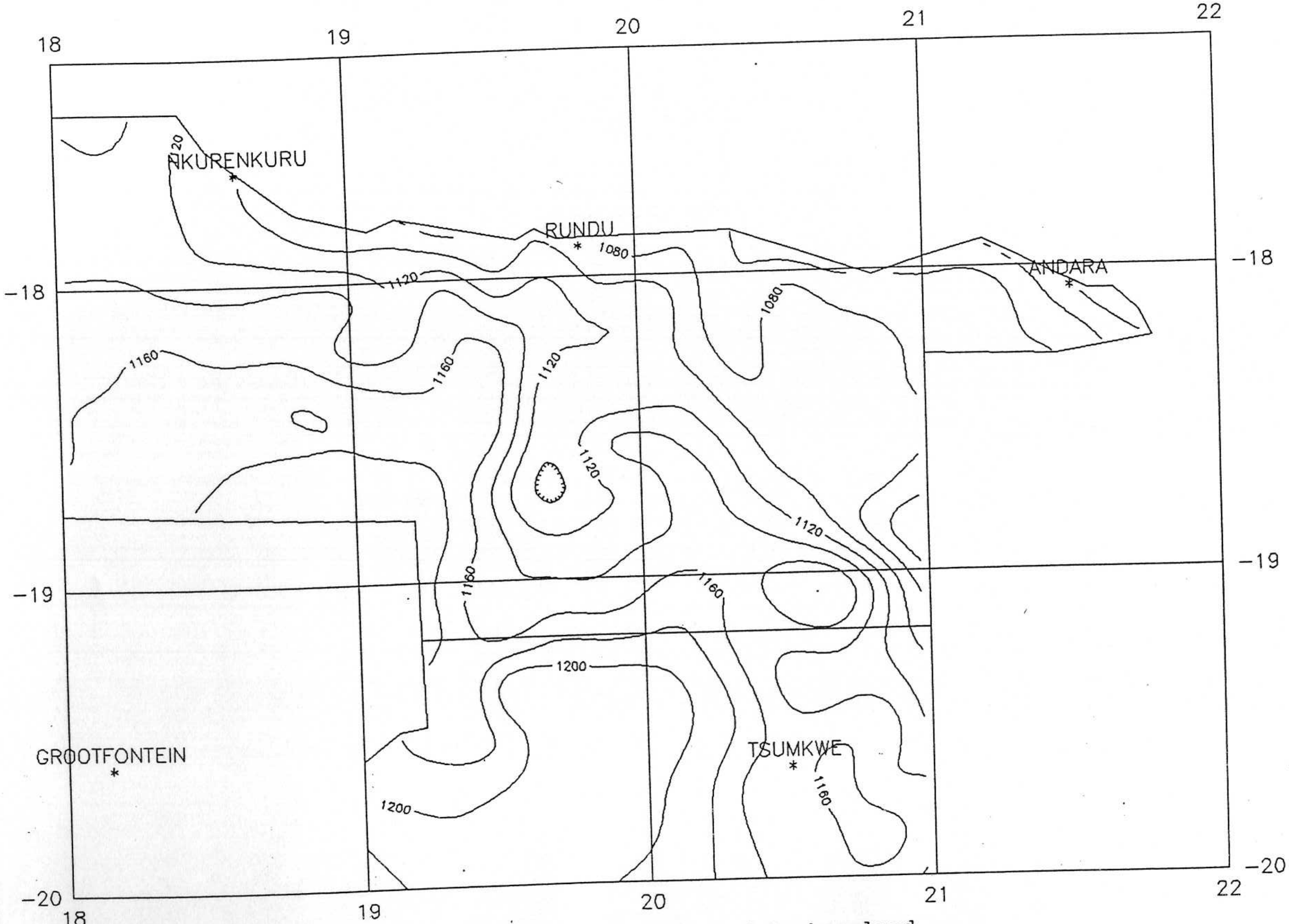


Figure 3 Generalized topography of Kavango and Bushmanland

variations of up to 20° C during summer and 13° C during the winter months. Relative humidity ranges from 30% for the dry season to 60-70% for the rainy season. Rainfall averages 600 mm decreasing slightly from northeast to southwest across the territory. Although the rainy season lasts from October to April, 80% falls during the period December to March.

2.2.2 BUSHMANLAND

The northern, central and western parts of Bushmanland are sand covered and relatively flat (Figure 3), the only surface features being permanent longitudinal, eastward oriented dunes. In the southeast the essentially flat surface is broken by the Aha Mountains which extend eastward into Botswana. Much of the surface in this part of the territory is covered by a thick calcrete layer which gives rise to an essentially thorn scrub type of vegetation. This is in contrast to the woodland vegetation which is more prevalent in the sandier areas of western Bushmanland.

Negligible surface runoff takes place in the sand covered parts due to their higher absorption capacity. The three major omiramba in Bushmanland are the north flowing Omatako in the west, the northeast flowing Nhoma in the north, and the east flowing Danieb in the south. In the east, limited surface runoff accumulates in numerous pans.

Bushmanland receives 400-500 mm rainfall annually, most of which falls during the period October-March. Evaporation ranges from 2600-2800 mm/a.

2.3 VEGETATION

The vegetation in Kavango and Bushmanland is classified as 'forest savanna and woodland' by Giess, W., in his 1970; Vegetation Map of South West Africa. This consists of trees and shrubs in variably sized stands intermixed with grassveld. The typical "dry forests" of the north containing dense concentrations of a variety of trees, including palms which have adapted to the humid conditions, cover most of Kavango. Open grassveld and shrubs occur locally along interdune corridors and omurambas.

2.4 GEOLOGY

2.4.1 GENERAL GEOLOGY

An overview of the general geology and stratigraphy of the region is given in Table 1 which has been compiled from a number of references. Stratigraphically the overall sequence can be described as : basal rocks of the Damara Sequence, followed by Karoo Sequence sediments overlain and intruded by volcanics of Karoo age and covered by Cretaceous Kalahari Group sediments.

2.4.2 REFERENCES FOR TABLE 1

1 Boocock and von Straten, 1962;
2 Haughton, 1969;
3 Truswell, 1970;
4 S.A.C.S., 1980;
5 Albat, 1978.;
6 Hegenberger, 1982;
7 Hegenberger, 1983;

8 Siedner and Miller, 1968;
9 Siedner and Mitchell, 1976;
10 Meddlycott, 1980;
11 Wilson, 1980;
12 Balfour, 1981a;
13 Hegenberger et al., 1983;
14 Hedberg, 1979;
15 Martin, Geol. Map of S.W.A., 1963;
16 Martin & Porada, 1977.

2.4.3 TECTONICS

The broad tectonic framework of the area is dominated by the configuration of the pre-Kalahari surface (Figures 4 and 5). The north-northeast trending basement ridge in the east of the area forms the eastern limit to the westward deepening Kalahari Basin. In the north this basement high is less well defined with areas of elevated basement beneath the Omatako Omuramba, to the west (ie. south of Mashari), and to the east near Andara. Irregular pre-Kalahari topography to the west of Bushmanland forms the western and southwestern boundary to this important sediment repository.

Albat (1978) suggests that the outer limits and the floor of the basin consisted of uplifted fault blocks and associated sub-basins and the general stratigraphy is locally dependant on distance from, and the nature of, the rocks comprising the basement highs (Figures 6 and 7).

The thickness of the Kalahari Group sediments increases from the Dobe Pan - Sikereti area towards the concave westward, arcuate, basin axis in central west Bushmanland and southern Kavango. This axis which reaches a depth of more than 300 m extends northeastwards through southwestern Kavango into Owamboland (Figures 5 and 6).

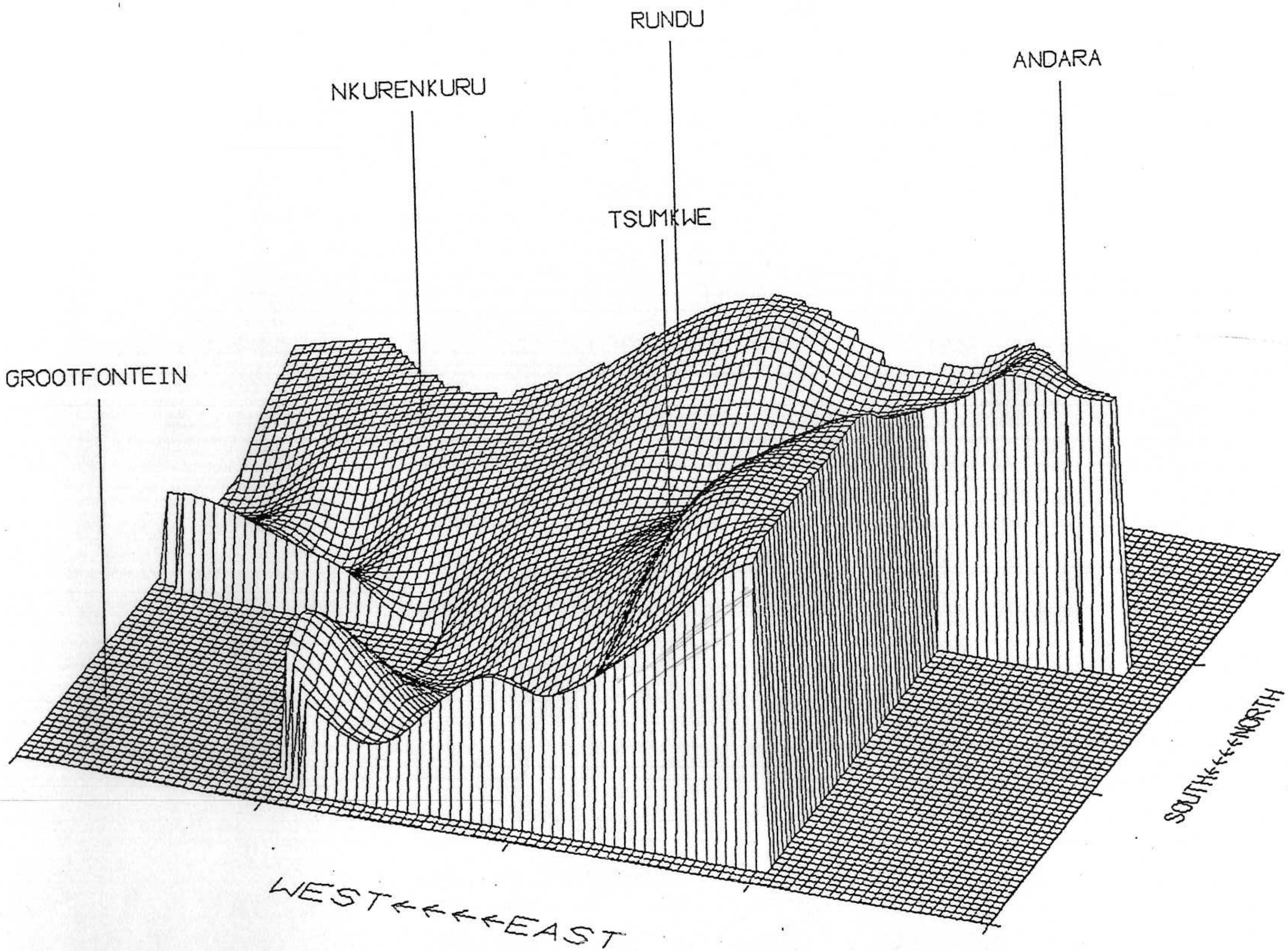


Figure 4 Kalahari Group basin floor topography

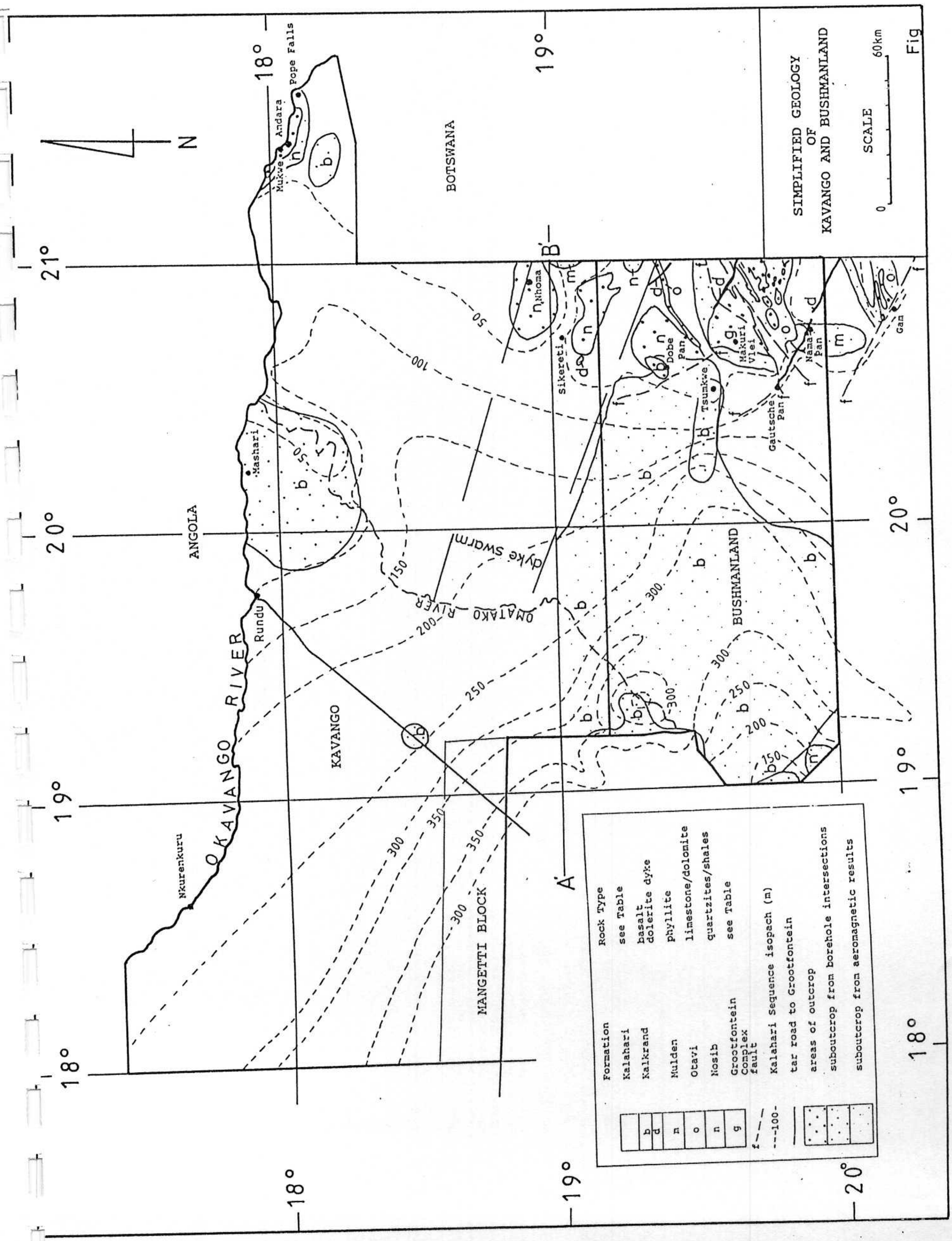


Figure 5 Simplified geology of Kavango and Bushmanland

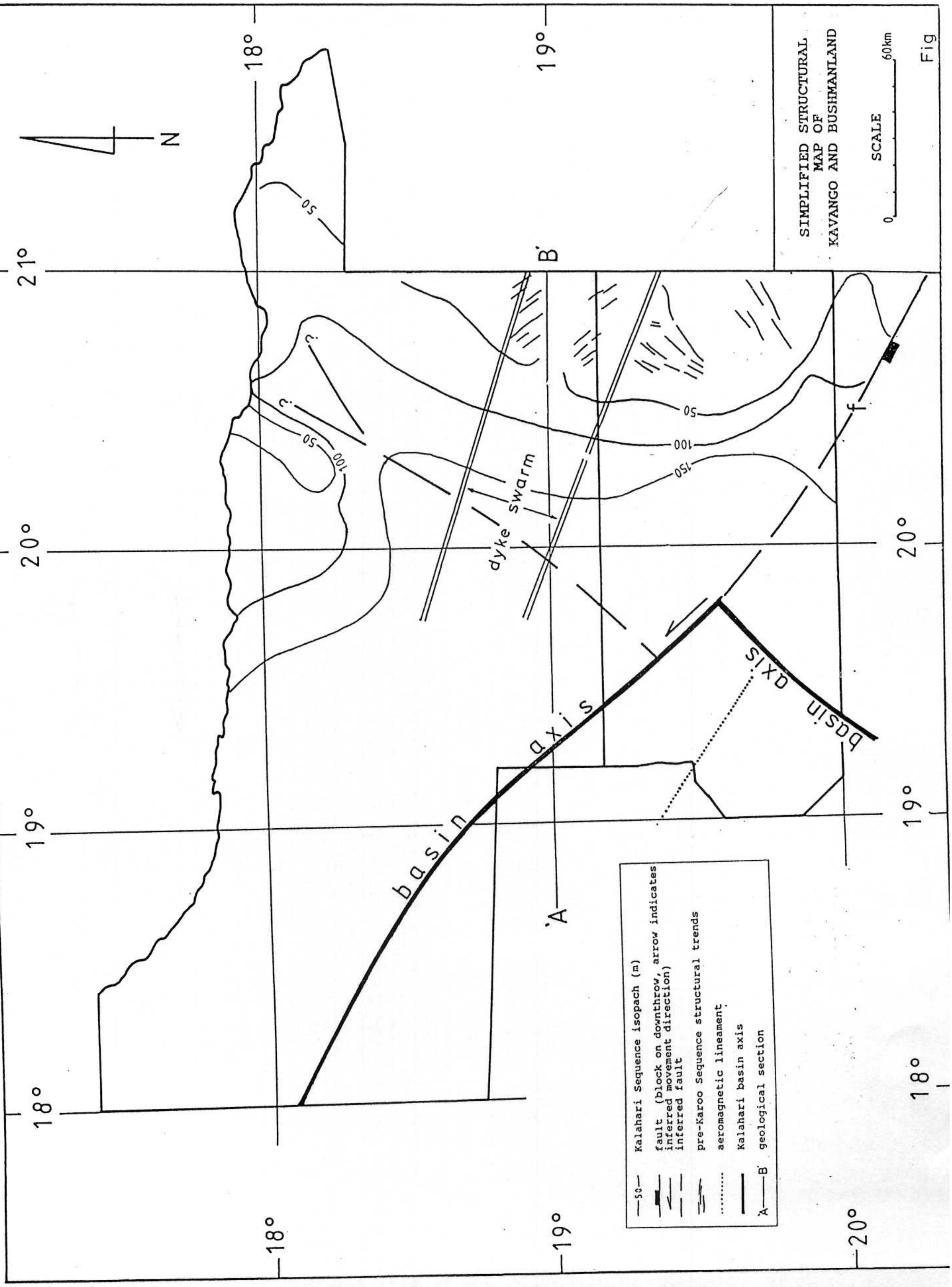


Figure 6 Simplified structural map of Kavango and Bushmanland

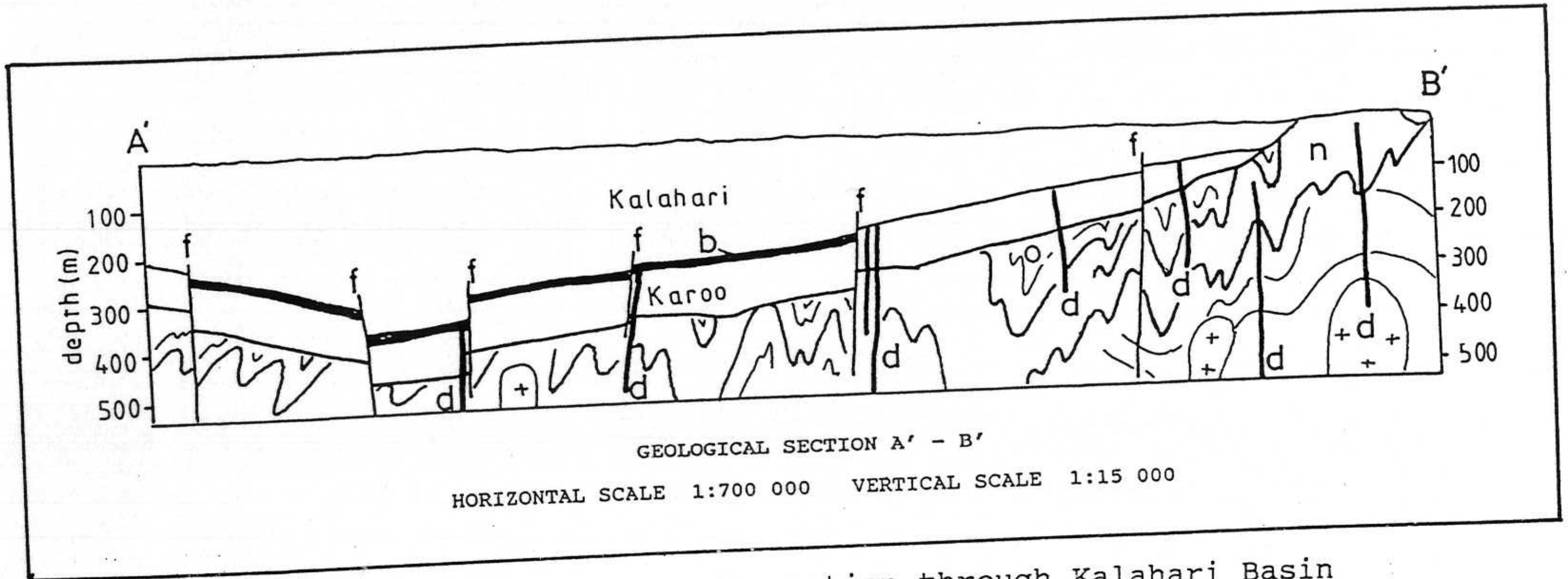


Figure 7 Schematic E-W cross-section through Kalahari Basin

See Figure 5 for legend.

The two arms of the basin axis reflect the two dominant structural fracture trends in the study area, these are :

* a strong northeast trend coincident with the Damara Orogen,

* a less dominant northwest fracture direction.

Reeves (1978c, Photogeological Map of Botswana 1978) has interpreted these two directions as tension faults and their recent seismic activity points to an association with the still active East African Rift (Jones, 1962; Scholtz et al., 1976; Reeves, 1972, 1978a). A southeastern extension of the northwest arm of the basin axis may be reflected in the faulting of Damaran carbonates at Gam in northeastern Hereroland. It is these faults which Albat (op cit) has reasoned to be the major control in the formation of the Kalahari Basin.

A change in the structural trend lines in the Damaran and pre-Damaran rocks occurs between Dobe Pan and Tsumkwe where the strong northeast Damara trend turns to the northwest. Hegenberger (1982) infers a natural swing in the basement structure as there are no obvious fault lines separating the areas. This structural discordance is partly coincident with the southern boundary of the east-southeast trending dyke swarm which Reeves (1978a and c) has interpreted as the failed arm of a short-lived Gondwana spreading axis (Figure 6).

2.4.4 GEOPHYSICAL CONSIDERATIONS

Various geophysical methods have in the past been employed to locate suitable aquifers in the study area. These are summarised below.

KAVANGO/BUSHMANLAND: GENERAL GEOLOGY AND STRATIGRAPHY

AGE	GROUP/SEQUENCE	FORMATION	DESCRIPTION	SURFACE DISTRIBUTION	REMARKS
recent	KALAHARI (5,6)	'Kalahari Sand' (1,2,3,4)	thin aeolian sands and loamy, calcareous soil with crusts of ferricrete and calcrete.	laterally extensive regional covering to all older rocks. Semistable to shifting dunes.	causes characteristic Kalahari surface features; longitudinal dunes with interdune drainage (omurambas).
to		Omatako Formation	ferricrete and ferruginous sandstone.	borehole intersections only	regional dips <5°; thickness of members variable and depend on proximity to edge of sedimentary sub-basins or floor rock highs; lower units reflect high energy scree erosion of fault activated Kalahari highs into depressions by sheetflow and minor drainage channels; silcrete and calcrete reflects moist and arid climes; CaC03 from Damara lithotypes.
		Eiseb Formation	thick layered, light coloured, sandy silcrete and calcrete; conglomerate bands in middle units	borehole intersections only	
late Cretaceous 64m.y.		Tsumkwe Formation	reworked sandy to clay rich conglomerate, poorly sorted basal scree with calcareous cement; minor mudstones.	borehole intersections only	
			4 small kimberlite diatremes; xenoliths of Nosib quartzites, Karoo dolerite + basal Kalahari rocks (11,12,13)	southwest of Sikereti	strongly altered- carbonatization and argillation; no diamonds were found.
Cretaceous	KAROO (6,7)	Kalkrand	plateau basalt.	borehole intersections only eg.; western Bushmanland, west of Tsumkwe, Dobe Pan area, Omatako/ Kavango river area, south of Andara and northeast of Mangetti Block.	aeromagnetic data indicate extensive distribution; western and central to eastern Bushmanland; probably underlies much of area under study.
to			dolerite dykes and dyke swarms	east-southeast trending dyke swarm through Sikereti; other east-southeast trending dykes to the south.	well defined on aeromagnetic data.
Jurassic 126-178m.y.		Omingonde (10)	conglomeratic mudstone	borehole intersections only; 12km southwest of Sikereti	intruded by dolerite dykes ref:'Sikereti Mudstone'; may be more extensive beneath basalts(6)
early Cambrian 500m.y.	DAMARA	Mulden (6)	greyish phyllite and quartz phyllite	borehole intersections only; Nama Pan area	aerial photographs indicate more extensive areas to south into Hereroland East overlain by thin cover.
Namibian 700m.y. to		Otavi (6)	northeast trending, folded light-grey to pink stromatolitic limestone and dolomite and minor dark shale.	Aha Hills and northeast linear strip to north.	forms most significant relief in study area
early Namibian 900m.y.		Nosib (15,16)	fine-grained greyish to brown, feldspathic quartzites with interbedded sandy shales.	along Tsumkwe-Sikereti road and Nhoma Omarumba, Andara and Popa Falls area.	aerial photographs indicate more extensive areas; the resistant quartzites form rapids and cataracts in Kavango River(14).
>1800m.y.	PRE-DAMARA (6)	Grootfontein Complex	coarse-grained pink to grey porphyritic granite intruding amphibole schist, gneissic granite, minor metalava and quartzite.	Makuri Pan, Gamsa Pan and Gautsche Pan areas and to northeast.	forms small isolated outcrops; locally sheared; quartzite xenoliths in granite.

Table 1. Kavango/Bushmanland:General Geology and Stratigraphy

2.4.4.1 Seismology

During 1968 limited seismological survey work was carried out along the road between Tsumkwe and the Botswana border to the east. The work was conducted by M.R. van der Spuy of the Geological Survey, Windhoek to locate water in the area.

Four velocities were delineated which corresponded to an upper, dry, coarse sand (245-900 m/s), sandy clay (1000-1800 m/s) with clay-rich sand (1800-2850 m/s) of the Kalahari Group and the underlying granitic basement with velocities between 3200 and 7000 m/s. The profiles indicated reflective surfaces consistent with the stratigraphy in the area; that is, a thin dry sand cover overlying clay-rich sand and sandy clays underlain by a variable granitic basement.

From these profiles, Kalahari sediment-filled basement palaeovalleys which extended beneath the known water table level were targeted and drilled for water without success. At the time of this test work, a borehole 19km east of Tsumkwe (WW9158) which was drilled into granite, yielded 1.125 m^3/h. It appeared that the water was derived from fractured and weathered basement rather than the overlying Kalahari sequence.

It was concluded that the Kalahari sediments in this area are not thick enough to provide a reliable aquifer. Water located within these palaeovalleys is likely to be somewhat isolated with poor recharge unless adjacent to basement features which facilitate inflow from other areas.

2.4.4.2 Aeromagnetic Data

Semi-detailed aeromagnetic survey coverage at a scale of 1:250 000 is available for the extreme southern part of Kavango and Bushmanland (sheets 1918, 1919 and 1920) (Figure 8). The survey was conducted at a height of approximately 100 m above ground over one kilometre spaced north-south survey lines. Although the resolution is too coarse to provide useful detail of local structures, it does afford an excellent regional guide to subsurface lithologies.

The late-Karoo plateau basalts which, from borehole intersections are limited to the extreme western parts of Bushmanland and west of Tsumkwe, exhibit a highly turbulent magnetic signature. The distribution of this signature indicates that much of central and western Bushmanland is underlain by this rock type. Similarly, the dolerite dykes exhibit a diagnostic intense linear magnetic pattern. The dyke swarm which passes through Sikereti is easily discernable as are the twelve individual dykes comprising the swarm. Interestingly, the southernmost dyke of this swarm truncates the basalt forming its northern margin in this area.

Several northeast- and northwest-trending magnetic lineaments are apparent within the area underlain by basalts. These are interpreted as faults providing discontinuity in the magnetic fields and/or dykes underlying the basalts which probably also acted as feeders to the lavas. Of significance is a prominent northwest-trending linear magnetic feature in southwestern Bushmanland which is coincident with that mentioned by Simmonds (1986). It is pointed

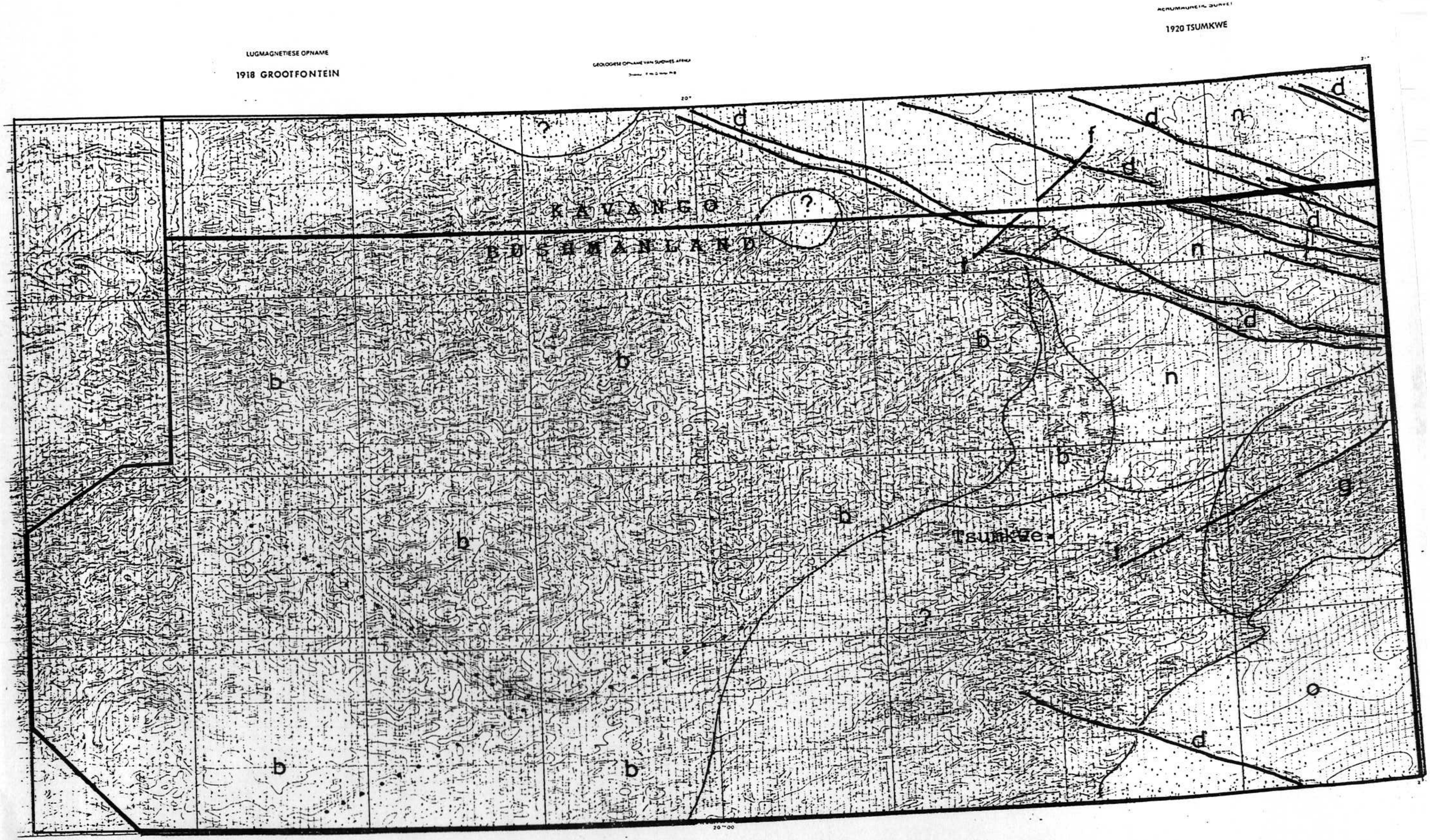


Figure 8 Semidetailed aeromagnetic survey of Bushmanland

out in this report that south of this linear feature, borehole yields decrease markedly (Figure 8).

The basement rocks are illustrated by a diagnostic variation in magnetic intensity. The oldest Grootfontein Complex rocks exhibit strongly northeast-linear, complex patterns suggestive of highly variable lithologies and intense tectonism. The carbonate rock types of the Otavi Formation have in contrast, a subdued, quiet signature indicative of the magnetic homogeneity of this rock type. Areas underlain by the Nosib quartzites have similar calm magnetic properties although interference from the dyke swarm causes local linear turbulence (Figure 8).

2.4.4.3 Ground Magnetic Survey Work

Little is known of any attempts to locate water bearing structures in the study area using ground magnetic survey work. It is apparent that this method should be useful in delineating contacts between contrasting lithologies in areas of shallow or sub-outcropping basement. Dykes within basement should be easily delineated and faults may provide sufficient discontinuity across them to be discernable. Although this method is relatively quick, it does not provide any positive indication for the presence of water. Therefore this method should be used to detect favourable structures only and should be augmented with electrical techniques. In addition, care must be taken in the interpretation of the results to assess correctly the depth of any features delineated so that only near-surface structures are considered.

2.4.4.4 Electrical Methods (Resistivity)

These methods have been widely used in the study area with varying degrees of success (Howard, 1989; Simmonds pers. comm). In areas of shallow basement, profile surveys should be used to detect steep structures such as are usually found in basement environments (lithological contacts, faults and/or fracture zones etc.). If local water table conditions are not known, sounding surveys should precede the profile surveys to assess the expected water table depth and background resistance of the lithologies. Sounding surveys should also be used to determine the presence of shallow, conductive clay-rich layers which reduce current penetration and hamper definition of deeper structures.

In areas underlain by thicknesses of Kalahari sediments greater than water table depth, sounding surveys provide important information regarding expected drilling depth and aquifer conditions. Layers of high resistance (>100's ohm/m) are usually silica-rich and provide the best yielding aquifers, either as coarse sand-rich horizons or silcrete beds. Layers of low resistance (<100's ohm/m) reflect clay-rich layers which should be avoided. Intermediate resistances should be assessed in the light of other data for the area, such as hydrochemistry, stratigraphy and structure.

2.4.4.5 Summary and Conclusions

Two domains of differing geophysical applications are present within the study area. These are :

* In areas of shallow or sub-outcropping basement where the water table is deeper than Kalahari Group sediments, aquifer location relates to basement features. Knowledge of basement geohydrological conditions is necessary and geophysical methods should be directed through the cover rocks. Useful geophysical methods include : ground magnetic surveys and resistivity profile and sounding surveys. The distribution of this area follows the basement high along the eastern part of the study area northwards towards Andara and westwards along the Kavango River towards Rundu.

* Within areas underlain by thick Kalahari Group sediments, only resistivity sounding surveys are of real value in targeting potential aquifers. It appears from the highly variable nature of the Kalahari stratigraphy that a knowledge of water table depth determines the minimum drilling depth and survey interpretation targets the aquifer.

Sufficient data is presently available to assess the general nature of the underlying lithology and structure of a particular area. Provided this assessment is done early in any groundwater investigation programme, the pertinent geophysical methods can confidently be applied and result in a fair level of success.

2.5 REGIONAL HYDROGEOLOGY

In broad terms water bearing strata, in the study area, can be sub-divided into two main classes, namely :

* primary aquifers - sand and sandstone of the Kalahari;

* secondary aquifers - fractured and weathered, pre-Kalahari bedrock.

Kalahari cover ranging from nil to in excess of 350 m in thickness is predominant throughout Kavango and Bushmanland and therefore constitutes the major aquifer (Figure 5). Pre-Kalahari inliers are present in the eastern parts of Kavango and Bushmanland where groundwater supplies are abstracted from secondary aquifers.

Attempts have been made to correlate Kalahari stratigraphy with groundwater regimes. Lower, middle and upper Kalahari aquifers have been defined and postulated as corresponding to the Tsumkwe, Eiseb and Omatako Formations respectively (Hegenberger 1982). For this concept to have practical field application it is necessary to establish beforehand, the existing level of knowledge regarding the distribution of the formations and how they correspond to variations in borehole yield and groundwater quality.

As shown in Section 2.4.3 above, the Kalahari was deposited in an undulating, tectonically active basin which, during Tsumkwe times, at least, comprised a number of sub-basins. The rates of deposition and sediment composition would therefore have shown some degree of variation across the area. Hegenberger (op. cit) states that periods of erosion followed the deposition of each of the formations. As a result it is not possible, with any degree of certainty, to assign thicknesses to any of the formations. Consequently, borehole depth and geographical location will not facilitate the identification of any particular water bearing horizon. Lithological information from borehole cuttings may give some indication of formation but in the absence of distinct marker horizons it is not possible to confidently identify which formation is intersected.

According to the CSIR water quality study (Huyser; 1980 & 1981), 13.9% of the boreholes in Bushmanland, and 6.5% in Kavango, yield water of quality poorer than C-Standard. These results are for areas of both primary and secondary aquifers and show no stratigraphic or lithological correlation.

Huyser (1982) presents a statistical summary of average and median water strike depths, borehole yields and TDS values related to lithology. No clear relationships are apparent from this summary which has thus little apparent practical value.

From recent drilling carried out by the Department of Fisheries and Water in the Mangetti of eastern Owambo, a deep sub-artesian Kalahari aquifer (>100 m from surface) has been intersected with indicated yields of >80 m^3/h (N. Hoad, pers. comm.; Sept 1990). Here the indication is that a distinct aquifer, characterised by high yields, underlies the Mangetti, presumably extending eastward into Kavango.

It is concluded that no obvious correlation exists between borehole yields, groundwater quality, and the regional Kalahari stratigraphy relating to distinct aquifer types.

In the case of secondary aquifers boreholes are aimed at distinct structures hosted by particular lithologies and as a result the relationship between lithology and variables such as yield and quality can be assessed in a more meaningful manner.

The lithologies hosting secondary aquifers include the following :

* Granite and metamorphic rocks of the Grootfontein Complex - the groundwater is commonly located in fractures, pegmatitic intrusions and in deeply weathered zones. Yields vary from around 0.1 to 3 m^3/h and quality from very poor to good.

* Dolomite and related carbonate rocks of the Otavi Formation - groundwater is abstracted from lithological contacts and from faults and joints which have been subjected to a degree of solution weathering. The main area for these aquifers is in the vicinity of the Aha Mountains of southeastern Bushmanland. Water quality is usually fair but with high alkalinity and hardness.

* Quartzites of the Nosib Formation - groundwater is abstracted from weathered faults and fracture zones. The main area for these aquifers is northeastern Bushmanland. Waters from the quartzites are mostly of good quality.

* Post Karoo basalt and dolerite - these rocks underlie large areas of Bushmanland and northern Kavango may yield groundwater along weathered faults. Clay development along the faults can result in poor yields, and at a few localities such as Dobe Pan, very bad water quality has been reported.

Regional borehole yield statistics, taken from the Departmental database, irrespective of aquifer lithology are illustrated in Figures 11 and 12 and for Kavango and Bushmanland can be summarised as follows :

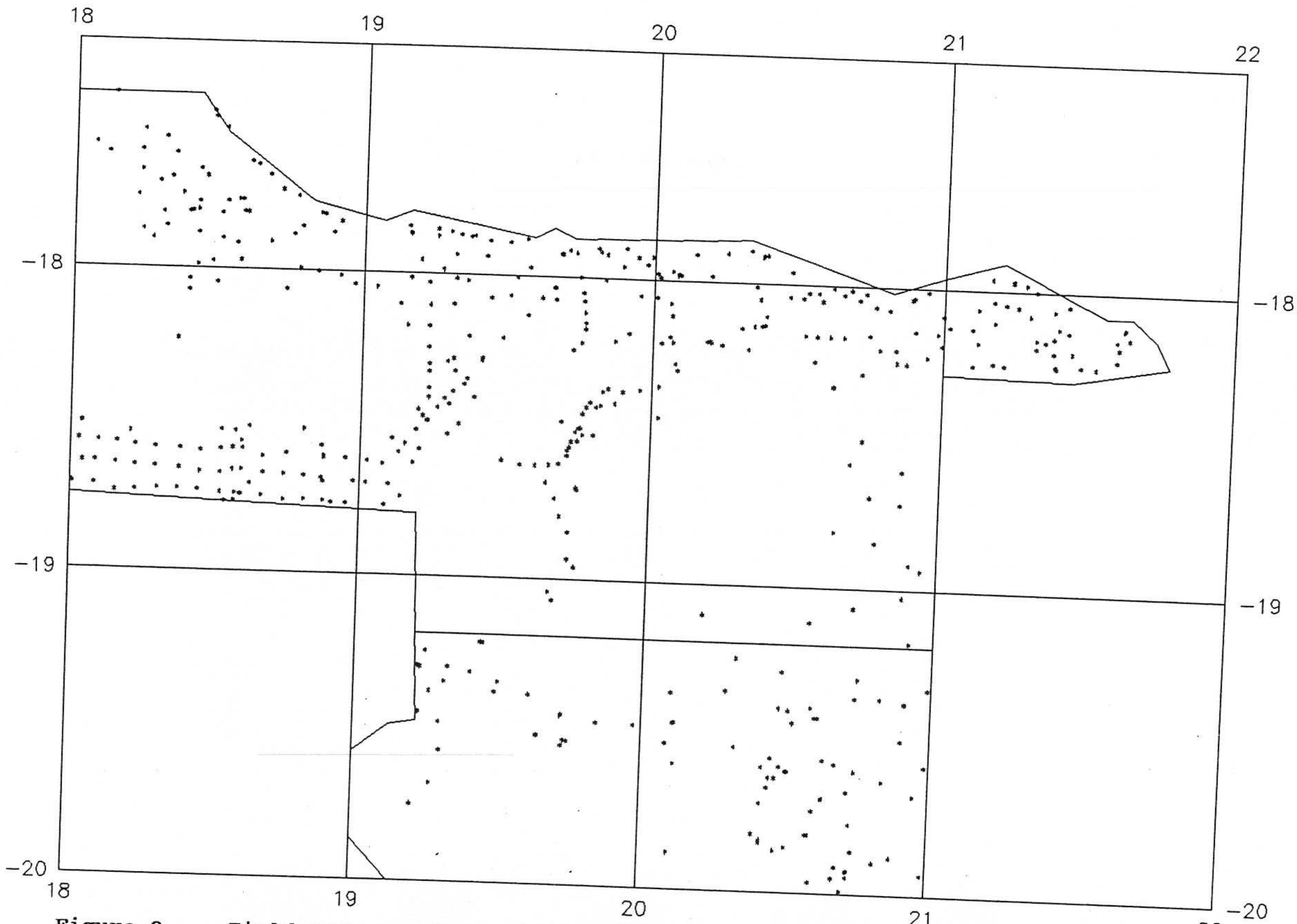


Figure 9 Field survey water point positions

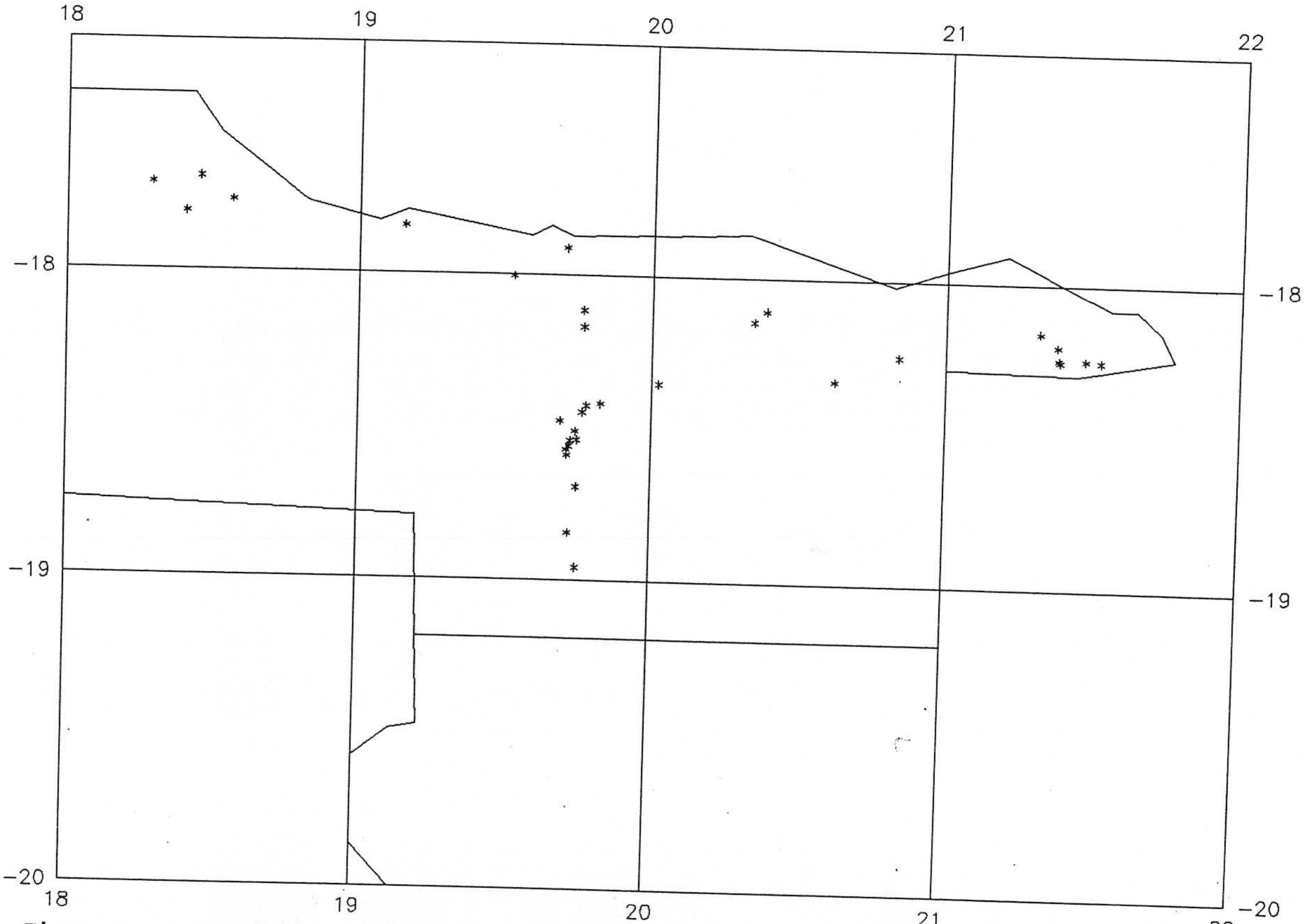


Figure 10 Dug-well positions

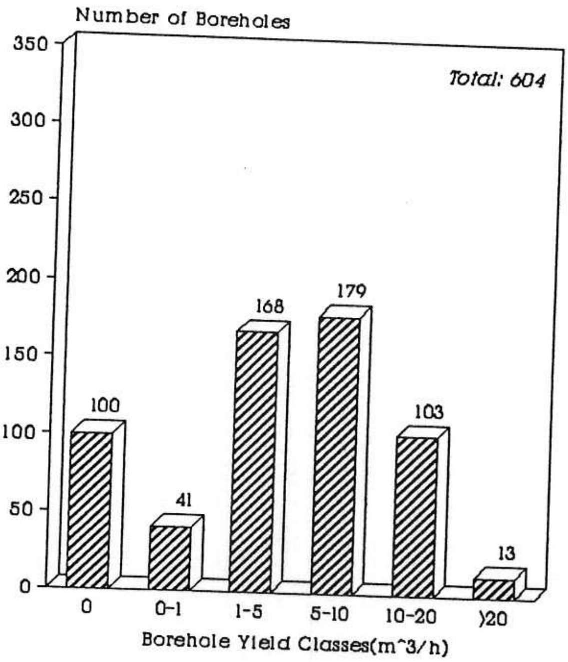


Figure 11 Borehole yield statistics (excluding adjacent farms)

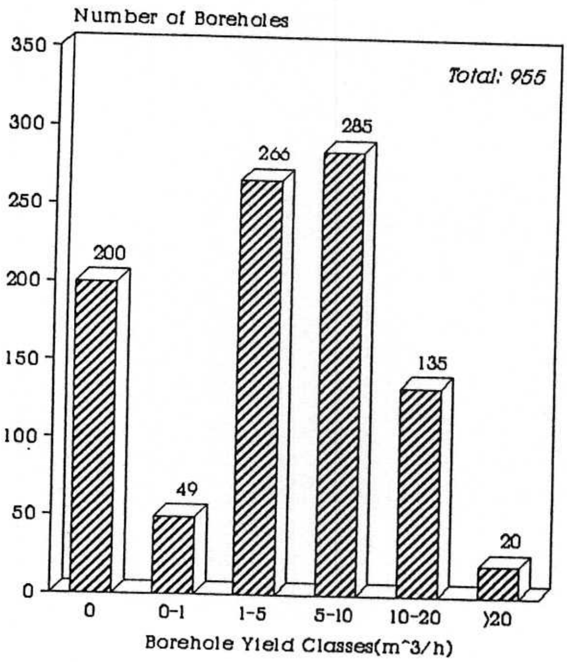


Figure 12 Borehole yield statistics (including adjacent farms)

* approximately 77% of boreholes have intersected strata capable of yielding in excess of 1 m^3/h (assuming that drilling has penetrated sufficiently below the water table);

* 49% of boreholes have yields reported to exceed 5 m^3/h:

* 19% of boreholes are capable of yields exceeding 10 m^3/h;

* 16% of boreholes failed to intersect useable quantities of groundwater.

Note: the statistics quoted are from Figure 11, ie. statistics from farm boreholes are excluded. Figure 12 includes all borehole statistics from degree squares 1718-1721, 1818-1821, and 1918-1920, as held on the database named GENERAL, and therefore include some 350 farm boreholes.

3 INVESTIGATION PROCEDURE

The work programme completed during Phase 1 is described in terms of the following components :

3.1 DESK STUDY

The desk study entailed the compilation, correlation and assessment of available information pertaining to the distribution, occurrence and utilization of groundwater in Kavango and Bushmanland. This exercise was conducted during September 1990 and presented as Progress Report No. 1. This report was an initial attempt to co-ordinate and integrate groundwater information for the study area and formed the basis for the planning and execution of the field survey. Notwithstanding the addition of significant quantities of information collected in the field, and which could have affected the overall picture, it was found that the historical data used, and the manner in which this was presented in the desk study report, afforded an accurate and reliable reference to groundwater conditions in Kavango and Bushmanland.

For the purposes of the desk study data was gathered from the following sources :

* Geohydrology Division , Department of Fisheries and Water;

* Ju/wa Bushman Development Foundation (JBDF);

* Department of Veterinary Services;

* Department of Wildlife, Nature Conservation and Tourism, Windhoek, Mangetti and Rundu;

* Ministry of Lands, Resettlement and Rehabilitation;

* Directorate of Geological Survey, Ministry of Mines and Energy;

* Department of Agriculture, Rundu

3.2 FIELD SURVEY

3.2.1 OBJECTIVES

In accordance with the requirements of the Tender No. F1/11 - 9/90, a field hydrocensus was carried out to assess the present status of groundwater resources in Kavango and Bushmanland. This involved a visit to all groundwater dependent communities in order to inspect, detail and measure aspects of the water installation, and obtain certain demographic information from the residents themselves. A summary of data recorded at each water point is as follows (see also the field questionnaire Appendix 5) :

* the location of used and abandoned or disused water points;

* the identity of the parties responsible for construction of the water points;

* any borehole number which would assist in identification on the database listings;

* the present situation regarding equipment installed, the condition, utilization, present yield (pumping rate), abstraction method etc.;

* static water level (after full recovery);

* number of and types of consumers (people, large stock and/or small stock, areas of crops irrigated etc.);

* the level of infrastructure, for example, schools, hostels, shops, hospitals which are dependant on the water point;

* the location of each water point on the appropriate 1:50 000 topographic sheet;

* the permanent marking of the water point with a new survey number for future identification;

* the sampling (750ml) of all water points visited. Where possible samples were taken from the water outlet while pumping was in progress.

3.2.2 PROCEDURE

Field teams operated on the basis of 3 x 6 day weeks in the field, returning to Windhoek every fourth week to report on progress and submit invoices. Regular trips were made to the project field office situated on farm Deo Volente 1026, Grootfontein District, 150km south of Rundu, to deliver water samples and submit field sheets. The database maintenance at the field office ensured the up-to-date entry of field data during the field survey.

The conductivity and pH of the samples was measured and rated to attach priorities to the samples for analysis. Samples were then despatched from the farm to the Departmental laboratory in Windhoek for analysis.

The Kavango Broadcasting Service of the NBC was used to create widespread awareness of the project and encourage co-operation from the rural population. In Bushmanland, contact with the development agencies active in the area served a similar purpose.

The Departments of Veterinary Services, Nature Conservation and Agriculture in Rundu were visited and discussions were held with relevant personnel throughout the duration of the field survey. This was done to keep them informed of progress and invite their comment.

The Department of Agriculture in Rundu has installed and is maintaining nearly 300 boreholes throughout Kavango. This infrastructure supplies more than 90% of the groundwater dependant population in the country and therefore formed the basis for the field survey. Mr P Horn, Director of this department provided great assistance in supplying maps and information pertaining to these installations.

To facilitate this maintenance, five teams, operating out of the agricultural tribal office within each tribal area, regularly visit these installations monthly, effecting repairs, and providing fuel and general back-up. This logistically difficult scheme must be commended as it is efficiently run and provides water supply points to very remote areas throughout the region.

Dr T Tolmay, Head of Veterinary Service , supplied current statistics on stock numbers throughout Kavango which have proved very valuable in cross checking those obtained during the field survey.

Nature Conservation has installed a number of water points in eastern Kavango in the Kaudom Nature Reserve and in eastern Bushmanland to supply game in the area. Mr B

Bytel of this department also provided information regarding these installations and made available accommodation at the Nature Conservation rest camps.

Two field teams, consisting of a consultant and an interpreter/guide, were deployed from Rundu. The interpreters were acquired on the recommendation of Mr P Horn as they have all had experience with the mobile maintenance teams and therefore have 'hands on' local knowledge of the tribal areas and the installations. The field survey teams moved through the country systematically from one tribal area to the next so that the benefit of the services of each interpreter/guide could be used to the full.

In Bushmanland, the field survey was largely based at Tsumkwe for access to the eastern parts of the country and interpreter/guides were drawn from the community at Gautscha Pan who are associated with the JBDF. These people were extremely helpful in providing information on the water point installations in the area. In western Bushmanland the two teams were based at Mangetti Duin and interpreter/guides were hired ad hoc from the areas in which operations were conducted.

It should be noted that the reactions of the many and varied communities to the field teams were very positive. This greatly assisted in the fulfilment of the field survey.

3.2.3 PROBLEMS ENCOUNTERED

The main problem encountered during the survey was accurate field navigation. The 1:50 000 topographic sheets were compiled from 20 year old aerial photographs and thus do not show any of the development of recent years. In Kavango, deviation off the main access roads resulted in negotiating heavy, soft sand tracks which could only be travelled at slow speeds and with four wheel drive. In addition to this, the seemingly endless forests through which these tracks penetrate, severely hampered navigation and map reading. Distances and compass directions were constantly monitored to locate positions on the map. Reasonably sound roads in the northwest of Kavango installed by the South African Defence Force (SADF) during their occupation of the territory afforded better access.

Conditions in western Bushmanland are similar to those in Kavango but improve eastwards where the thick, soft sands give way to harder, calcrete and consolidated sand surfaces in many places. In western Bushmanland various SADF bases have reasonable gravel road access built to support heavy military transport.

Although the interpreter/guides were of great assistance, difficulties were experienced in obtaining reliable demographic information, particularly stock figures, from the communities. The headman of a village, although revered for his age and standing in the community, usually had little knowledge concerning demographic statistics. The headmaster or teacher of schools serving an area were more aware of population numbers but less aware of the stock situation, and the pumpman appointed by the Deptartment of Agriculture to attend to the water installation, usually provided more accurate stock estimations.

It has been found that in many places, the historic data from the Departmental database does not correspond with the situation in the field. These circumstances have arisen owing to the fact that since the original water point development, replacements have been installed and the older installation lost with time. The only surviving 'remnants' of many older boreholes may be the database records themselves. Some boreholes, plotted on the Geohydrology Division's 1:50 000 topo sheets are far from any present settlement or infrastructure. Owing to the dense vegetation and general access difficulties, if no information is available from the locals as to the existence of a water point, it is virtually impossible to verify its position on the ground.

3.2.4 GEOPHYSICS

In spite of the presence of the Kalahari Group which provides a continuous aquifer virtually across the study area and results in readily available groundwater, there are incidences where water quality and/or yield are not suitable. As mentioned above, areas of poor yield are largely restricted to those underlain by shallow pre-Kalahari lithotypes where aquifers are hosted by basement rocks. Limited orientation geophysical survey work was attempted to correlate hydrogeological conditions with measured results.

Two areas were selected for this. These are in northeast Kavango, where poor quality water is abstracted from a lower, confined aquifer together with good quality water from an overlying perched aquifer, and in eastern Bushmanland where groundwater is hosted by structures in pre-Kalahari bedrock.

3.2.4.1 **Kavango**

Schlumberger resistivity depth sounding surveys were conducted over four localities in northeast Kavango to gauge the value of this method over variable quality groundwater conditions. The aquifer lies entirely within Kalahari Group lithotypes. The characteristics of each of these areas and the results of the surveys are described briefly in Section 4.3 below.

3.2.4.2 Bushmanland

As mentioned in Section 3.2 above various direct and indirect geophysical methods have application in locating potentially water bearing structures in pre-Kalahari bedrock. Variations of these methods were tested during the field survey and the results are presented, with comment on their applicability to local conditions, in Section 4.3.

3.3 DATA MANAGEMENT

3.3.1 PROJECT DATABASE

To facilitate the efficient completion of a task as broad as Phase 1 of the groundwater investigation in Kavango and Bushmanland, utilization of a suitable database is imperative. For this purpose "dBase IV" was purchased and a database designed to meet both the immediate needs of the desk study and the projected needs of the field survey. The development of a "down load" facility, enabling the transfer of data in ASCII file format, from the Geohydrology Division database, housed in the NCR running a UNIX operating system, to personal computers running on MsDos, cleared the way for the early manipulation of large volumes of data and the comprehensive assessment of regional characteristics and trends.

Difficulties were experienced with dBase IV not accepting the 'pipe' (¦) field separator, assigned to the ASCII files generated during the down-load from the Geohydrology database. To circumvent this the fields were initially imported into a spreadsheet programme, "Quattro Pro", and after transformation, exported in a from readily accepted by dBase. Manipulation of the data through dBase IV was straightforward and files were generated in forms acceptable for statistical and graphic applications in other software packages (see Section 3.3.2).

Appendix 4 lists the field specifications for the project database named "GENERAL", into which all basic borehole information was downloaded. This database has had an additional 126 borehole records appended to it from completion certificates held by the Department of Agriculture. The information held in this database covers some 933 boreholes of which approximately 300 are situated on farms adjacent to the study area. A 3,5" diskette has been supplied to the Department of Fisheries and Water, Geohydrology Division, which contains an ASCII text file, "GENERAL.TXT" which is a 'master listing' of data from boreholes, for which records are available, in Kavango and Bushmanland.

In relatively few places minor errors were detected in the raw data obtained from the Geohydrology database, eg. the switching of longitude and latitude co-ordinates or the omission of borehole function codes from boreholes clearly used for farming. These errors have, as far as possible, been checked on the borehole completion certificates, and subsequently corrected on the project data base.

A second project database, "CHEMDATA" has also been created to hold hydrochemical data, both historical and current. Historical data is incomplete on the Departmental database although printed records of analyses have been obtained for many boreholes. These have, together with the results from the current sampling been entered onto the project database.

The field specifications for CHEMDATA are also given in Appendix 4. Appendix 2 is a listing of the hydrochemical data entered onto CHEMDATA database from analyses of samples collected during the field survey. Data entered from pre-existing analyses had not been included in this printout but has been given to the Department on disk.

Due to the differences between the type of data contained in GENERAL and that generated during the field survey, a separate database "F_SURVEY" was set up for the field data entry. Field specifications for this database are given in Appendix 4. The original data held in GENERAL have been kept distinct from data in F_SURVEY. Where borehole data has been correlatable, selected fields have been copied from GENERAL into F_SURVEY to make these records more complete. An abbreviated listing of F_SURVEY is given in Appendix 1 while a more complete listing has been separately bound and handed to the Geohydrology Division of the Department of Fisheries and Water to serve as a ready reference to groundwater points in Kavango and Bushmanland.

Corrections have been made, on the database F_SURVEY, to the records from a number of boreholes that were found, during the field survey, to be incorrect. These records have NOT been amended in GENERAL.

3.3.2 COMPUTER-DRAWN CONTOUR MAPS (DATA MANIPULATION)

A grid system was constructed to accept the longitude and latitude co-ordinates from the database into a computer contouring software package called SURFER (Golden Software inc.). Contour maps were generated to illustrate the broad characteristics of the study area. To maximise the authenticity of data representation, the following procedures were carried out :

* To correct for the unequal dimensions of longitude and latitude on a square grid without distortion, the latitude, or y values, were modified by the formula :

  y(lat.) = ((lat. - 17.13393) x -1.05)-17.13393

* Contouring was constructed from a 25 x 18 line square matrix creating 450 additional calculated values over the grid for contouring. Various statistical procedures were applied to the data being contoured in order to detect any linearity in trends that may be present.

* For the purposes of the desk study report, borehole data for the farms in the Grootfontein area and Caprivi West were included (see below) and contouring of the whole map area was specified (that is, 17.25/18.00°E to 20.00/22.00°S). The area outside the boundary of Kavango and Bushmanland was then blanked resulting in the plotting of contours within this boundary only. This method therefore incorporated data outside the study area and increased confidence levels with respect to interpretation and edge effects.

* The gridded data was then quarter-splined resulting in a smoothing effect to produce meaningful trend definition without the clutter of extraneous local irregularities.

* All the contour maps were plotted at a scale of 1:2 000 000 (that is, 1cm = 20km = 0.1874941 degrees of longitude or 0.1785658 degrees of latitude)

4 INVESTIGATION RESULTS

4.1 HYDROGEOLOGY

4.1.1 WATER TABLE ELEVATION

Figure 13 is a contoured plan of the elevation of the groundwater table above mean sea level, generated from data collected during the field survey. A similar plot was presented in the desk study (Progress Report No 1) derived from water levels measured, in general, at the time of drilling only. As a result, water levels were taken over several decades and may have incorporated fluctuations through time. The same broad features are displayed by the two plots with only minor discrepancies regarding detail. The inference is, therefore, that in this region the overall patterns of groundwater movement are constant, as would be expected, and that the picture produced from historical data, which represents a large time span, is still of relevance. Potential differences in these patterns may be present due to the incorporation of an additional 300 farm boreholes into the original Departmental dataset. This would have influenced marginal areas only and should not affect the surface significantly.

A criticism that may be levelled at the basic method used for these plots is that collar elevations are, in all cases, merely estimates from the plots of borehole position on the 1:50 000 topo sheets, and would therefore suffer from any inaccuracies in plotting. In spite of these constraints, the topography of the water table surface clearly indicates the main directions of groundwater movement and the location of recharge areas.

probe aquif.

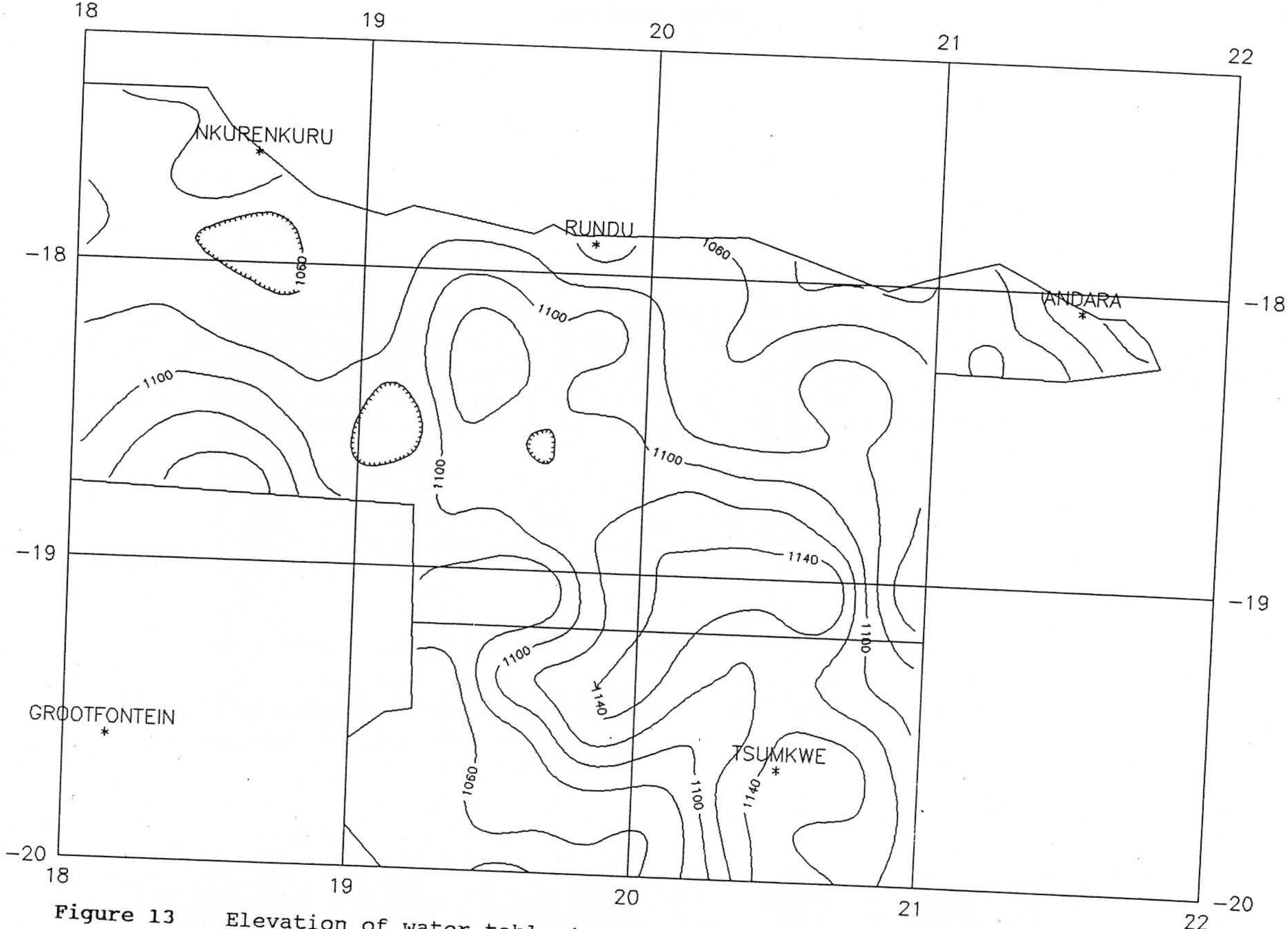


Figure 13 Elevation of water table (contour interval 20 m amsl)

Regional flow characteristics suggested by the updated water table surface (Figure 13) are as follows :

* An elongate ridge in the water table passes approximately northwest from near Tsumkwe to immediately southwest of Rundu. Groundwater drains towards the northeast and southwest.

* Another pronounced area of elevated water table underlies the Mangetti, draining northwards towards the Okavango River.

* South of Nkurenkuru, a water table depression is shown by the 1060 m contour line. Simmonds (1987, p 220) suggested that this may result from a permeable bedrock feature which drains groundwater from all sides. In this area the Kalahari exceeds 200 m in thickness and therefore this feature must be supplied through the Kalahari lithotype rocks, probably via reactivated bedrock structures within the Kalahari sequence.

* For most of its course across northern Kavango the Okavango River may be considered to be 'gaining', ie. groundwater is seeping into the river as opposed to river water replenishing the groundwater.

* In southwestern Bushmanland a marked drop in the water table is shown.

4.1.2 WATER REST LEVELS

One of the major factors to be considered in an appraisal of the groundwater is the water rest level (depth from surface to water table). This will determine whether hand dug wells or shallow boreholes equipped with hand-pumps will be adequate, or alternatively, whether deep boreholes with motorized pumps will be required for groundwater abstraction. A contoured plot of water rest levels was generated from historical data and seen to mimic the same plot derived from data collected during the field survey (Figure 14). From this figure, a large area, extending from east of Rundu southwards to around Tsumkwe, is shown as having a rest water level of 20 m and less. This area of shallow water table corresponds well with the main central groundwater divide described in Section 4.1.1 above. Comparison of this 20 m contour with a plot of the positions of dug-wells visited during the field survey (Figure 10) serves to illustrate the correlation of water rest level with abstraction practice.

In the western part of Bushmanland and central southern Kavango (in a zone approximately parallel to the axis of the Kalahari Basin as described in Section 2.4.1), the depth to water table increases to in excess of 100 m which necessitates deeper, more expensive drilling. Costs are further affected by the need for motor-driven pump installations in this area.

Artesian conditions exist along the Omuramba Nhoma, at a borehole drilled by the Department of Nature Conservation and Tourism approximately 19 km southwest of Sikereti. Another occurrence of artesian water is at Shiguru, near the confluence of the Omatako and Okavango Rivers. Unfortunately the latter example produces water of very poor quality (see Section 4.2 below). These boreholes are indicated by an 'a' on Figure 14.

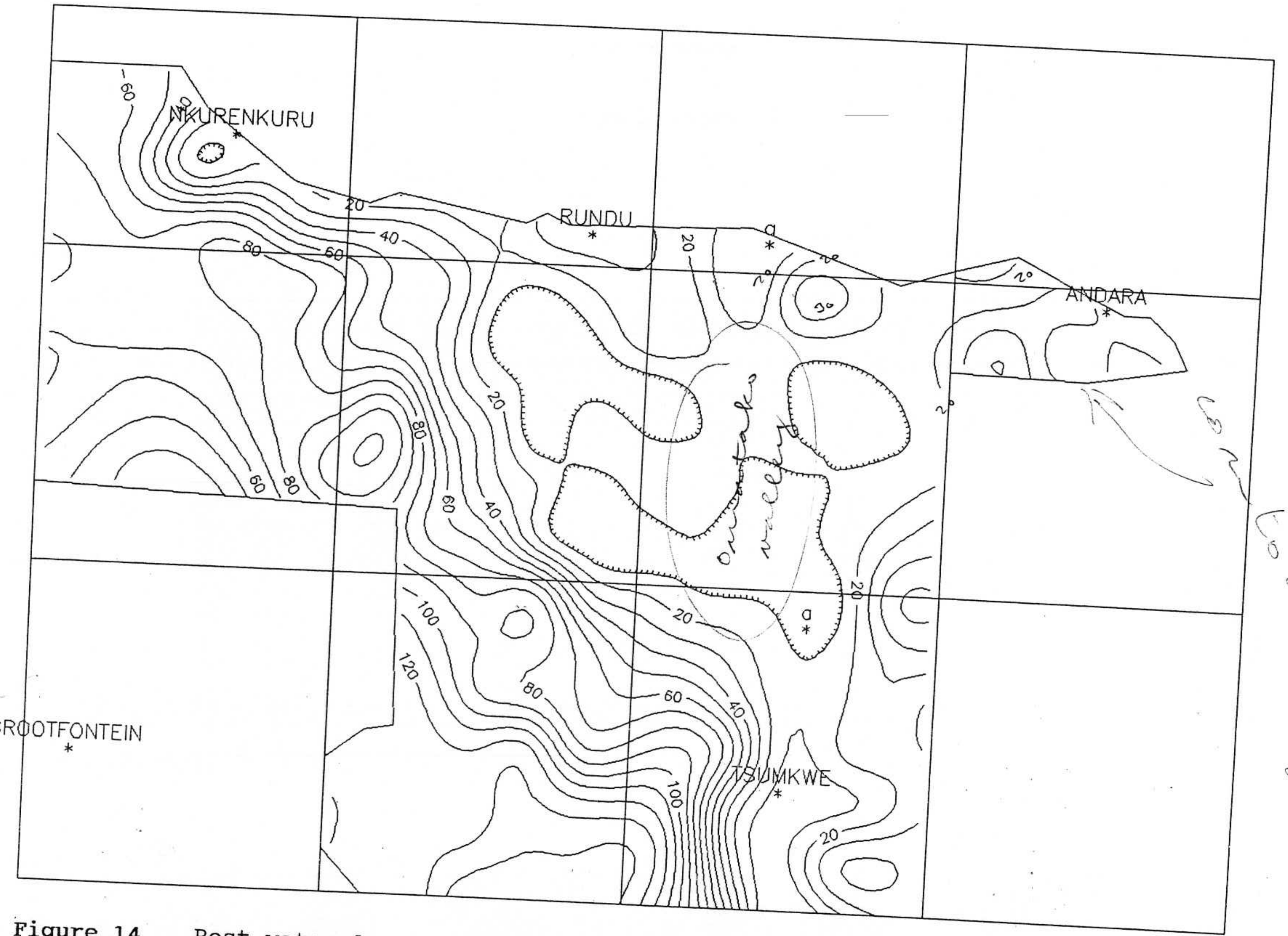


Figure 14 Rest water level contours (contour interval 10 m below surface)

4.1.3 BOREHOLE YIELDS

For the purpose of the desk study, borehole yields, listed on the Departmental database, were presented in the form of a contoured plot. These yield contours showed a broad northwesterly trend, in which yields exceed 8 m^3/h, extending from near Tsumkwe to southwest of Rundu, approximately coincident with the central water table divide described above. Although yield figures were not obtained as part of the field survey, the database has been supplemented with additional records from the Drilling Section of the Department of Agriculture in Rundu and resulted in more widespread data points (Figure 9). The 'updated' plot of borehole yields (Figure 15) shows a markedly different distribution to the earlier plot, with the central, northwesterly trend resolving into a number of smaller trends. Eastern Bushmanland is characterised by contours defining a rough northeasterly zone. In southwestern Kavango the 8 m^3/h contour has been extended to cover most of the Mangetti. Areas of yield exceeding 10 m^3/h are limited in extent and result in 'bulls eyes' as opposed to linear zones.

4.1.4 PIEZOMETRIC LEVELS

In a borehole the distance water rises from where it was struck, to its rest level, is referred to as its pressure or piezometric head. If the water rises and emerges from the ground surface, the condition is referred to as artesian. In cases where the water is struck at a level higher than the rest level, the situation is one of a 'perched' water table. If, however, no difference is noted between the water strike and water rest levels, a water table aquifer is present. The piezometric head therefore provides some indication of the degree to which an aquifer is confined. From Figure 16 it can be seen

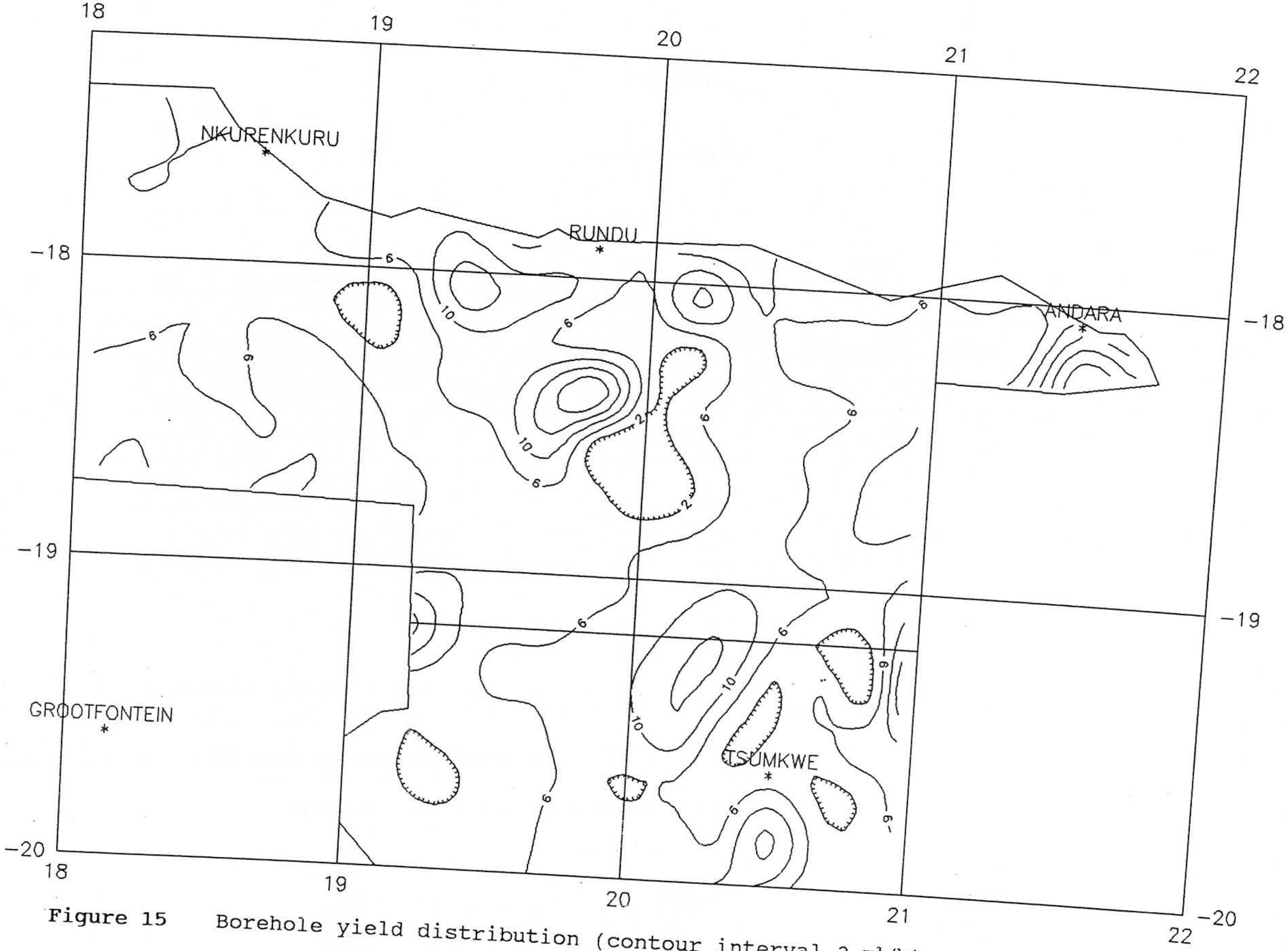


Figure 15 Borehole yield distribution (contour interval 2 m^3/h)

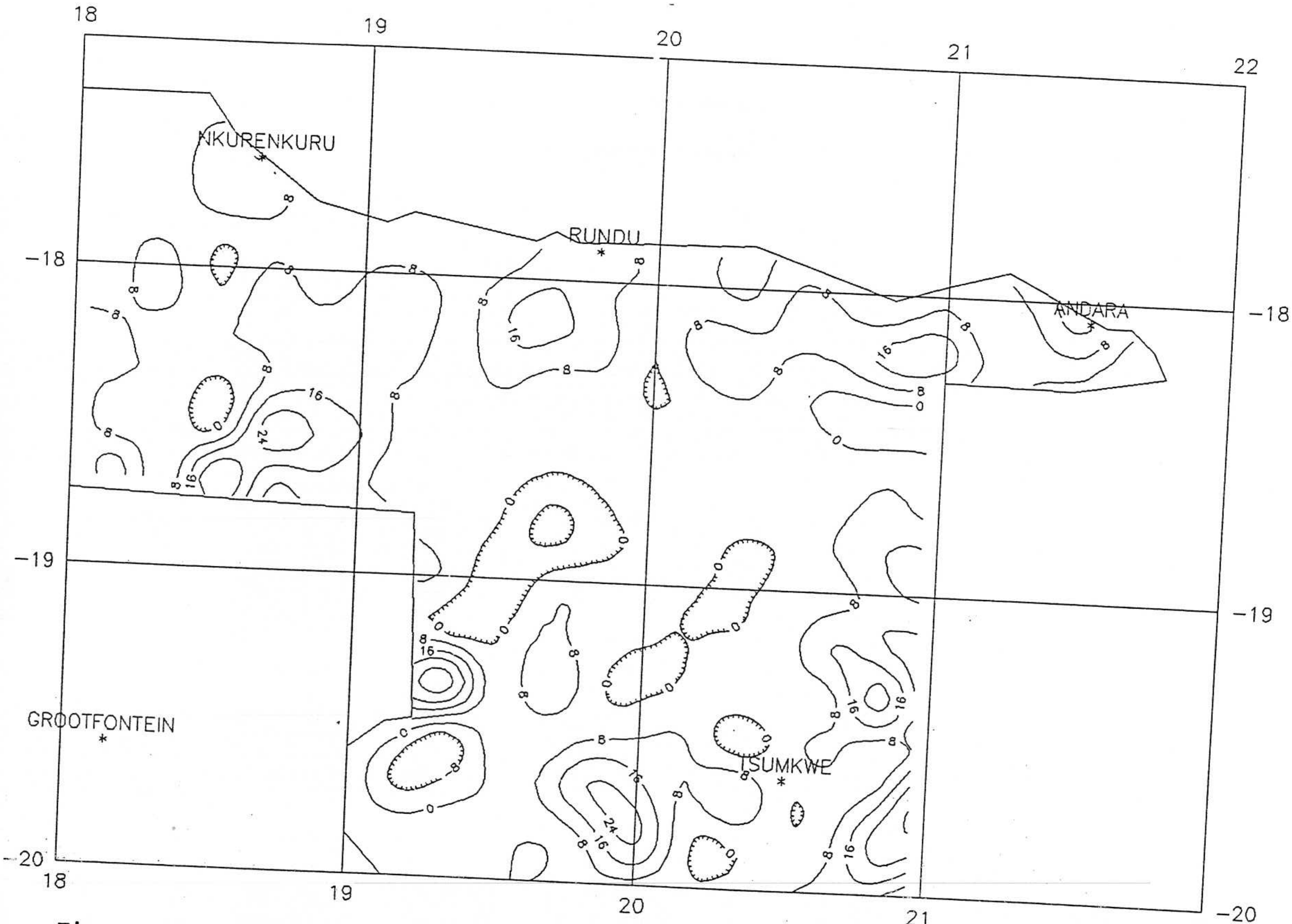


Figure 16. Distribution of piezometric head (water strike - rest level)

that groundwaters throughout the study area commonly have some degree of confinement. Both water table aquifer conditions and perched water tables are rare in Kavango and Bushmanland.

The data used to generate this plot were largely derived from the Departmental database but have been augmented by data from completion certificates obtained from the Drilling Section of the Department of Agriculture in Rundu. The overall picture presented in Progress Report No. 1 remains essentially unchanged.

4.2 HYDROCHEMISTRY

4.2.1 HYDROCHEMICAL SURVEYS

With the exception of the CSIR study (Huyser, 1981 [Bushmanland] and 1980 [Kavango]) no comprehensive hydrochemical surveys had been conducted in the area, prior to the present study. The CSIR survey was part of a nationwide project aimed at the production of a water quality map. For the purposes of the survey in Kavango and Bushmanland, the CSIR obtained the results of available water quality analyses from the Department of Water Affairs in Windhoek. This present investigation not only draws on more recent data held in Departmental files but includes the results of the most comprehensive sampling programme carried out to date in Kavango and Bushmanland. During the CSIR survey data 142 boreholes in Kavango and 46 boreholes in Bushmanland were used. Analyses have been obtained for 271 of the boreholes listed on the Departmental database (for Kavango and Bushmanland) and have been entered onto the project hydrochemical database. A total of 375 analyses from sampling carried out during the field survey have also been entered.

4.2.2 WATER QUALITY

Table 2 and Figures 17 and 18 summarize the results of analyses of the water samples collected during the field survey.

No of Samples	Criteria	Cumulative %
15	TDS >2000 mg/l	4
21	TDS >1500 "	6
53	TDS >1000 "	15
359	TDS > 30 "	100
		% in each Class
189	CLASS A	53
126	CLASS B	35
19	CLASS C	5
25	CLASS D	7

TABLE 2 WATER QUALITY IN KAVANGO AND BUSHMANLAND

The lowest TDS value recorded during this survey is 36 mg/l from borehole 1821AA 1005 at Shakashi. A total of 9 samples have TDS values of less than 100 mg/l. At Mayana, borehole 1719DD 1010, the highest TDS value of 6686 mg/l was recorded. This is one of only six samples with TDS levels exceeding 3000 mg/l. These statistics serve to highlight the high overall quality of groundwaters in the region.

Definitions of National Water Quality Classification are given in Appendix 6.

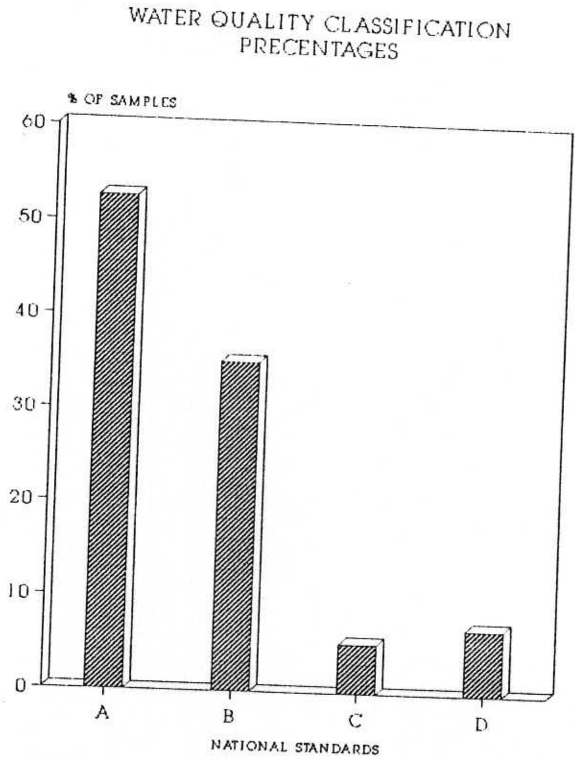


Figure 17 Water quality - TDS cumulative percentage

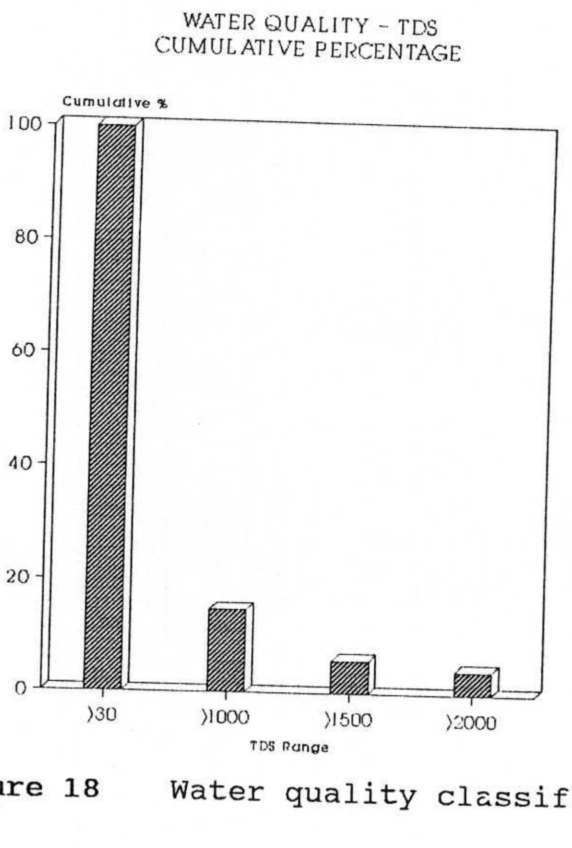


Figure 18 Water quality classification percentages

Summarizing the findings of previous studies (Huyser, 1980, 1981; and Simmonds and Schumann, 1987) the following have relevance :

4.2.2.1 Kavango

Good quality groundwater predominates throughout Kavango and TDS levels seldom reach 1000 mg/l. A number of small, isolated exceptions occur where values range from 1000-2000 mg/l and three very localized patches where values may reach 10000 mg/l (Huyser 1980; Figure 40). In all of the areas shown by the CSIR study as being of TDS > 2000 mg/l (Huyser op.cit.), the data pertains to a single borehole, and within a radius of approximately 5 km, another borehole has intersected good quality water.

Only 7.2% of the analyses failed to meet the requirements for C-Standard water. 2.0% of the analyses have failed to meet the national standard for stock watering and fluoride enrichment has been the major cause for sub-standard classifications..

4.2.2.2 Bushmanland

Groundwaters are predominantly of good quality and TDS levels are generally lower than 1000 mg/l. However, localised TDS levels as high as 3000 mg/l occur throughout the territory. At Dobe and Gautscha Pans boreholes have intersected waters with TDS values as high as 5000 - 10000 mg/l. Subsequent drilling at both of these pans has yielded more potable groundwaters, which serves to highlight the localized nature of poor quality groundwaters.

Using the national classification system, only 13.9% of the analyses used in the CSIR study failed to qualify as C-Standard.

4.2.3 HYDROCHEMICAL TRENDS

In order to assess and interpret the data collected in the present sampling exercise, analyses have been arbitrarily subdivided according to quarter degree squares. Data from each block has been downloaded from the project database as ASCII files and imported into a software package called PLOTCHEM (Techsoft Inc.) from which output has been in the form of Piper Diagrams. Piper Diagrams provide a useful means of evaluating the hydrochemical character of samples and for illustrating any time or space related variations which may be present. Figure 51 taken from Johnson (1975) is a generalized guide to the interpretation of Piper Diagrams. Groundwater may be subdivided into 3 main classes :

* recent recharge, high Ca/Mg HCO_3 water;
* dynamic (co-ordinated) underflow, $NaHCO_3$ character waters;
* stagnant waters of Na_2SO_4 -> NaCl character.

With increased residence time the waters will develop higher TDS levels. Residence time may be related to the rate of flow as determined by hydraulic gradient and transmissivity.

Piper plots of all the samples analyzed during the present survey are presented in Appendix 2. Although the clustering of data points in some areas is too dense to identify individual analyses, more significant anomalous points are identifiable. The following is a brief discussion on the main points of interest arising from the hydrochemical study:

* samples from dug wells range in character from HCO_3 to SO_4^{2-} (Figure 24) without any appreciable increase in TDS level. As expected, these analyses do not fall in the basin underflow region as these structures are shallow and tap only the uppermost, (most recent?) layers of groundwater. It is presumed that the trend towards a sulphate-rich character, and away from the dynamic and co-ordinated regime, is an effect of unidentified pollution.

* In general, borehole samples display the character of dynamic (co-ordinated) waters of the basin underflow regime. Cl^- is typically low with correspondingly high HCO_3^- levels which tend to confirm that steady recharge is taking place in these aquifers.

* The plot of analyses from the area around Twitwima, Dumushe and Kandjara (Topo-sheet 1820 BB) indicates poor quality waters which display high NaCl and SO_4^{2-} rich character. The plot of a sequence of samples taken during four hours of pumping at 20 minute intervals from the borehole at Dumushe (Figure 25) shows that the chemistry of the water changes, after an initial pulse of NaCl-rich water, from that of a moderate HCO_3 content coupled with decreased Na^+, to NaCl - Na_2SO_4 -rich composition. This final composition plots squarely in the diagnostic area for seawater. During the start of pumping fresh water is abstracted which is soon replaced by saline water. The presence of a fresh water aquifer perched

above poorer quality, more saline water is indicated here.

Huyser (1980 & 1981) concluded that there was no correlation between aquifer lithology and hydrochemistry, although Simmonds and Schumann (1987) maintain that relative concentrations of major ions in the Mangetti area display evidence of recent dolomitic character which decreases towards the north. This would be in keeping with recharge from the Otavi Formation dolomites of the Otavi Mountains to the south. This is supported by flow directions as indicated by contours of the elevation of the water table (Figure 13). Nevertheless a clustering of points around the area diagnostic of recent dolomitic water in Piper plots, (Quarter degrees 1818C and 1818D in Appendix 3) does not display any clear progression towards the diagnostic area for recent recharge waters with increasing distance to the north.

Huyser (1980) suggests that the reason for excess Na^+ (and K^+), in groundwaters from Kavango, which is a general condition in approximately 90% of the analyses used (in the CSIR survey), is due to ion exchange, Ca^{2+} + Mg^{2+} in groundwater substituting for Na^+ + K^+ in the aquifer.

The major ion distributions as indicated by contoured plots of mg\l concentrations are as follows :

4.2.3.1 Total dissolved solids (TDS)

As indicated in Section 4.2.2 and Table 2 above, the overall good quality of groundwater in the region is confirmed by Figure 19 which gives the distribution of TDS as determined from the present sampling. High TDS levels are present in 3 localized areas of northern Kavango. The westernmost of these areas, south of Nkurenkuru, only reaches the 1500 > 2000 mg/l level, which according to the national system would classify them as B-Standard. It must be noted that this area corresponds to the groundwater table depression described in Section 4.1.1 as well as to an area of >20 m piezometric rise (Figure 16). More than 50% of Kavango and Bushmanland lie within the <500 mg/l TDS contour.

4.2.3.2 Total Hardness (as $CaCO_3$)

As indicated above, hardness is based on $CaCO_3$ concentrations and therefore the contour plot of the hardness level (Figure 20) provides an indication of $CaCO_3$ distribution. Examination of the Piper plot of quarter degree 1818C (Appendix 3) shows a distinct clustering of analyses in the diagnostic area for recent dolomitic waters which also have the highest hardness values (all are >400 mg/l). Maximum hardness (>500 mg/l) occurs in central south Mangetti. By inference then (and with reference to Section 4.2.3) the contours of hardness relate to the 'degree of recent dolomitic character' present in the waters.

4.2.3.3 Nitrate (NO_3^-)

Nitrate levels are conspicuously low throughout Kavango and Bushmanland with a few isolated areas of enrichment. The two highest values occur in southwestern Bushmanland and in western Mangetti (50 mg/l, and 20-30 mg/l respectively - Figure 21).

4.2.3.4 Sulphate (SO_4^{2-})

According to the national classification system the limits for A- and B-Standard waters are 200 and 600 mg/l SO_4^{2-} respectively. Examination of Figure 22 shows that most of the region is underlain by A class water with only 6 localized areas which classify as B-Standard.

4.2.3.5 Fluoride (F)

Fluoride distribution shows good correlation with areas of elevated bedrock, (ie. thin Kalahari cover) showing its main area of enrichment above the bedrock rise underlying the eastern parts of the study area (compare Figures 23 and 5). Predictably, maximum fluoride levels (3-5 mg/l - Class D) are associated with an area of granitic sub-outcrop of the Grootfontein Complex in southeastern Bushmanland. Most of this area is characterised by levels exceeding 2 mg/l (ie. class C).

4.3 GEOPHYSICAL SURVEY RESULTS

4.3.1 KOROKO SCHOOL - 1820BB 1005

No lithological records are available but this area is characterised by localised highly saline water (TDS 5768 ppm and conductivity 7.7 mS/cm). The two perpendicular sounding curves clearly indicate the rapid drop in resistivity (=rho, in ohm.metres) as the saline groundwater is encountered. The curve represents essentially two layers with the deeper asymptotic values

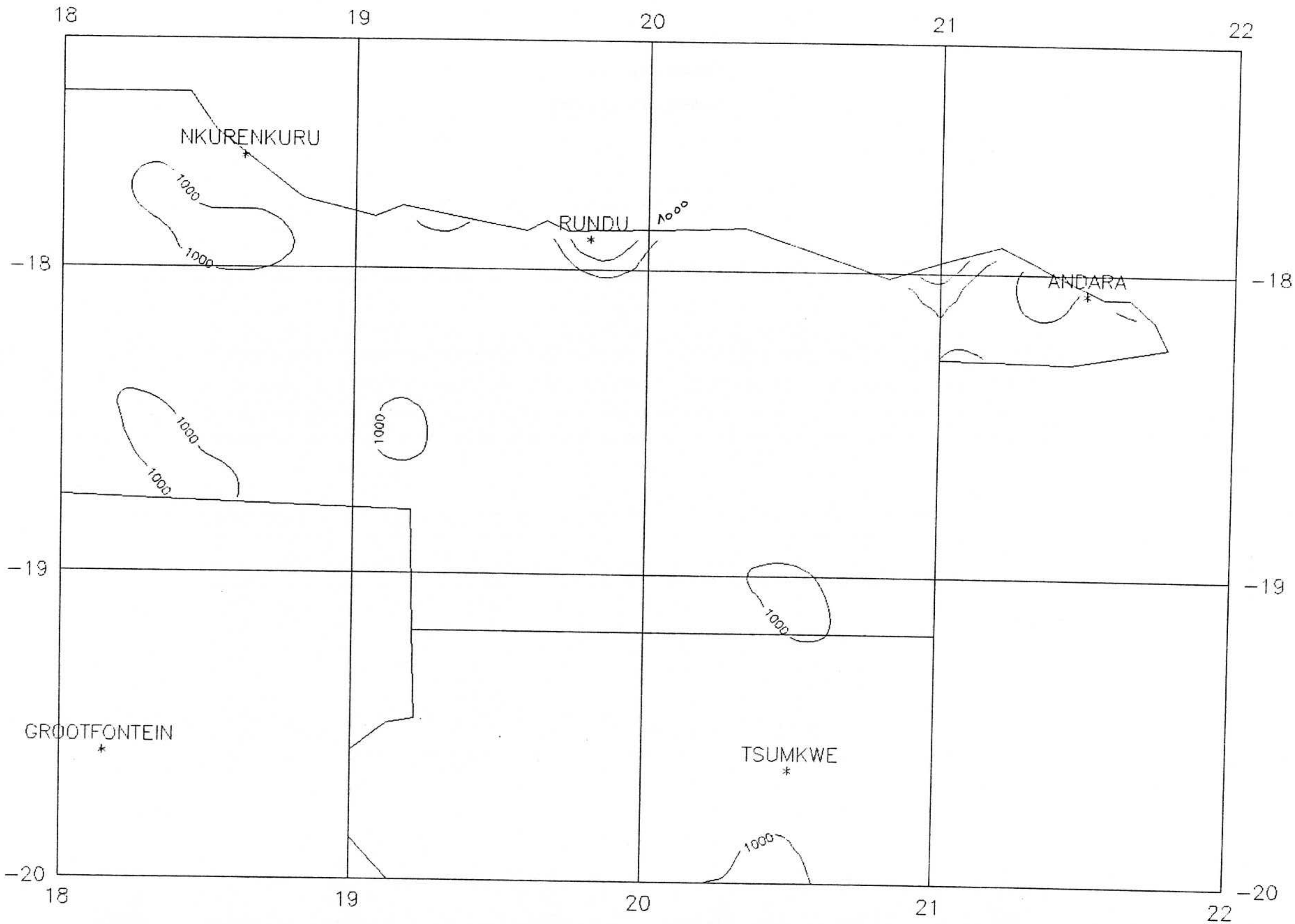


Figure 19 Hydrochemical distribution - TDS (contour interval 1000 mg/l)

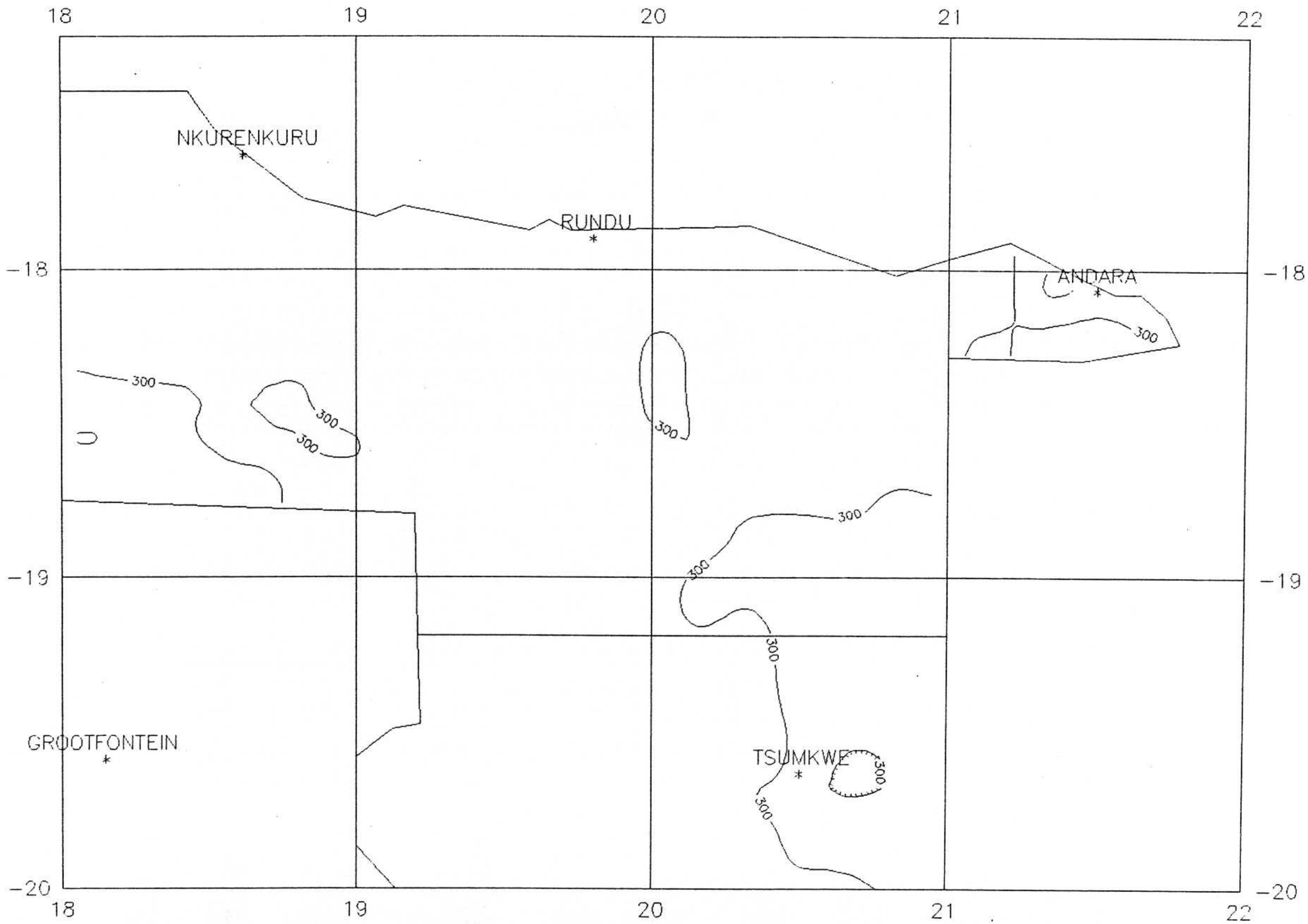


Figure 20 Hydrochemical distribution - Hardness (contours 300, 650 mg/l)

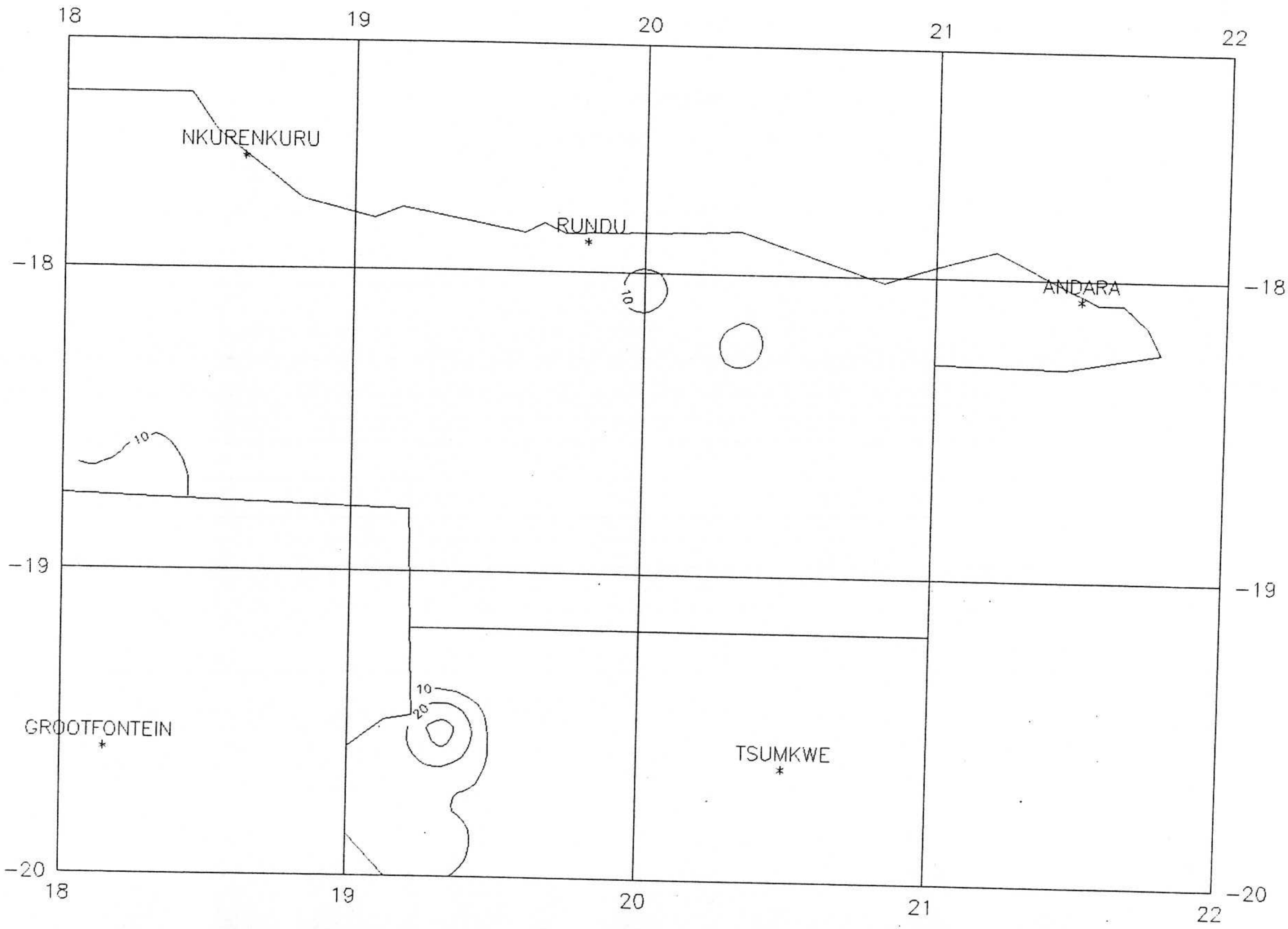


Figure 21 Hydrochemical distribution - NO_3^- (contour interval 10 mg/l)

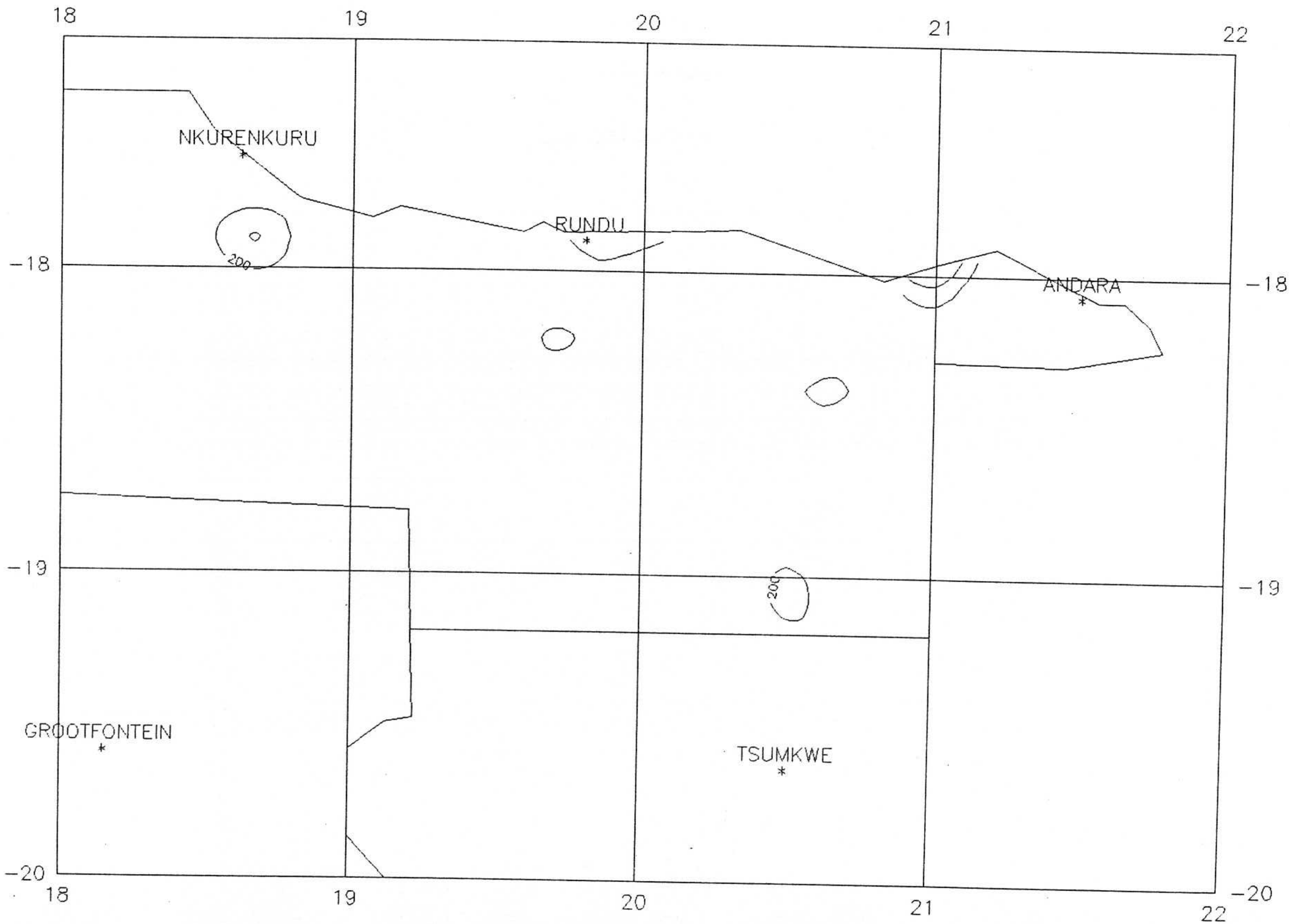


Figure 22 Hydrochemical distribution - SO_4^{2-} (contour interval 200 mg/l)

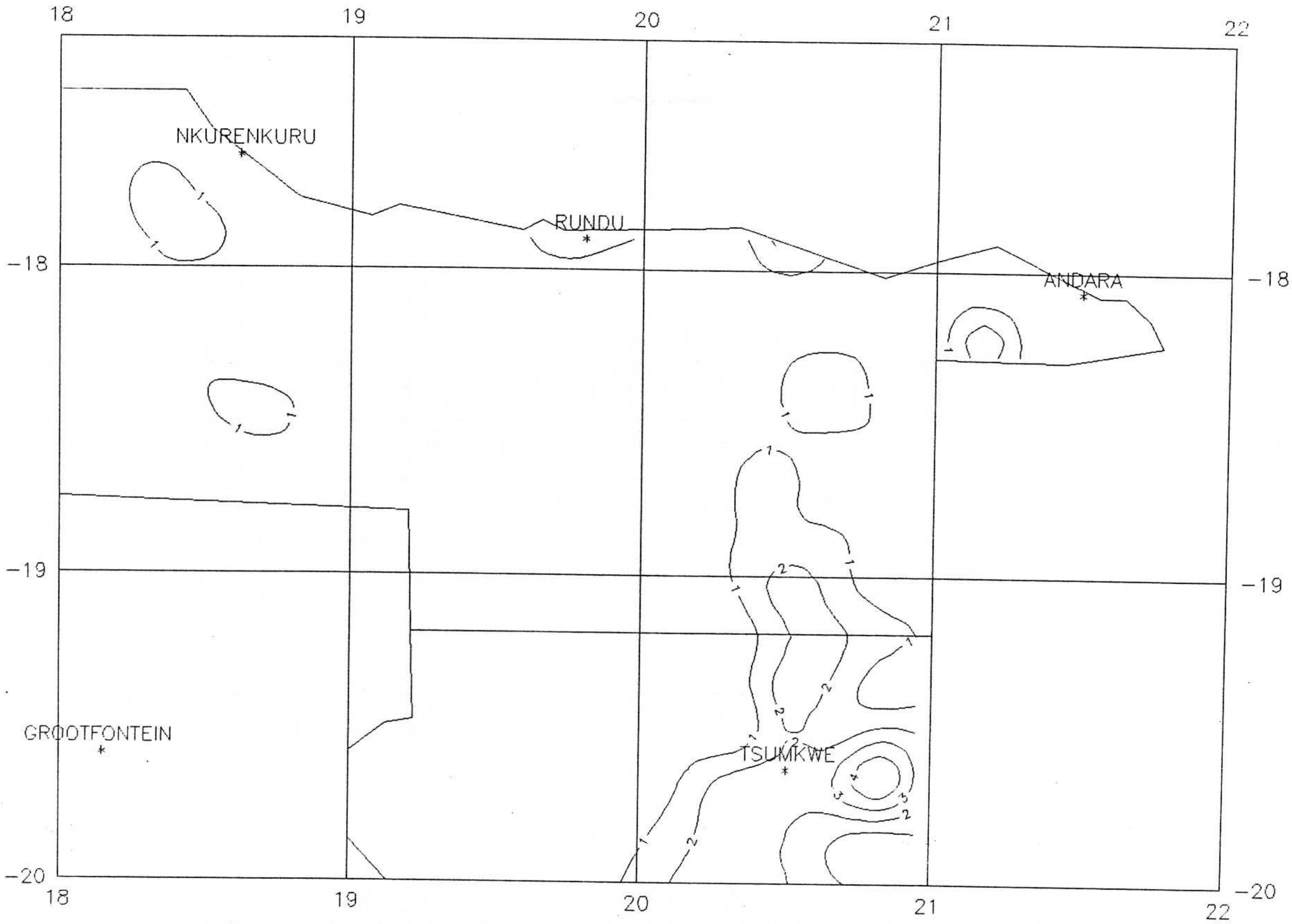


Figure 23 Hydrochemical distribution - F (contour interval 1 mg/l)

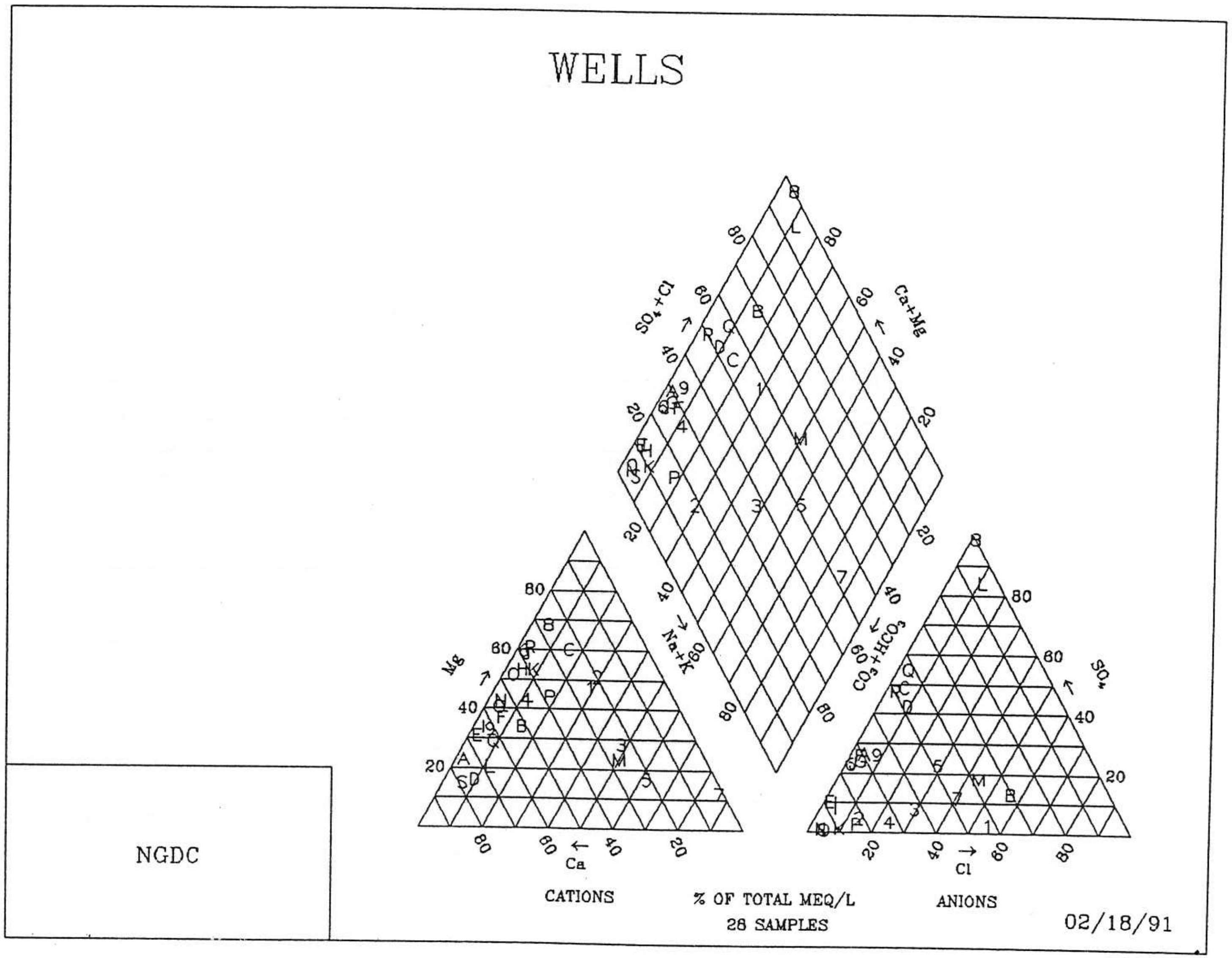


Figure 24   Trilinear plot of dug-well hydrochemistry

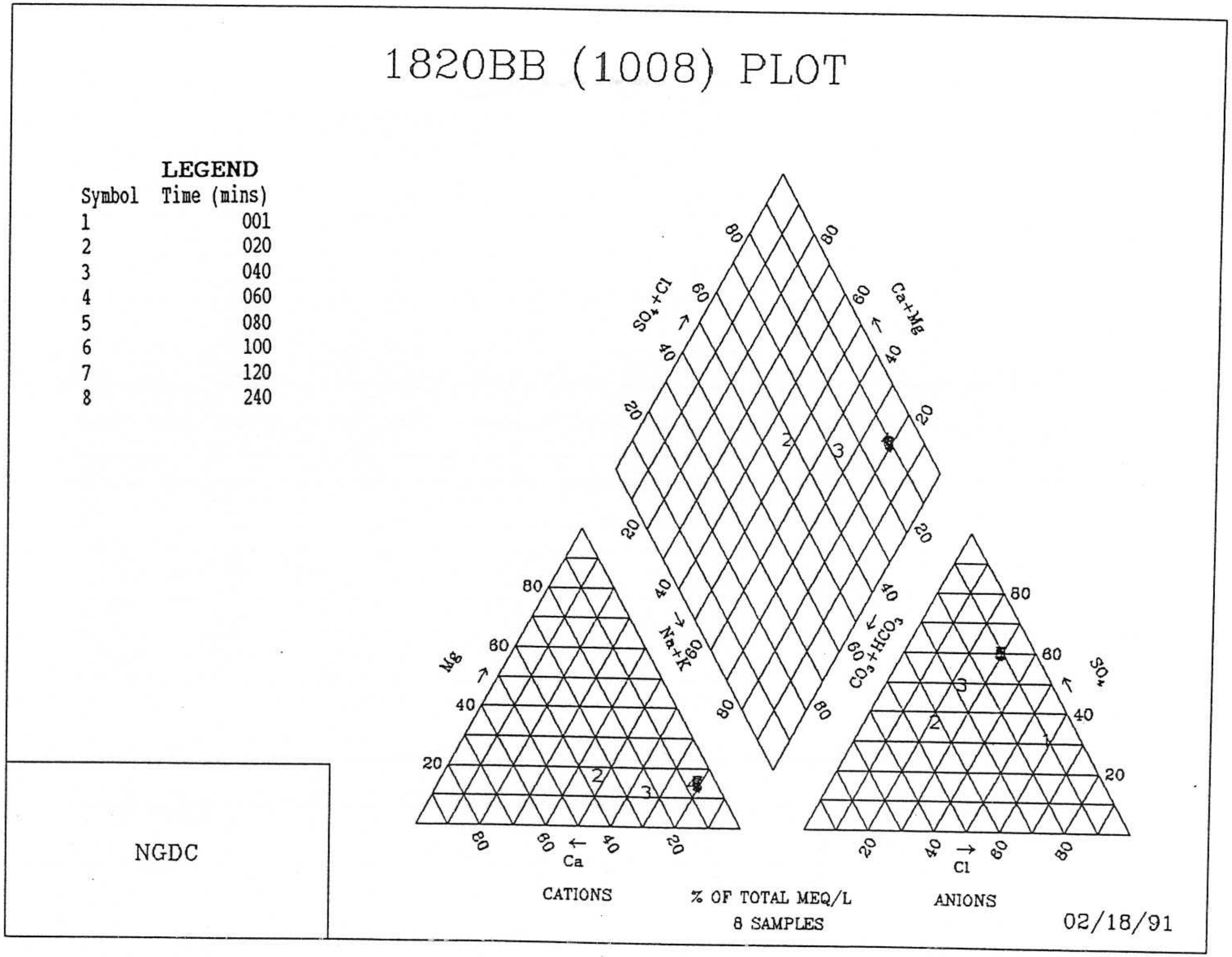


Figure 25 Trilinear plot of hydrochemistry of samples from 1820BB 1008

suggesting little change in the very low resistivity with depth (Figures 26 and 27).

4.3.2 TWITIMA - 1820BB 1006 and well no. 10/BH(T8305)

Detailed lithological borehole logs reveal a sequence of:

0 - 15	Fine, white sandy calcrete.
- 27	Very fine, white sandy calcrete.
- 52	Fine white sand.
- 55	Brownish-yellow, very fine sand.
- 61	Greyish-white, very fine sand.
- 64	Yellowish, slightly silty, very fine sand.
- 67	Greenish-yellow, silty sand.
- 71 m	Yellowish-green, very fine sand.

At preset the rest water level is at 17.93 m with good quality water. Although the sounding survey results are noisy and lack definition, the flat negative curve indicates a gradual decrease in rho to the water-table at 15 - 20m. The sharp 'cusp' at AB/2=50m suggests a thin arenaceous layer (Figures 28 and 29).

4.3.3 DUMUSHE - 1820BB 1008 WW9048 well no. 1820BC 2

This locality is characterised by good quality water overlying poor quality water, which is reflected by the chemistry of pumped samples taken at twenty minute intervals (see Figure 25). Moreover shallow wells in the area are used for drinking whereas the borehole water is used only for livestock. Sounding curves suggest a similar pattern to that at Koroko School, i.e. essentially two dominant layers of contrasting resistivities, the lower having very low values. In addition to this, the

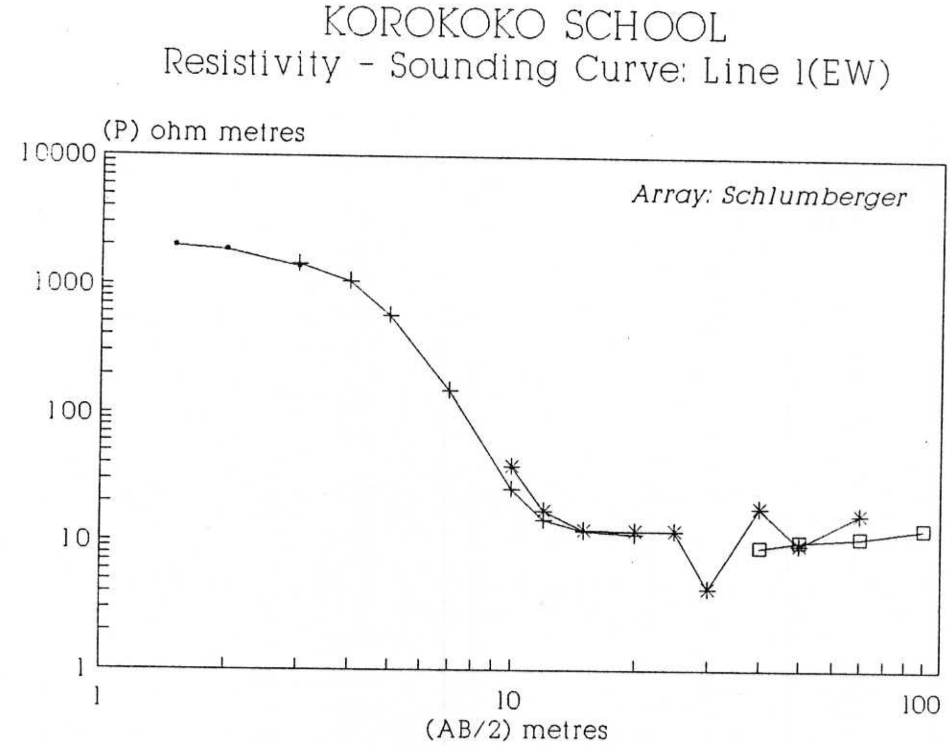


Figure 26 Koroko school resistivity sounding curve - line 1

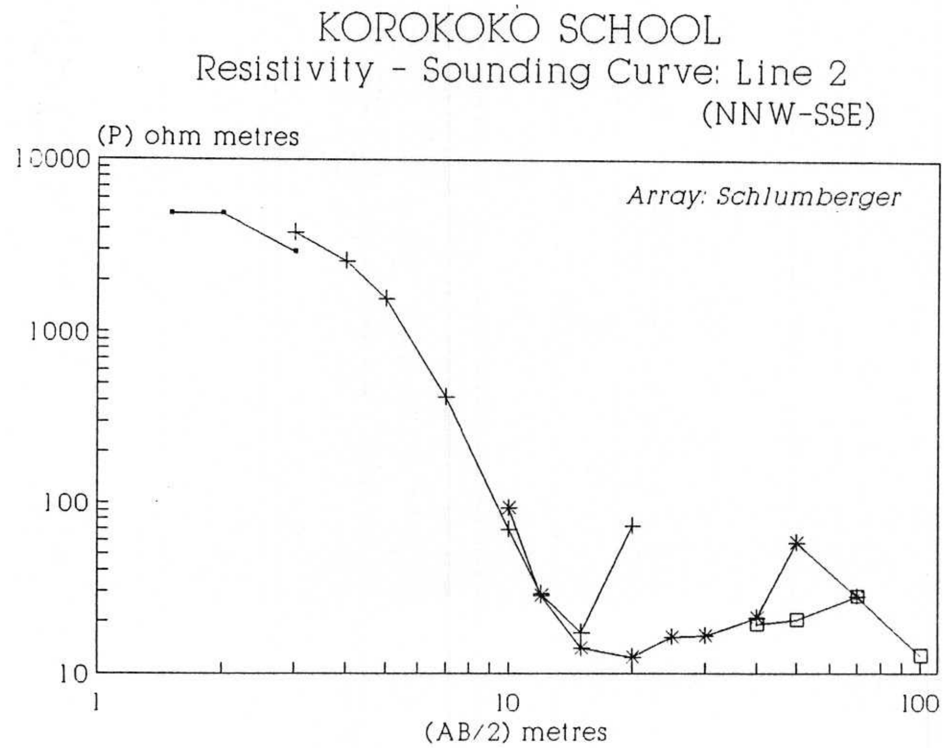


Figure 27 Koroko school resistivity sounding curve - line 2

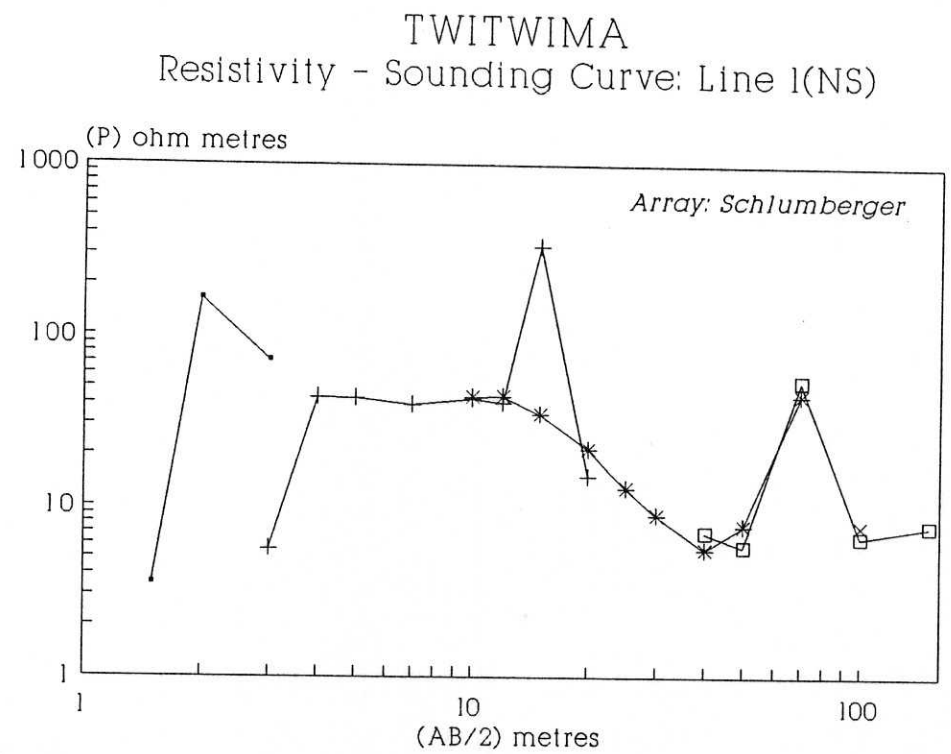


Figure 28 Twitwima resistivity sounding curve - line 1

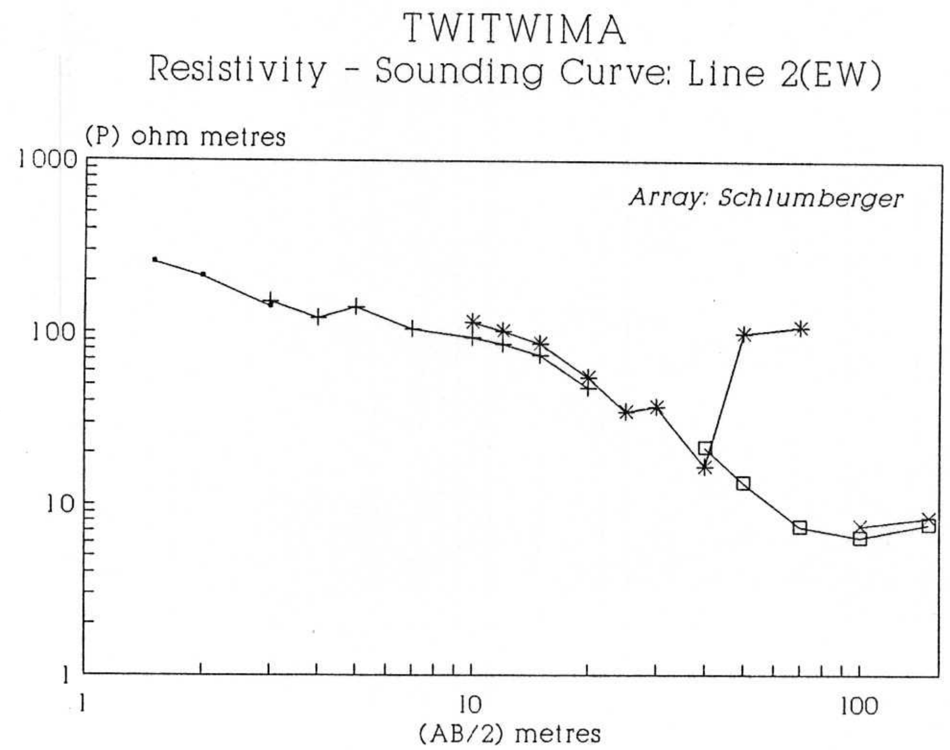


Figure 29 Twitwima resistivity sounding curve - line 2

curve is more complex and may reflect greater lithological inhomogeneity (Figures 30 and 31).

4.3.4 CAKUMA (CUMA) - 1820BB 1011

Clean sands and good quality water make up the sequence at this locality and therefore this site was suitable for orientation resistivity sounding. However, the results produced rather nondescript flat curves suggesting at least a three layer low contrast model (Figures 32 and 33). This is interpreted as:

* an upper dryish layer;

* an intermediate layer increasing in saturation;

* a low resistance layer, probably the rest water level (rwl) of the saturated layer.

The resistances of the sequence are surprisingly low and suggest a clay fraction interstitial to the sands.

4.3.5 GAUTSCHA PAN - 1920DC 1003 + 1012

Examination of the aerial photographs covering the pan show two faint northwest-southeast lineations adjacent to the two boreholes visited. The geological and aeromagnetic data indicate the presence of a dolerite dyke at a similar orientation (Figures 6 and 8). No evidence of this is observed on surface nor was any dolerite intersected by the boreholes.

Orientation magnetometer traverses were conducted over each of the supposed features and produced very similar results (Figures 34 and 35). The magnetic profiles

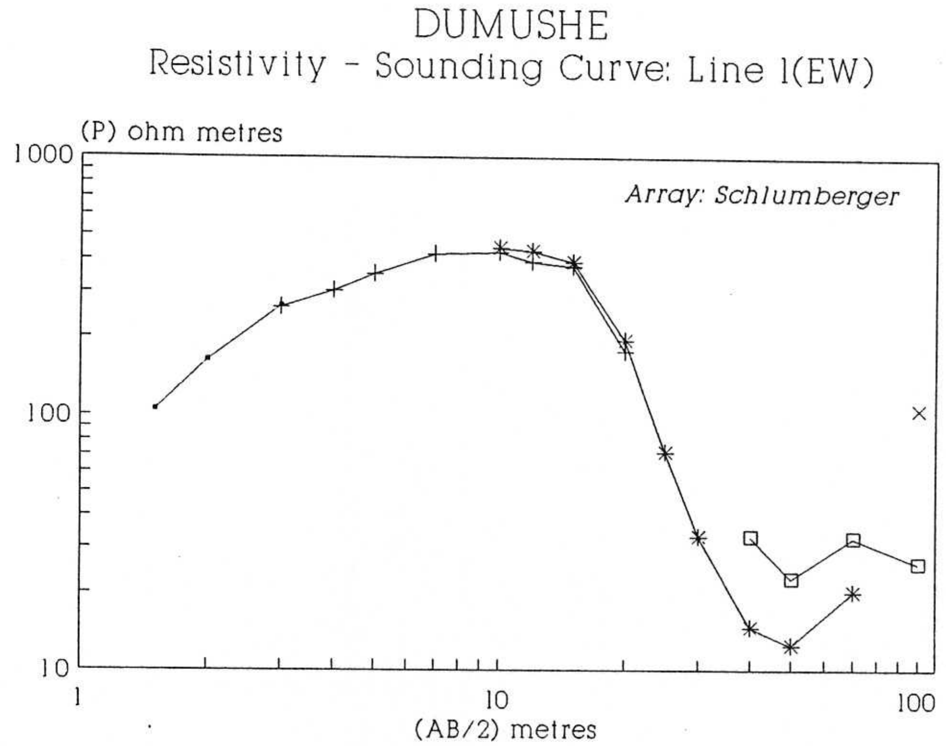


Figure 30 Dumushe resistivity sounding curve - line 1

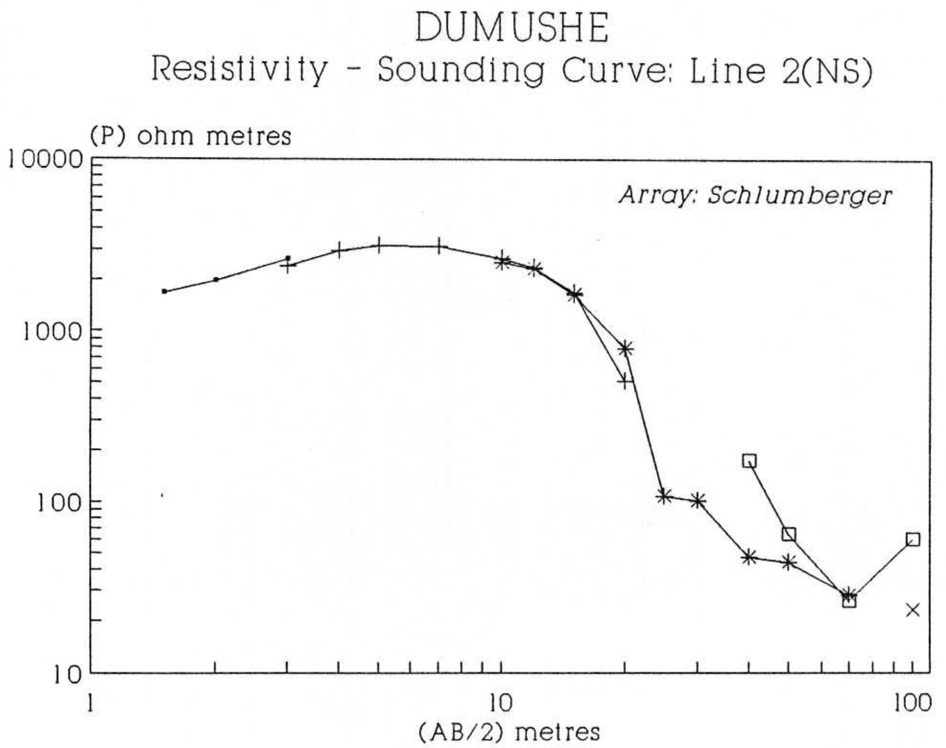


Figure 31 Dumushe resistivity sounding curve - line 2

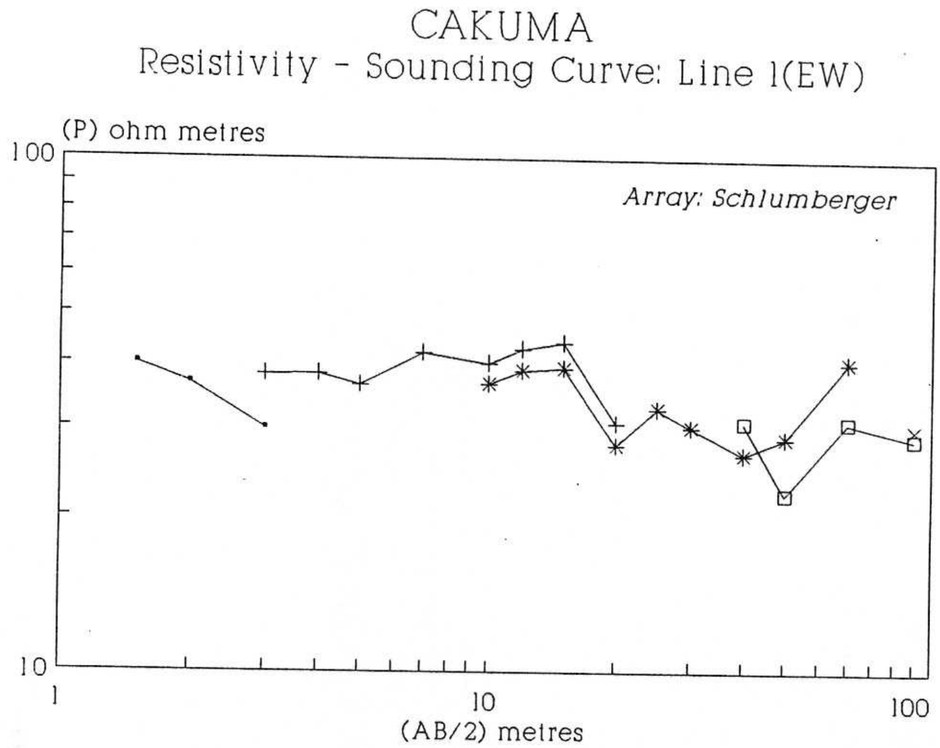


Figure 32 Cakuma resistivity sounding curve - line 1

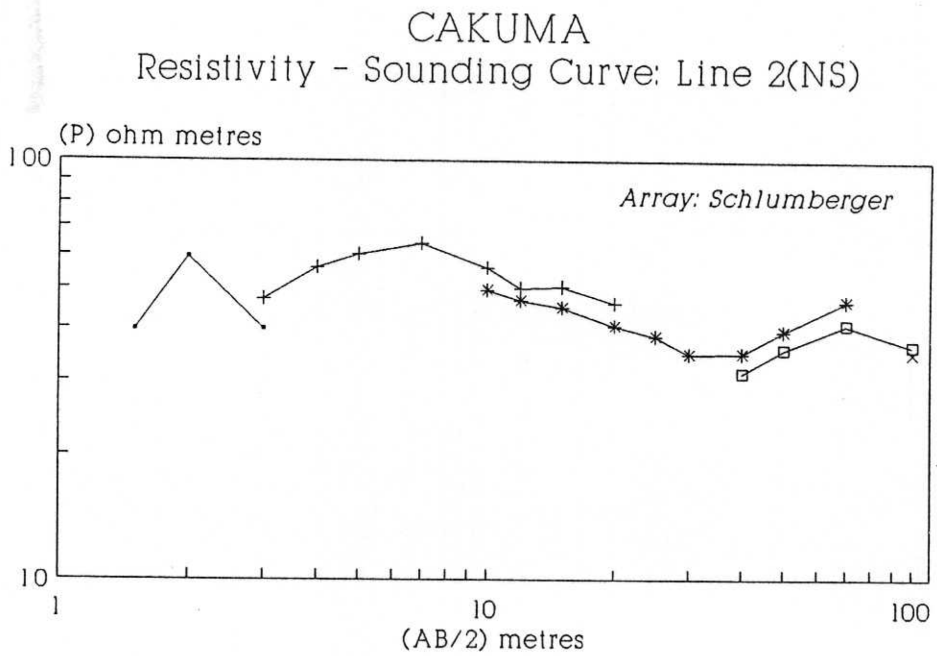


Figure 33 Cakuma resistivity sounding curve - line 2

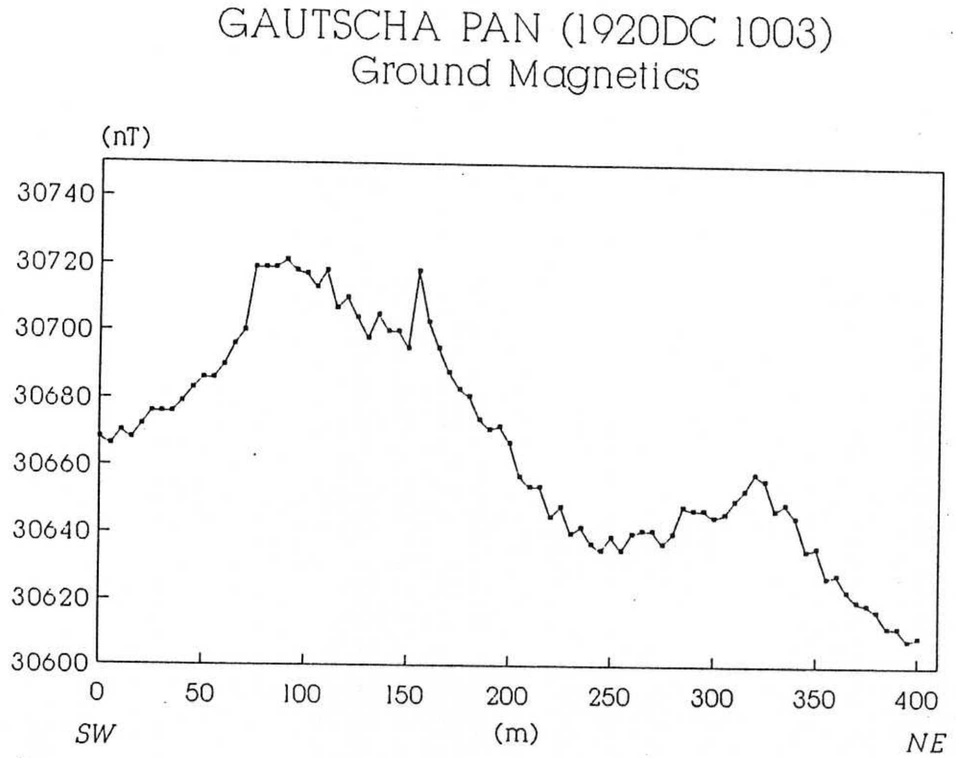


Figure 34 Gautscha Pan ground magnetics (1920DC 1003)

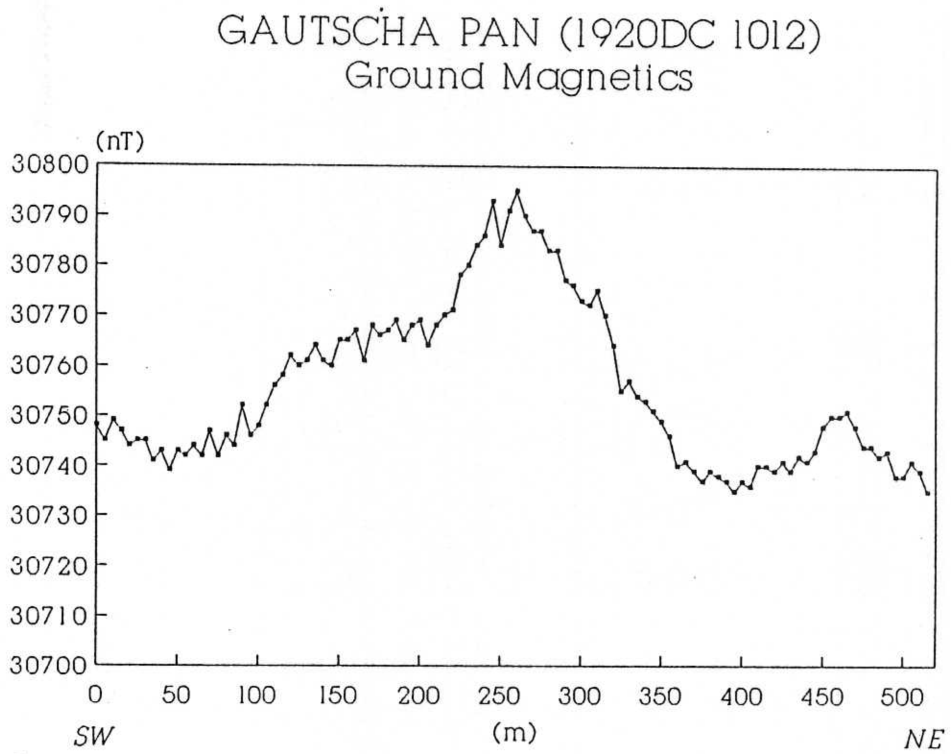


Figure 35 Gautscha Pan ground magnetics (1920DC 1012)

suggest the presence of features with a possible steep dip to the northeast. Although the boreholes did not intersect dolerite, it is likely that, owing to the orientation of the lineations and the well-defined magnetic anomalies, these structures are associated with the dolerite intrusions.

4.3.6 //XA/OBA - 1920BC 1004

Approximately half-way between Tsumkwe and Sikereti the structural fabric of the Nosib changes from a northeasterly trend to a more northerly trend (see pre-Karoo structural trends indicated on Figure 6). This trend persists and approximately 5 km north-northwest of Dobe Pan, is clearly depicted by a dense line of trees almost 1 km in strike length. The //xa/oba borehole was sited at the southernmost end of this feature (Simmonds, pers.comm.). Final borehole site selection was carried out geophysically using two Schlumberger gradient arrays (AB 180 and AB 420). This technique, using 2 different AB spacings, affords 2 depths of penetration and has been successfully applied in many areas. An indication of the vertical continuity of structures and of possible dip direction is derived from the double array.

The initial shallow penetration array exhibited a pronounced trough at the western edge of the tree line. This anomaly was confirmed by the deeper array (Figures 36 and 37) and is seen to have an almost vertical attitude.

During the field survey the site was also tested using an EM 34, with a coil separation of 20 m, giving theoretical penetration depths of 15 m (vertical coil) and 30 m (horizontal coil). From the results (Figure 38), very little indication of anomalous conductivity is shown in the deeper (horizontal) profile while the shallower

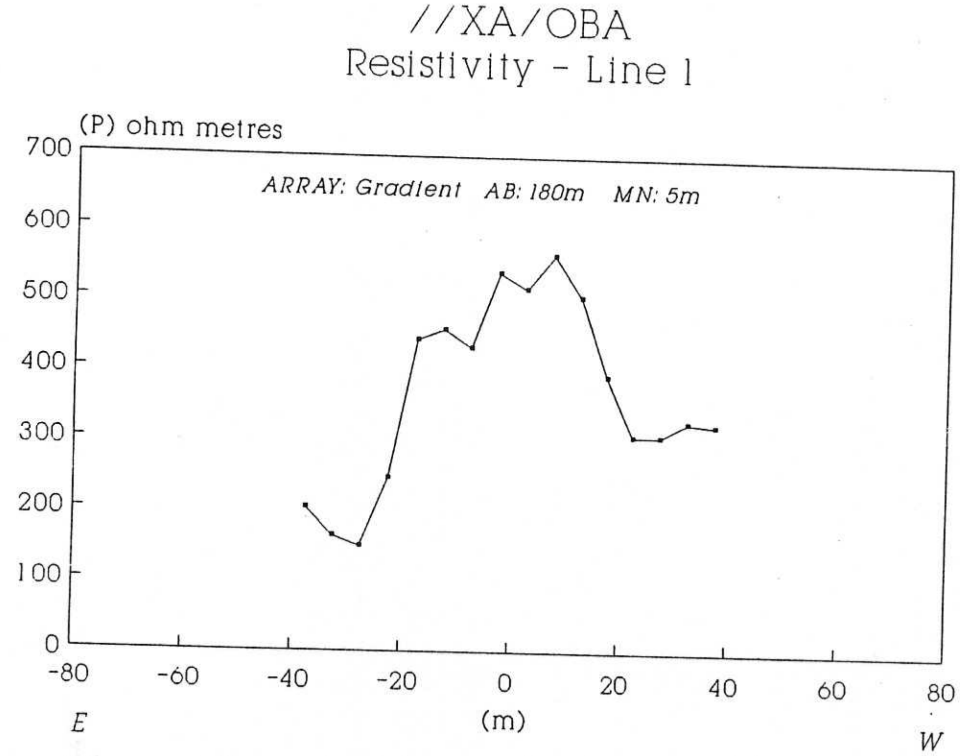


Figure 36 //a/oba resistivity - line 1

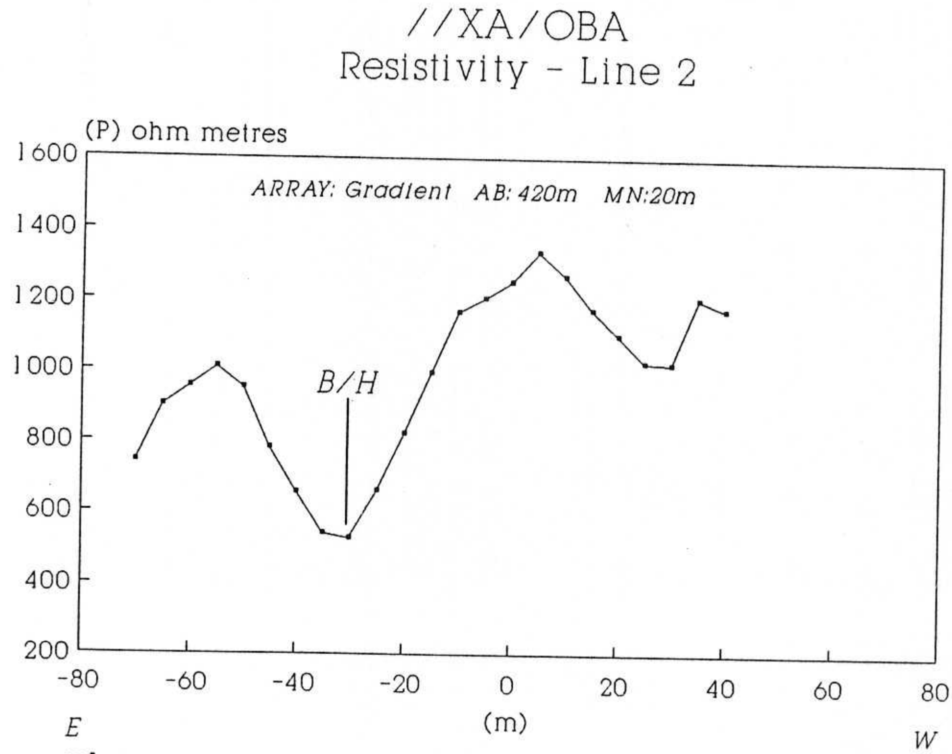


Figure 37 //a/oba resistivity - line 2

profile shows a broad anomaly (positive ie. higher conductivity) to the east of the borehole, across the wide tree line. This result lacks definition and is not clear enough to warrant drilling.

Drilling (of the resistivity anomaly!) intersected a series of weathered siliceous rock types and the borehole was air-lift tested at 8 m^3/h.

4.3.7 CGWIKWA (#IKWA) - 1920BD 1001 + 1002

Two 2 successful boreholes have been drilled at this settlement. The first, 1920BD 1001, was sited using photogeological interpretation only (F. Bockmühl, ±1987-88). The feature selected for drilling is a well-defined northeast-southwest lineation interpreted as a recent fault in the underlying Nosib quartzites. Water was intersected in weathered siliceous material and the borehole yield was air lift tested at 5 m^3/h. Borehole 1002, drilled later by the JBDF, was sited using resistivity (D. Howard, 28/07/1989) and passed through a sequence of lithologies that included some deeply weathered diabase and siliceous fault material yielding 2 m^3/h of potable groundwater.

Resistivity arrays conducted over the feature are presented in Figures 44-47. Gradient arrays with AB separations of 90, 120, 150 and 180 m all reveal the same strong negative (low apparent resistivity) anomaly with values around 200 Ωm. An orientation traverse using EM 34 was also conducted but yielded no clearly defined anomalies (Figure 39).

Results from ground magnetic surveys, which were carried out over the resistivity traverses (Figures 40 - 43), show

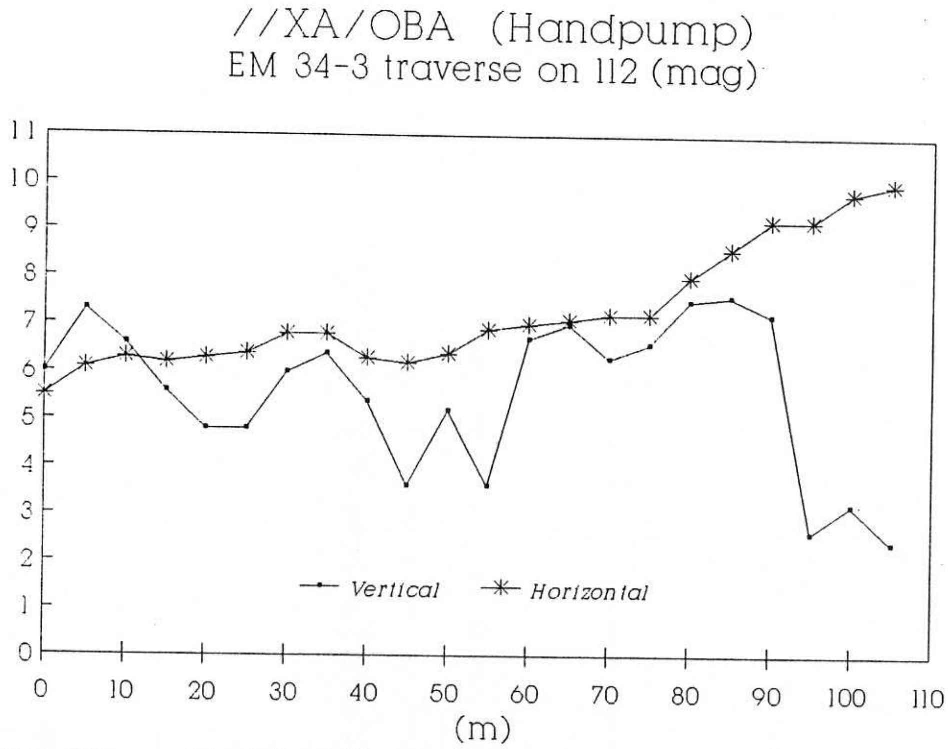


Figure 38 //a/oba EM 34-3 traverse on 112°(mag)

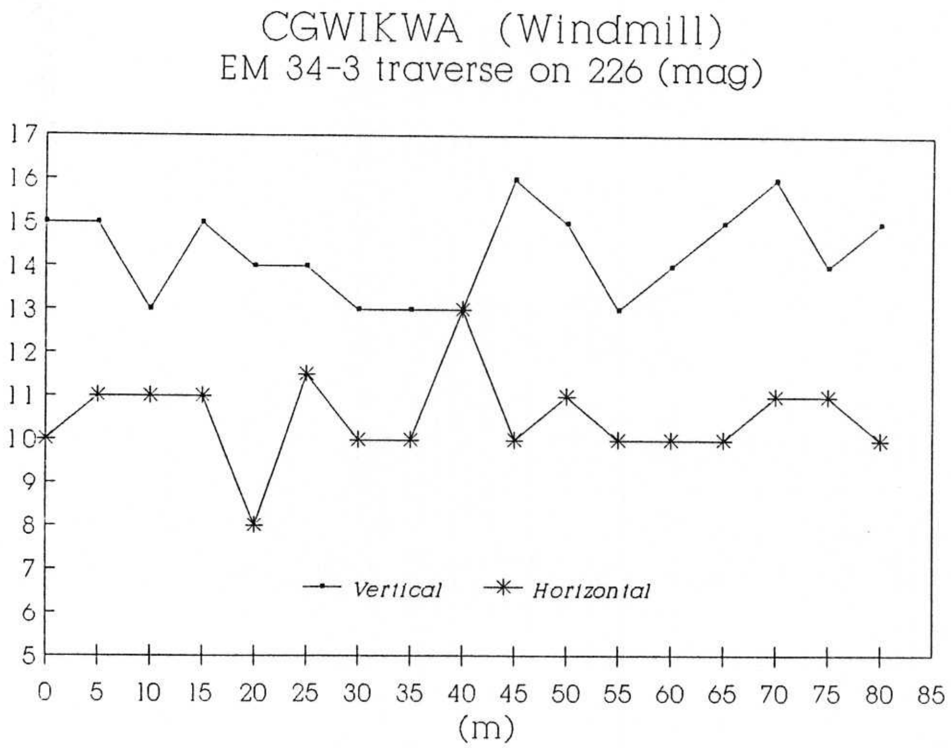


Figure 39 Cgwikwa (windmill) EM 34-3 traverse on 226°(mag)

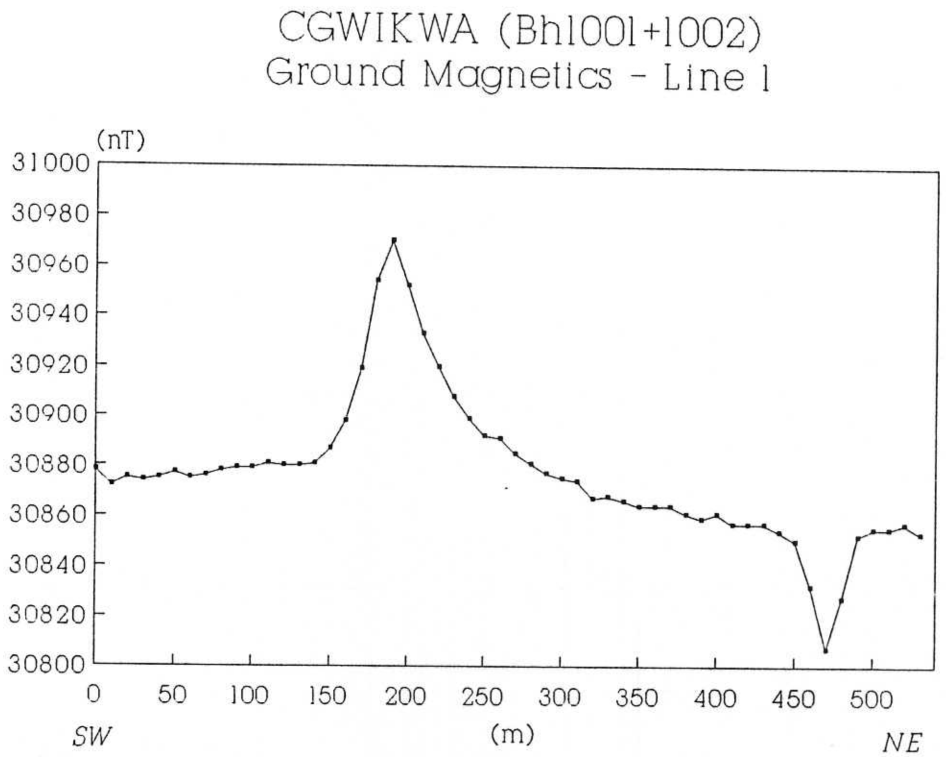


Figure 40 Cgwikwa ground magnetics - line 1

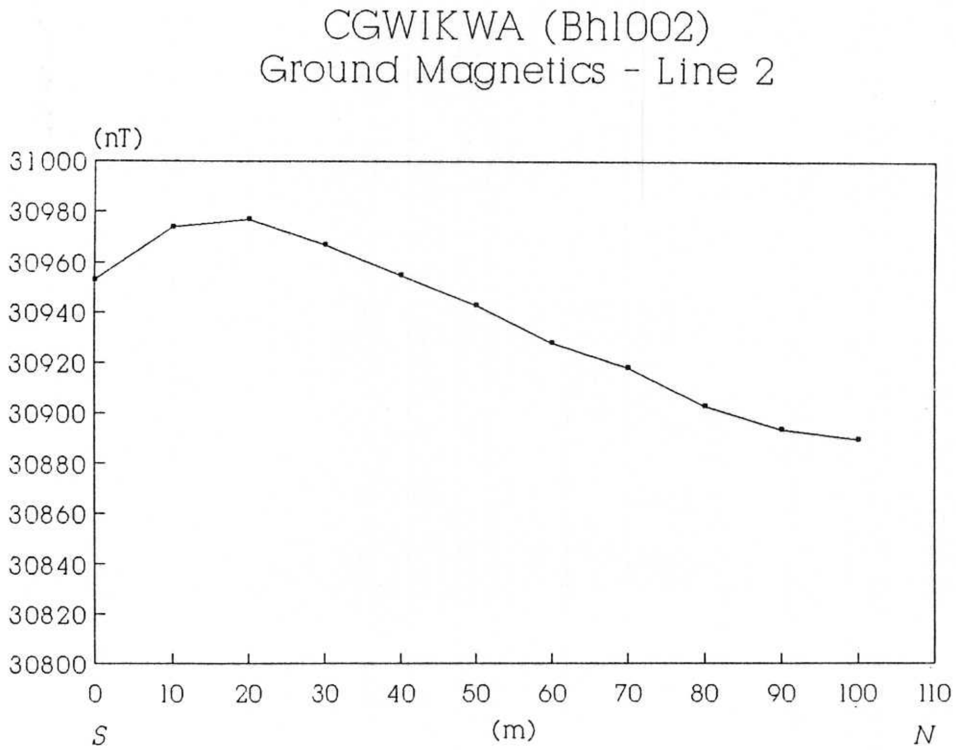


Figure 41 Cgwikwa ground magnetics - line 2

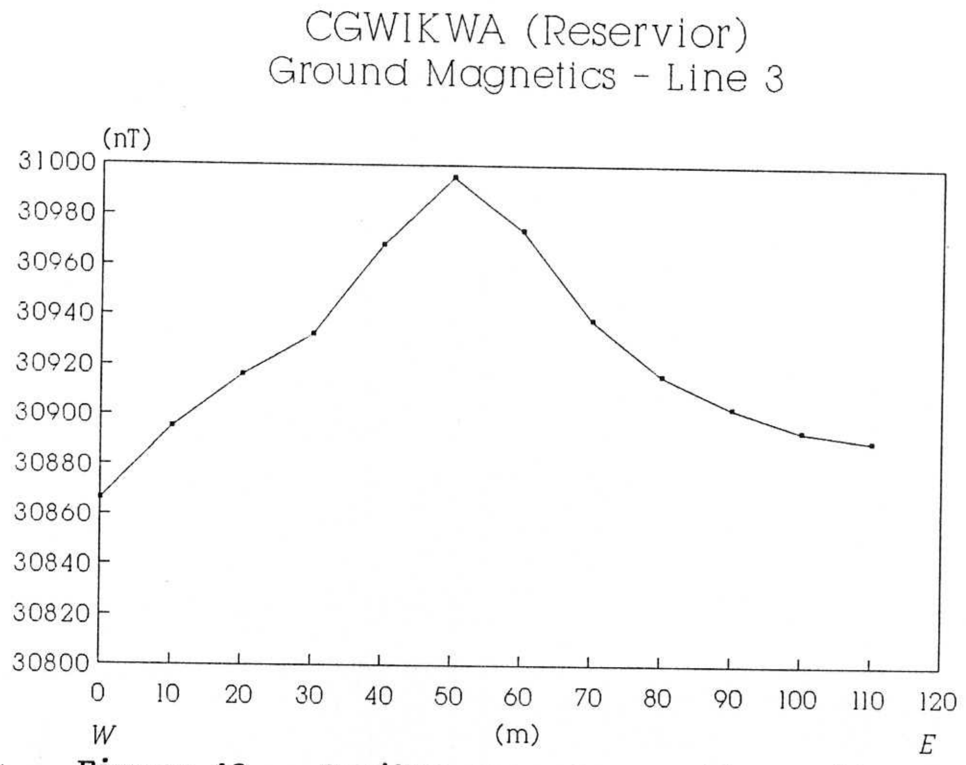


Figure 42 Cgwikwa ground magnetics - line 3

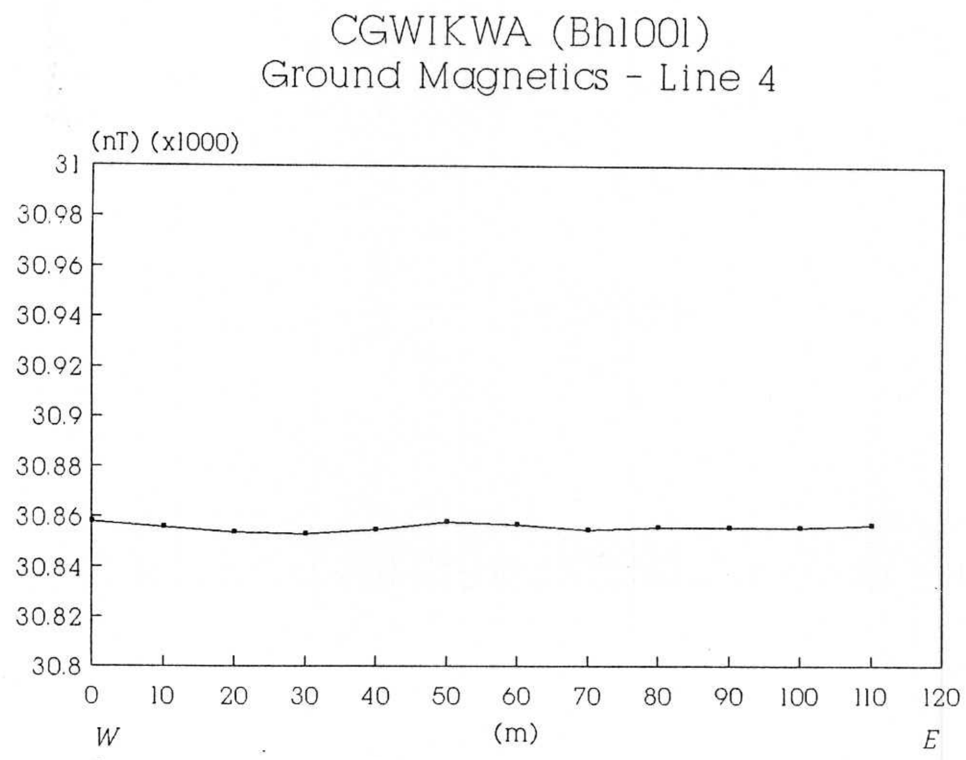


Figure 43 Cgwikwa ground magnetics - line 4

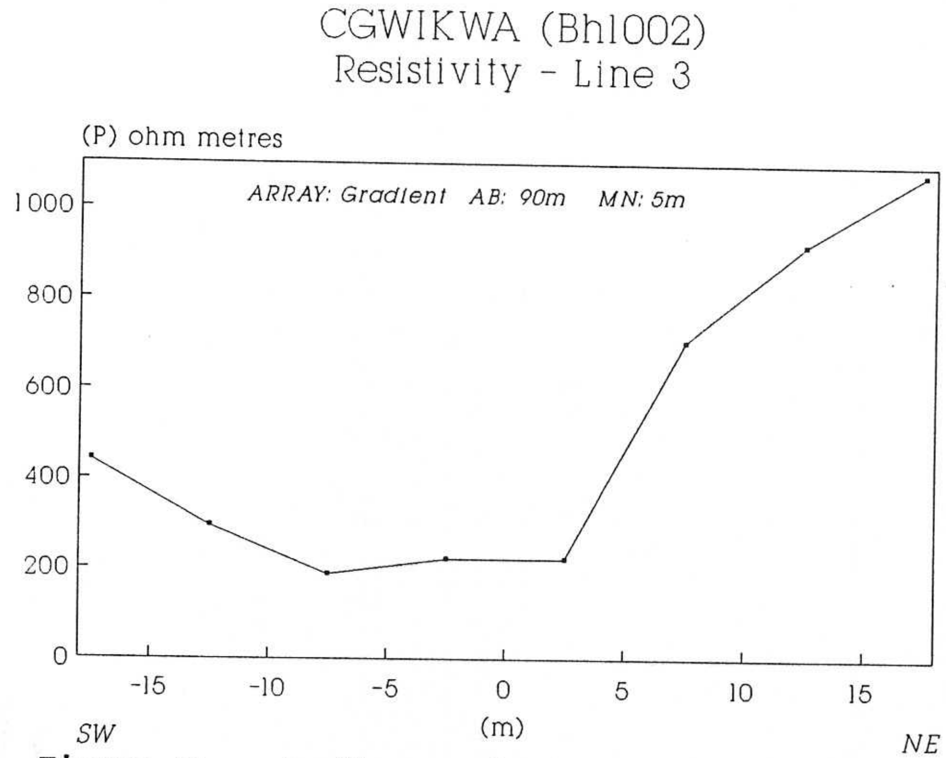


Figure 44 Cgwikwa resistivity - line 3 (AB=90)

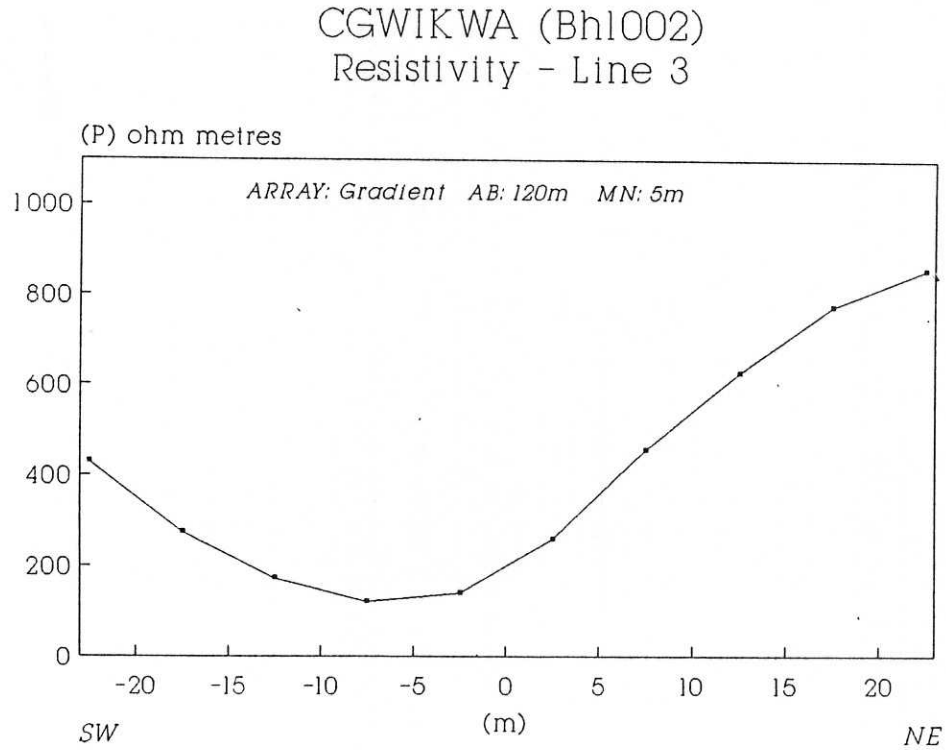


Figure 45 Cgwikwa resistivity - line 3 (AB=120)

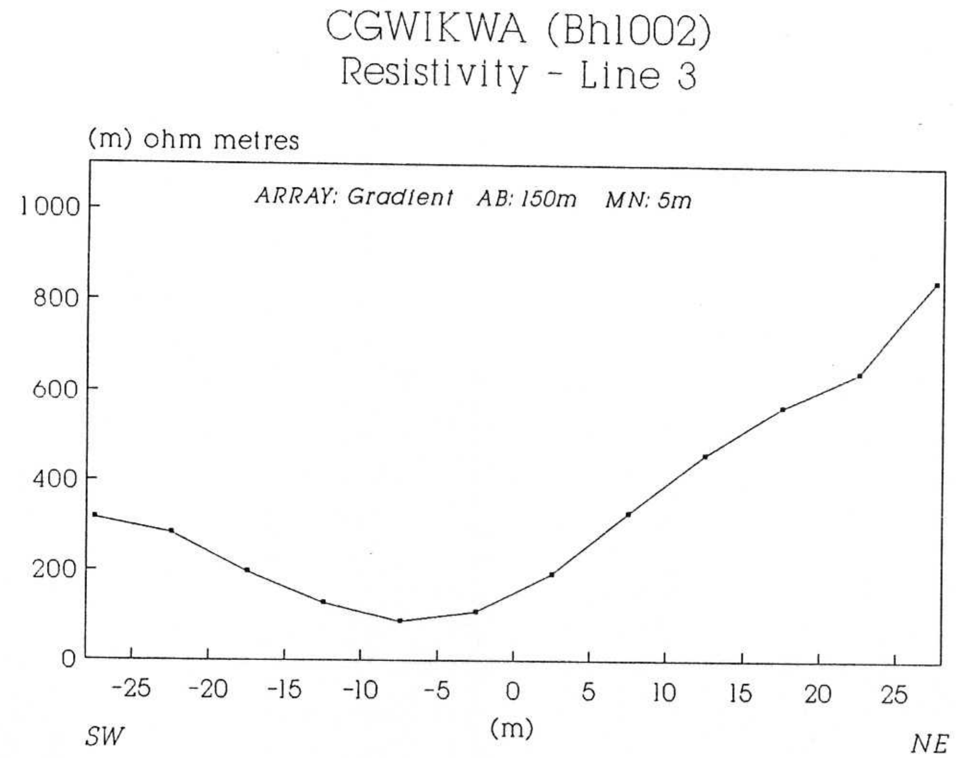


Figure 46 Cgwikwa resistivity - line 3 (AB=150)

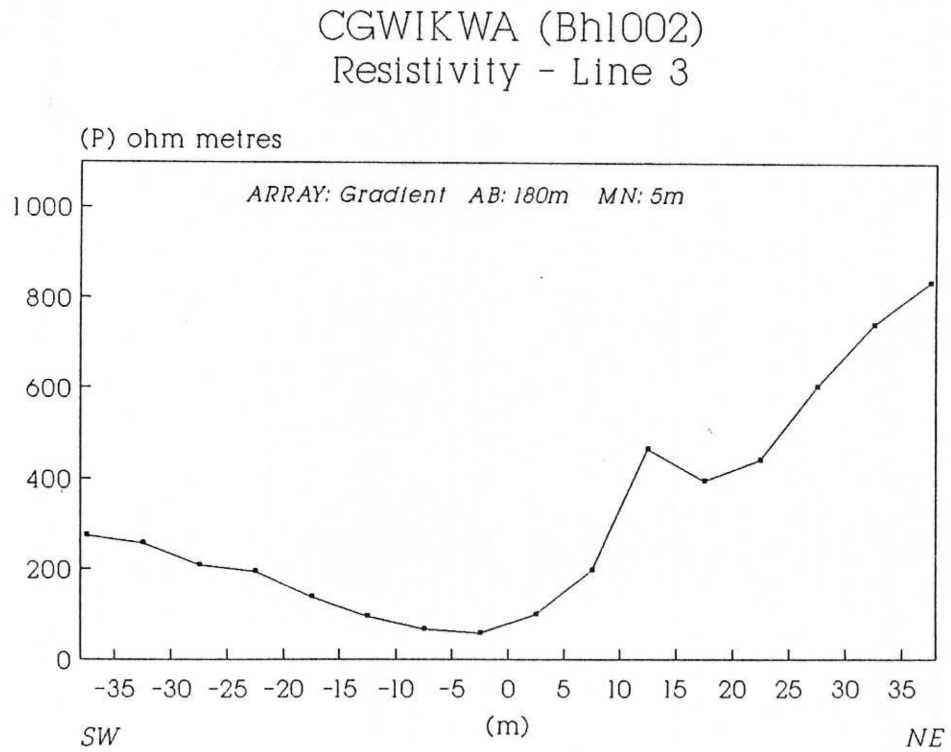


Figure 47 Cgwikwa resistivity - line 3 (AB=180)

a positive anomaly which correlates well with the position of this feature from the resistivity surveys.

Both boreholes are sited along a very striking calcrete ridge with dense, high trees. A depression (vlei or omuramba) parallels the ridge to the immediate west. These features suggest sub-surface linear structures with good groundwater potential.

4.3.8 SUMMARY OF GEOPHYSICAL RESULTS

4.3.8.1 Vertical Soundings

Provided the lithology is essentially uniform, saline (poor quality, highly conductive) water is indicated by high contrast curves where 2 main resistivity regimes are represented. These are a high shallow rho dropping off to very low rho, the latter a function of the saturated zone which may produce a flat asymptotic curve.

Good quality water results in flatter, low contrast curves suggesting gradual saturation.

In general, although the interpretations are largely qualitative, layers of higher resistance usually provide the best aquifers as they indicate either more sandy horizons or silcrete beds and good quality water. Caution should be exercised where large contrasts are encountered in the sounding curves, particularly similar to that at Koroko School and Dumushe, as this is indicative of low permeability clay layers or poor water quality.

4.3.8.2 Resistivity

Gradient array techniques have been used extensively with reasonable success in borehole siting on fractured bedrock. The orientation surveys have confirmed the usefulness of the technique in eastern Bushmanland and it is concluded that, although it is time-consuming, this method is the most applicable to conditions here.

4.3.8.3 Ground magnetics

Magnetometer surveys are quick and simple to conduct and for this reason alone they have appeal. Not all structures will produce a magnetic anomaly, and not all anomalies are due to structural features, but where anomalies are found, and where their position is confirmed on aerial photographs or by vegetation distribution, they can save time in narrowing down the search radius over which resistivity gradient arrays are to be directed.

4.3.8.4 EM 34-3

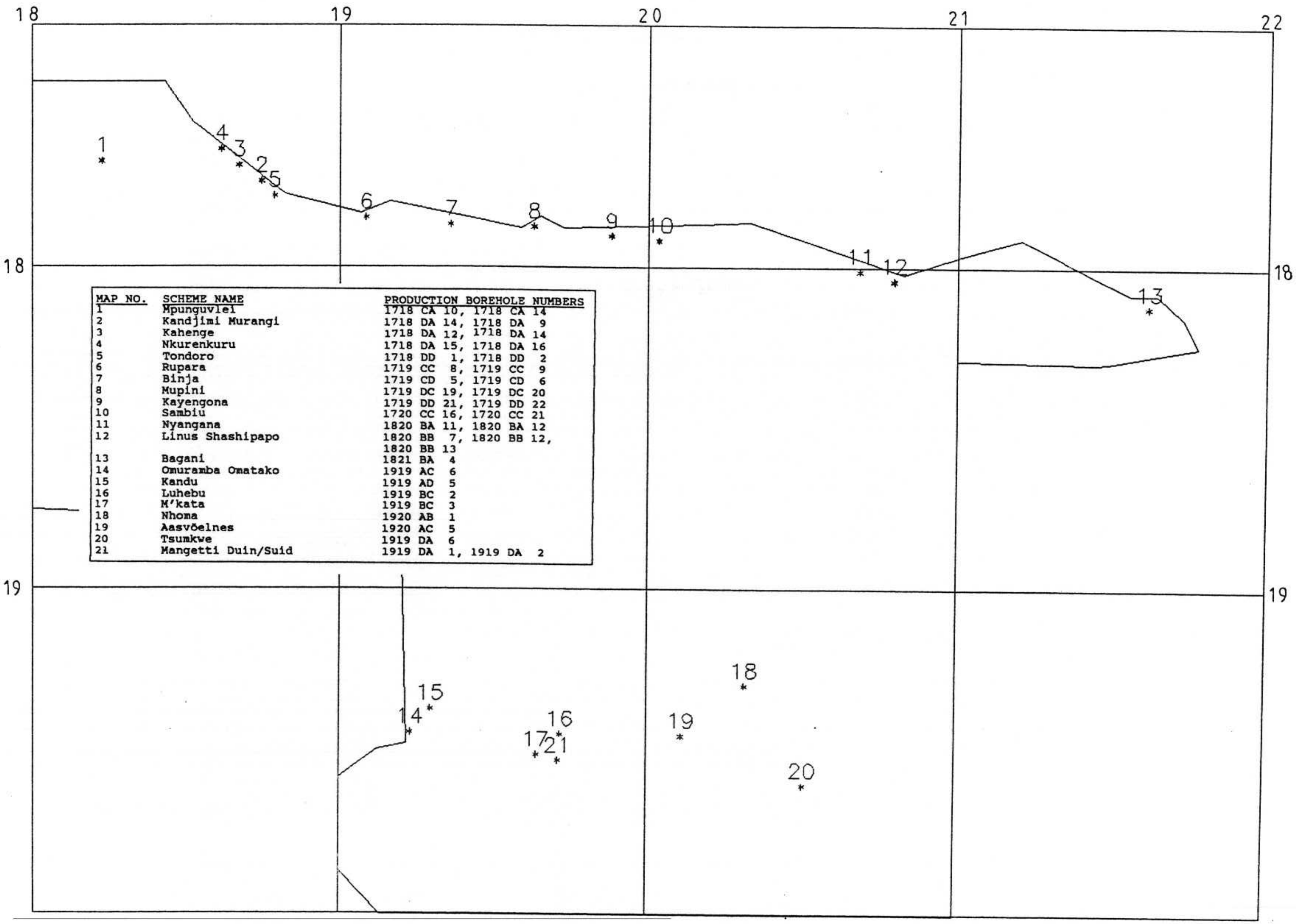
This instrument is reported to be as efficient as resistivity in locating bedrock structures, as it is' quicker and simpler to use. As the EM survey results did not support the results of resistivity profile orientation surveys, which produced clear anomalies over water bearing structures, the value of the EM method in east Bushmanland must be considered doubtful.

4.4 GROUNDWATER UTILIZATION

Water supply boreholes in the Kavango can be divided into two broad classes : State-owned and operated, and non-State-owned. In the case of the former, boreholes can be further classified as either pertaining to Central Government (Department of Fisheries and Water) or to the Department of Agriculture (formerly Kavango Administration). Non-State boreholes fall into a number of diverse classes amongst which are communal, privately owned and institutional (missions, development corporations, co-operatives). The various types of water point are illustrated in Appendix 7. With the exception of records kept for state water scheme boreholes, no current information on groundwater utilization in Kavango and Bushmanland is held by the Department of Fisheries and Water. Data collected during the field survey has provided a comprehensive record of the current status of boreholes throughout the region. At many places boreholes listed on the Departmental database were found to be unserviceable and, in some cases, to have been replaced. Completion certificates for more than 120 boreholes, drilled mainly as replacements, were obtained from the Department of Agriculture in Rundu. None of these boreholes were present on the Departmental database. These have now been added to the downloaded copy of the database ('GENERAL') being used for the project. Where positive identification of boreholes has been established, information collected during the field survey has been used to update their status in the database. Several previously listed boreholes were not positively identified in the field whilst others were not found at their reported locations. The project database 'F_SURVEY' has a listing of the boreholes and dug-wells visited during the field survey (see Appendix 1). Figure 9 and 10 shows the distribution of water points included in the field survey. It is of interest to note that the number of boreholes listed on the Departmental database corresponds well with the number of water points identified during the field survey.

No information pertaining to groundwater development by missions and other institutions is available, although some details have been obtained from the FNDC representative in the Mangetti. Results from the drilling of 23 boreholes in the east of Bushmanland over the past 2 years were submitted to the Department by the Ju/wa Bushman Development Foundation and have been appended to the Departmental database.

Figure 48 illustrates the distribution of the 22 water schemes maintained by the Department of Fisheries and Water in Kavango and Bushmanland (data obtained from Geohydrology Division). The Division maintains monthly records of abstraction volume, pump hours, rest water level and pump water level. This information is processed and forms the basis for an effective aquifer management practice. Records of monthly rest water levels, from state water scheme boreholes, show that abstraction is far exceeded by recharge and water rest levels behave almost independently to the volumes abstracted at any one point. The bulk of boreholes listed in the Geohydrology Division database were drilled for water supply to rural communities, either to be operated by the locals or by the regional authorities. For these the only information available is mostly entered on the completion certificate, giving details from the time of drilling which only relate to such things as locality, construction and yield. Records relating to pumping installations and pumping rates of boreholes in the Kavango are held by the Department of Agriculture in Rundu, but pumpage figures and water level records are unfortunately not maintained. No records pertaining to the subsequent operation of non-state water scheme boreholes in Bushmanland were located.



MAP NO.	SCHEME NAME	PRODUCTION BOREHOLE NUMBERS
1	Mpunguvlei	1718 CA 10, 1718 CA 14
2	Kandjimi Murangi	1718 DA 14, 1718 DA 9
3	Kahenge	1718 DA 12, 1718 DA 14
4	Nkurenkuru	1718 DA 15, 1718 DA 16
5	Tondoro	1718 DD 1, 1718 DD 2
6	Rupara	1719 CC 8, 1719 CC 9
7	Binja	1719 CD 5, 1719 CD 6
8	Mupini	1719 DC 19, 1719 DC 20
9	Kayengona	1719 DD 21, 1719 DD 22
10	Sambiu	1720 CC 16, 1720 CC 21
11	Nyangana	1820 BA 11, 1820 BA 12
12	Linus Shashipapo	1820 BB 7, 1820 BB 12, 1820 BB 13
13	Bagani	1821 BA 4
14	Omuramba Omatako	1919 AC 6
15	Kandu	1919 AD 5
16	Luhebu	1919 BC 2
17	M'kata	1919 BC 3
18	Nhoma	1920 AB 1
19	Aasvöelnes	1920 AC 5
20	Tsumkwe	1919 DA 6
21	Mangetti Duin/Suid	1919 DA 1, 1919 DA 2

Figure 48 Distribution of State Groundwater Schemes in Kavango and Bushmanland

Borehole installations include both hand-operated and motor-driven pumps. Due to the general forest cover in sand covered regions (ie. most of Kavango), wind pumps are seldom used. Some wind pumps are in use in eastern Bushmanland where the vegetation is generally more open. Where motorised pumps are utilized, storage tanks are necessary. Reticulation may either extend to several users (in rare cases) or, more commonly, to a single point which serves the community. With hand-pump abstraction no storage is necessary and water is merely carried in containers from the pump outlet or led via a conduit to a drinking trough.

In rural areas of Kavango the responsibility for the maintenance of pumps, and in the case of motorized pumps, the provision of fuel, is commonly that of the Department of Agriculture who have permanently mobile maintenance crews. These crews visit all Department of Agriculture water points in the territory on a monthly basis, repairing or replacing pumps and motors and delivering diesel and oil. In Bushmanland this responsibility falls either to the JBDF who continually visit settlements under their control, or in the case of settlements under the jurisdiction of the San Affairs Committee, to the Department of Fisheries and Water in Rundu. JBDF settlement boreholes are either installed with wind pumps or with lift type hand-pumps, whereas all San Affairs boreholes are equipped with diesel powered mono pumps.

A number of boreholes have been drilled in the grounds of schools along the main road from Bagani through to Nkurenkuru. These schools are mainly close to the Okavango River and the boreholes are for the purpose of improving general health standards for the scholars. Some of these boreholes are found at a few schools along the tarred road from Rundu to Grootfontein. Drilling was carried out by the Department of Agriculture on behalf of the Department of National Education. The boreholes are equipped with hand-pumps, mainly of the mono type. At Koroko, in Dciriku territory, the water from the school borehole is saline and only used for domestic purposes by the local people.

Corrosive agents in groundwater, such as low pH or anaerobic, sulphur reducing bacteria, may attack the steel of borehole installations and cause rapid deterioration or even complete collapse within as little as 2-4 years (Simmonds, 1988). Similarly the clogging of screens and filters by encrustation or the ingress of fines is also a common problem, limiting both yield and in some cases, borehole life, in these Kalahari aquifers. Although mention was made by Mr Loubser, of the Water Supply Section of the Department of Agriculture in Rundu, of 'several boreholes that have collapsed throughout Kavango', no quantitative and definite statistics were available on the possible causes, the life of plain steel cased boreholes or the actual number of 'collapsed' boreholes. In areas of anticipated corrosive groundwaters the use of uPVC and other non-corrodible materials for borehole casings and screens has been tested with some measure of success.

Hand-dug wells are very common where the water table is shallow. In the Sambiu tribal area, along the Omiramba Omatako and Fonteine, dug-wells form a major part of the water supply. Other areas where wells are important are indicated on Figure 10 which shows the locations of dug-wells visited during the field survey. These structures may reach depths in excess of 20 m, eg. in southern Mbukushu, and they may be lined with brick or wooden lattice work or, more commonly, are unlined. In the case of the latter, problems with collapse are frequent, particularly after periods of heavy rainfall. Hand dug-wells usually have no parapet and are therefore highly susceptible to pollution from the surface. Abstraction is normally limited to bucket-and-rope methods limiting supply capacity.

5 CONCLUSIONS

It is concluded that :

5.1 In Kavango and Bushmanland two aquifers are present. These are :

5.1.1 the Kalahari Group strata, constituting a primary aquifer yielding easily located, reliable sources of generally good quality groundwater;

5.1.2 secondary aquifers hosted by structures in pre-Kalahari bedrock lithologies where exploration for groundwater is more difficult and supplies are of varying reliability and quality.

5.2 For the purpose of groundwater supply the area can be subdivided into :

5.2.1 areas where the water table is deep, requiring the drilling of boreholes, installation of motorized pumps and the provision of surface reservoirs;

5.2.2 areas of shallow water table where groundwater may be abstracted from either boreholes or hand dug-wells through the use of hand-pumps.

5.3 Artesian water is present in only two places.

5.4 No extensive areas of poor quality groundwaters are present. In most areas, potable water can be located within approximately 5 km of boreholes which have intersected unusable water.

5.5 Groundwater is continually flowing into the Okavango river and no recharge takes place from the river into the Kalahari Group aquifer.

5.6 Increases in fluoride and alkalinity are noted in groundwaters flowing from bedrock recharge areas.

5.7 Two discrete aquifers, one fresh and one slightly saline, are present in the Dumushe area (Ref W3, Figure 50).

6 PROPOSED PROGRAMME FOR PHASE 2 INVESTIGATION

6.1 INTRODUCTION

In terms of Paragraph 2.4.6 of Tender Number F1/11-9/90, the final report for Phase 1 was required to contain proposals for the second phase (Phase 2). These proposals were to outline an investigation programme, the aim of which is to provide a better understanding of the groundwater resources of Kavango and Bushmanland. This will allow a more cost-effective and beneficial exploitation of one of Namibia's most important groundwater reserves.

Kalahari Group lithologies provide a continuous aquifer virtually throughout the study area with readily located, reliable sources of potable groundwater. Little quantitative information regarding aquifer parameters, which control groundwater distribution and the yield capacity of the system, is available. The proposed investigation aims to provide such quantitive information.

It must be stressed at the outset that this programme remain flexible. If information gained during the course of investigation dictates a change in the direction of any aspect of the programme, this should be accommodated where possible. Accordingly, regular meetings will be held with the Department of Water Affairs to discuss progress and aspects of the programme which may require revision.

The proposed programme is divided into the following components:

* Preliminary data assessment

* Geophysical investigation

* Drilling and test pumping programme

* Shallow well programme

6.2 PRELIMINARY DATA ASSESSMENT

Structural and stratigraphic controls which may influence groundwater distribution will be assessed by:

* The study of Landsat images and air photos with the aim of identifying geological structures. Major structures tend to appear as linear features showing either tonal or topographic association on the image. An example of such a linear feature would be the Omuramba Omatako.

* Elementary lithofacies analysis of the strata with the aid of reasonably detailed lithological records from earlier drilling. If correlation of lithofacies with available hydrogeological data proves practical, then this would provide a useful tool for use in groundwater exploration.

This assessment will lead to the identification of target areas.

6.3 GEOPHYSICAL INVESTIGATION

Geophysical surveying over target areas should confirm postulated structural and stratigraphic controls.

Structural features are to be investigated by the application of ground magnetics and various geoelectical profiling techniques, which will permit the accurate siting of boreholes. Indications of the stratigraphic sequence anticipated at specific sites will be provided by geoelectrical soundings.

6.4 DRILLING AND TEST PUMPING PROGRAMME

Drilling at confirmed targets will provide detailed lithological records and enable the determination of aquifer parameters through test pumping. This should substantiate the influence of postulated structural and stratigraphic controls.

Based on information presented in this report two large areas in Kavango and one in Bushmanland have been selected for Phase 2 drilling investigation. These areas have been selected for the following reasons:

* these areas coincide with different stuctural and groundwater regimes which should provide a better understanding of the aquifer conditions.

* there is a lack of groundwater information;

* the areas are largely uninhabited, and have potential for future development.

* as part of the broad land use policy being adopted in Kavango, the northern parts are reserved for communal lands, while the southern areas are intended for agricultural development.

Thirteen boreholes are planned for Phase 2: three in southern Kwangali, one in northern Kwangali, seven in southern Mbunza, Sambiu and Gciriku and two in western Bushmanland (Figure 49 and Table 3).

TABLE 3 DRILLING PROGRAMME : PHASE 2

Site No.	Exp. RWL	Exp. Bedrock	Compl. Depth
K1	65	340	200
K2	65	360	250
K3	85	300	200
K4	60	250	200
K5	70	250	200
K6	60	240	200
K7	10	200	200
K8	15	160	200
K9	10	110	140
K10	10	160	160
K11	130	300	200
K12	140	320	250
K13	50	250	200
		SUB TOTAL	2400
		PRODUCTION DRILLING	400
		TOTAL	2800

At each of the sites listed in Table 3, exploration boreholes are to be drilled. If, during the assessment of a borehole, the groundwater parameters indicate substantial yield potential (through pump testing etc.), a larger diameter production borehole is to be drilled. The exploration borehole will be used for observation during pumping tests on the production borehole. For this reason an additional 400 m of drilling has been included in the cost proposal. The drilling of production boreholes will only be carried out after discussion with the Geohydrology Division.

Exploration boreholes will be equipped with 150 mm perforated casings to ensure their future usefulness for either monitoring or production. Where practical, uPVC casings will be installed. The application of other non-corrosive materials, eg. Johnson Screen, is to be considered for production boreholes where uPVC is likely to cause problems during installation and development.

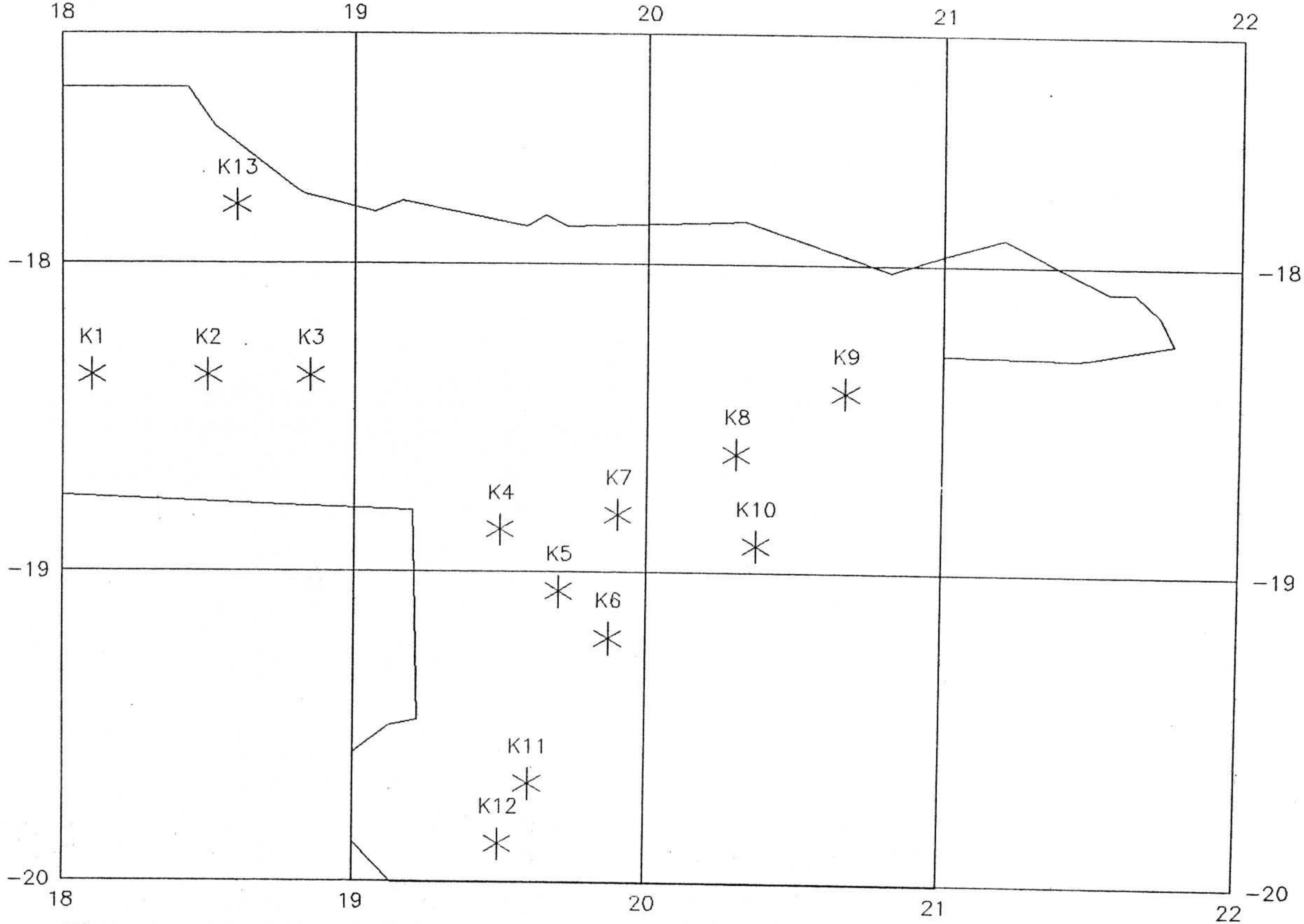


Figure 49 Proposed borehole positions for Phase 2

Production boreholes will also be equipped with a suitable filter pack.

Exploration boreholes are to be subjected to a series of 60 minute variable discharge tests which will determine a suitable rate for constant discharge testing. Constant discharge testing for a period of at least 24 hours is also planned for these boreholes. Production boreholes will, in addition to variable discharge testing, be subjected to a constant discharge test of 72 hours. The use of observation boreholes (original exploration boreholes), will enable the accurate determination of aquifer parameters such as storage coefficient and transmissivity.

6.4.1 SOUTHERN KWANGALI (Boreholes K1-K3)

Although there is no groundwater information, this uninhabited area is at present being developed into formal farms by the Ministry of Lands and Resettlement (P. Horn, pers. comm.). It is therefore of some urgency that the groundwater supply potential for this area be investigated.

This area straddles the northwest trending axis of the Kalahari Basin and overlies more than 300m of Kalahari Group sediments. The groundwater recharge area to the south of the Mangetti (Figure 13) ensures positive flow into this area which may be stratigraphically connected to deep, high yielding groundwater conditions to the west (N. Hoad pers. comm.). Although the borehole investigation is not aimed at the base of the stratigraphy, it will be augmented by deep geoelectrical survey work which may confirm the presence of these features and enable the delineation of the aquifer geometry.

6.4.2 SOUTHERN MBUNZA, SAMBYU AND GCIRIKU (Boreholes K4 - K10)

This area has been reserved for formal farm development (P. Horn pers. comm.) and therefore groundwater information is required. Investigation should take place well in advance of any specific planning, to enable pertinent decision making.

Boreholes K4-K6 are aimed at investigating the northwest trending zone, across which water rest levels increase towards the southwest (Figure 14). This zone is partly coincident with the water table ridge which also parallels the basin axis in the central and southern parts of the area. The strata in this area may reveal aspects of permeability and lithofacies which explain this increase in water rest level depths along this belt;

Borehole K5 has been positioned to coincide with possible lineament intersections, seen on Landsat images, defined by the Omurumba Omatako drainage. This will however be confirmed during the initial study and geophysical invetigation of the area. In addition, this area has reasonable road access along the omurumba.

Boreholes K7-K10 are aimed at the area underlain by shallow water rest levels to investigate possible deeper aquifers. The geometry of the water table in this area is independant of the Kalahari Group isopachs which results in significant thicknesses of readily accessible aquifer sediments (Table 3). As is seen from Table 3, drilling is intended to continue to bedrock in these boreholes and therefore should intersect all the aquifers through the sedimentary pile.

6.4.3 WESTERN BUSHMANLAND (Boreholes K11 - K12)

This drilling will investigate a number of anomalous groundwater related features.

* the general decrease in borehole yields towards the extreme southwest;

* relatively deep rest water level and low water table elevation which are independant of Kalahari Group thickness;

* the presence of Landsat lineaments which Simmonds (1986) considers may represent deep seated structures that have influenced the groundwater conditions.

Based on Landsat and air photo interpretation, with follow up geophysical survey work, this drilling investigation should provide important information in this poorly understood uninhabited aera.

6.4.4 YINSU (Borehole K13)

The water table depression at Yinsu, 20 km south of Nkurenkuru (Section 4.1.1) may be the result of reactivated bedrock structures (Simmonds, 1987). If this is supported by the Landsat and air photo study and confirmed by geophysical field work, one borehole is to be drilled to test this hypothesis.

6.5 SHALLOW WELL PROGRAMME

A limited well installation programme is to be implemented in areas of shallow watertable to investigate alternative methods of water abstraction aimed at providing improved, safe and permanent water supplies suited to rural community requirements. At present the dug-wells prevalent in the region are unlined and unsealed excavations which suffer collapse and siltation together with a general susceptibility to pollution. These wells are not satisfactory and suitable alternatives should be investigated and implemented as a matter of some priority.

Figure 10 shows the positions of dug-wells visited during the field survey and illustrates the present distribution of communities reliant on this type of water point. Examination of Figure 14, a contoured plot of water rest levels, shows large parts of the region to have a water table depth of less than 20 m. These comprise areas in which the wide scale application of properly constructed dug-wells or other structures suited to shallow water table, low volume abstraction, should be considered.

Four areas have been selected for the construction and testing of experimental shallow wells (Figure 50). Three of these will require the testing of different lining materials and construction techniques while a fourth (around Dumushe and Kandjara in the Gciriku tribal area) will be aimed at effectively exploiting fresh water from perched aquifers in an area where several boreholes have penetrated deeper, saline water (described in Section 4.2 above). It is proposed that two wells will be constructed in each area and that the wells should be situated near communities and fitted with robust hand-pumps. Locals should be encouraged to make use of the wells so that their performance over time can be monitored. (Hand-pump supply, installation and future maintenance will be negotiated with the Department of Fisheries and Water or the Department of Agriculture and Rural Development as it falls beyond the scope of this investigation).

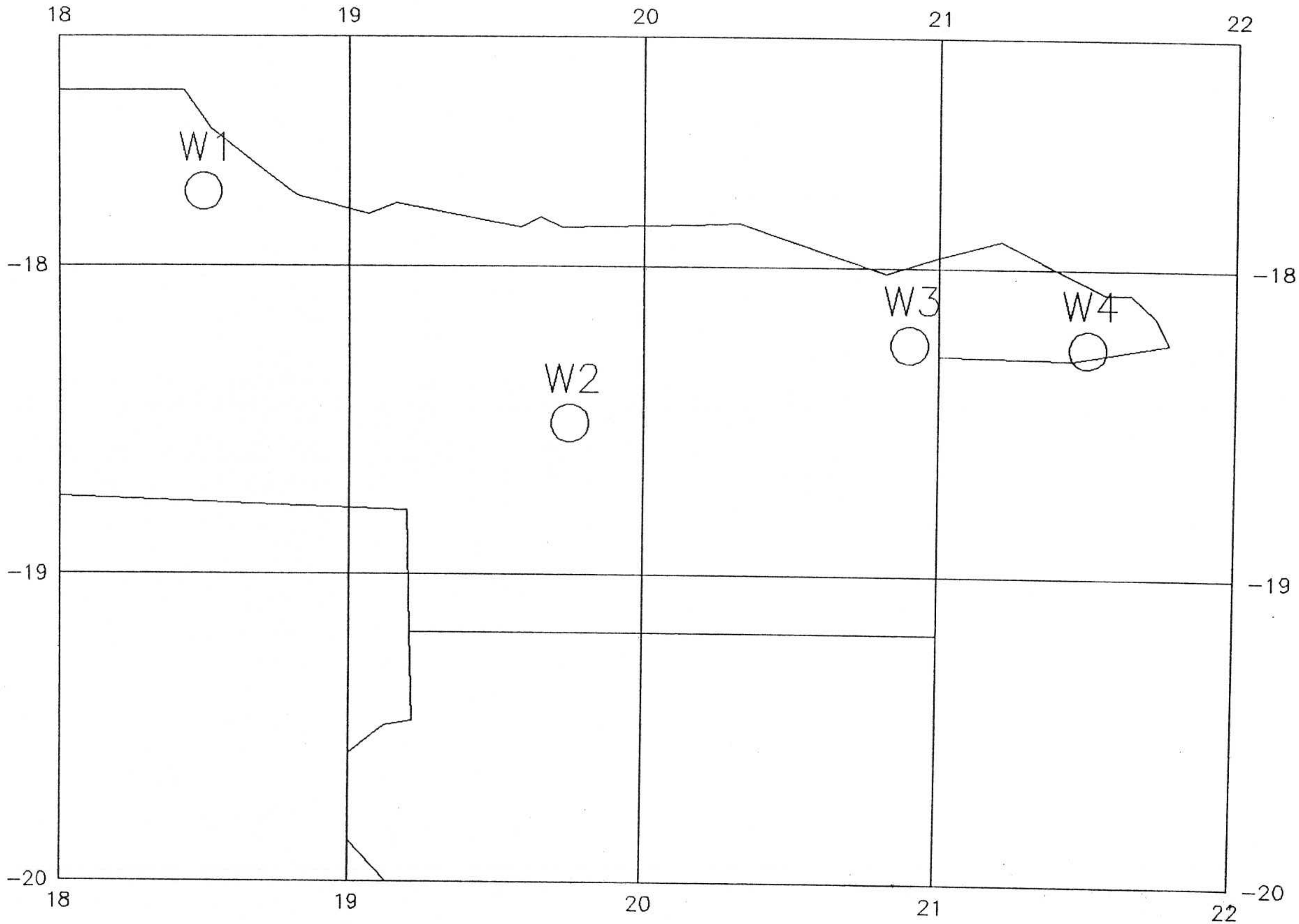


Figure 50 Proposed areas for dug-well testing, Phase 2

A brief description of the expected conditions and intended approaches to be employed in each of the areas follows.

6.5.1 NEPARA-MPUNGU VLEI (KWANGALI)(Figure 50, Ref W1)

Wells in this area are restricted to the omiramba and vary in depth from two to four metres. Here the main problems are pollution and impermanence . The loose, sandy substrate will probably be suited to the method known as caissonning described in Section 6.5.5 below.

6.5.2 OMATAKO AND FONTEINE OMIRAMBA (Figure 50, Ref W2)

Along these omiramba, extensive use is made of dug-wells which average approximately 2.2 metres in depth (maximum 8.1 m). Wells vary from vertical sided to shallow angle, funnel shaped excavations and consequently the methods to be employed will include in-situ lining and caissonning respectively.

6.5.3 DUMUSHE-KANDJARA AREA (EASTERN GCIRIKU) (Figure 50, Ref W3)

The wells in this vicinity are generally of the order of 2.5 metres depth and serve as sources of drinking water whilst borehole water, being of inferior quality, serves the domestic and livestock needs of the communities. It is likely that the caisson method will be most applicable here due to the unconsolidated nature of the sands.

6.5.4 SOUTHERN MBUKUSHU (Figure 50, Ref W4)

Semi consolidated sands in this area enable the excavation of vertical sided wells. Unlined wells reach depths in excess of 20 metres in some places here. These wells are susceptible to sidewall collapse after periods of intense rainfall and they become hazardous during subsequent cleaning operations. In-situ lining methods are to be tested in this area and some emphasis will be placed upon penetrating as deep as possible below the water table.

6.5.5 CONSTRUCTION OF SHALLOW WELLS

In areas of loose unconsolidated sands wells are constructed by sinking prefabricated concrete rings by excavating the ground from underneath them (as described in Simmonds 1986 & 1988; DHV 1979) (caissonning). Alternately, in areas of semi-consolidated ground, wells may be dug and an in-situ lining then emplaced.

In the first three areas included in the well programme (mentioned above) the caisson method will have to be considered due to the prevalence of loose sands. In Mbukushu the ground is more competent and in-situ linings will be more appropriate.

With the caisson method come a number of constraints and potential problems :

* Where loose sands are encountered difficulties arise when the well penetrates to over 1 m below the natural water level. At this point, the difference in the water level inside and outside the well causes a high entry velocity of the water flowing into the well underneath the cutting edge of the lowest ring. Considerable amounts of sand enter the well with this

water, streaming in as quicksand which can fill up the lower rings in a few seconds. This problem is accentuated with increasing differences in head outside and inside the well. DHV (1979, p 83) maintain that one should not attempt to construct a well in a layer of fine to medium sand that is more than 3 m thick without a stable basal layer (eg. clay). The lowest ring should be founded at least 30 cm into the stable layer to prevent sand ingress into the completed well.

* Sand entering the well underneath the cutting edge of the lowest ring causes the surface around the well to collapse.

* If sufficient time passes during well construction, the sand around the well will settle, building up pressure against the rings, increasing friction and inhibiting their movement down the well as excavation proceeds. Alternatively, if well rings are not well attached to one another there will be a tendency for the lower rings to pull away from the upper rings during continued digging.

Alternative approaches to the in-situ lining method have been considered. Methods described in literature include : concrete poured in-situ (shuttering or moulds erected in the pit); brick and mortar linings; wooden lattice work (more of a traditional approach) and the lowering of prefabricated rings into the completed excavation. It is suggested that galvanized iron water tank sections, of suitable diameter, be lowered into the excavation and a 'weak' cement sand backfill be used to fill the annulus. The tank sections would then be left in place and form a permanent inner liner. Minor corrosion of the liner would not present problems in the medium to long term as the stabilized backfill would prevent fall-in of sidewall

material. This method will be tested in one of the Mbukushu wells to demonstrate its practical application and potential cost advantages.
Where well depths with an internal diameter of 1.5 m reach 20 m or more it is intended that the excavation should be carried out to the water table. From this point the diameter will be reduced to ± 1.3 m and the saturated zone penetrated as deep as is required.

This reduced diameter approach may have relevance in the caissonning method where advantages are to be gained from using for example a Johnson 'Drive Point Screen' which would penetrate the saturated material at the base of the well.

An alternative to dug-wells, which has successfully been applied to shallow watertable situations in Tanzania, is the construction of hand-augered, lined wells. These, due to depth limitations, are restricted to areas of good permeability. Augered wells are constructed using temporary casing and may be finished off using uPVC casing and screen with gravel packing. Costs and availability of the required equippment are being investigated.

Detailed site investigation is essential before any digging takes place. Auger drilling is planned at each site to give some firsthand information on subsurface conditions. With this information it will be possible to tailor well designs to specific requirements and to ensure that essential materials and equipment are timeously delivered to site.

6.6 COST PROPOSAL

The estimated costs for the Phase 2 investigation are presented below in Table 4. It must be stressed that this constitutes a costing of projected activities but that these may, in consultation with the Department of Fisheries and Water, be modified during the programme and budget allocations will also change accordingly. The total amount allocated by the Department for Phase 2 is R1 000 000.00 (one million Rand) which should not be exceeded by any modifications to the programme.

TABLE 4 : PROVISIONAL COST ESTIMATE PHASE 2
Tender F1/11-9/90

RATES:

Personnel Rates:

Person	R/hour	R/day	
pc	92.00	736.00	(Principal Consultant)
sc	75.00	600.00	(Senior Consultant)
dt	28.75	230.00	(Data Typist/Secretary)
fa		100.00	(Field Assistant)
ga		50.00	(General Assistant)

Equipment Rates:

	R/day	R/km
Vehicle	115.00	1.15
EM 34-3	200.00	
Resistivity	50.00	
Prot. mag	40.00	
Auger drill	250.00	

PERSONNEL COSTS:

Activity	Days	Personnel	Cost	
Borehole Site Assess	40	pc	29,440.00	
Auger Drilling	20	pc	14,720.00	
Drilling Supervision	150	pc	110,400.00	
Dug-Well Supervision	80	pc	58,880.00	
Dug-Well Sinking	100	fa,3ga	25,000.00	
Pumping Test Sup.	60	sc	36,000.00	
Reporting	35	2pc	55,020.00	
				329,460.00

VEHICLE COSTS:

Activity	Veh/days	Veh/kms	Veh/Charge	
Borehole Site Assess	40	5000	10,350.00	
Auger Drilling	20	4000	6,900.00	
Drilling Supervision	150	10000	28,750.00	
Dug-Well Sinking	80	7000	17,250.00	
Pumping Test Sup.	60	5000	12,650.00	
				75,900.00

EQUIPMENT COSTS:

	Days	Cost	
Auger	20	5,000.00	
EM 34-3	20	4,000.00	
Resistivity	40	2,000.00	
Magnetometer	15	600.00	
			11,600.00

CONTRACTORS:

Drilling:- (See Table 4)	408,000.00
Pumping tests:- (See Table 5)	101,550.00

MATERIALS:

	Cost	
Stone aggregate } Cement } Reinforcing } Materials transport }	37,182.02	
Ring mouldings	4,000.00	
Sundries (Landsat images)	5,500.00	
		46,682.02

ADMINISTRATIVE COSTS:

Stationary & Photocopying } Telephone & Radio Calls } Accomodation }	5,000.00	
		5,000.00

TOTAL PHASE 2 COST :	978,192.02
SURPLUS =	21,807.98
CONTINGENCY(%) =	2%

TABLE 5 : DRILLING RATES

Establishment			@R		26,000.00	
Site moves		1500 km	@R	9.00	13,500.00	
Set ups		19	@R	150.00	2,850.00	
Meterage	85%	2040	@R	75.00	153,000.00	
	10%	240	@R	85.00	20,400.00	
	5%	120	@R	120.00	14,400.00	
Production bhs.		400	@R	100.00	40,000.00	(Approximate)
Casing (plain)		2160	@R	50.00	108,000.00	
Casing (perf.)		240	@R	95.00	22,800.00	
Standing time		40 hrs	@R	135.00	5,400.00	
Borehole marking			@R		150.00	
Lith. + water sampling			@R		1,500.00	

TOTAL COST: 408,000.00

TABLE 6 : PUMPING TEST RATES

	Rate	Amount	Cost
Transport	6.00 per km	2,400.00	14,400.00
Site moves	300.00 each	13.00	3,900.00
Installation & Removal	4.50 per m	1,300.00	5,850.00
Pumping rates	100.00 per hr	516.00	51,600.00
Recovery time	50.00 per hr	516.00	25,800.00

TOTAL COST : 101,550.00

7 RECOMMENDATIONS

It is recommended that :

7.1 this report be accepted in principle;

7.2 the proposals, outlined in Section 6, be used by the Department as the basis for the formulation of the final programme for Phase 2 of the investigation;

7.3 the unit tariffs for personnel and field equipment, as quoted in Section 6, be accepted by the Department as the applicable tariffs for Phase 2 of the investigation;

7.4 the estimated unit costs for transport, accommodation, communication, office rental, drilling and test pumping be used as a guideline in calculating the probable cost of any Phase 2 programme;

NAMIB HYDRO SEARCH (PTY) LTD

C. & S. EXPLORATION COMPANY (PTY) LTD

GEORGE, ORR AND CARR (PTY) LTD

28 FEBRUARY 1991

8 APPROVAL

8.1 This report is approved for submission to the Director: Investigations and Research.

CHIEF : PLANNING

Date: 12/04/1991

8.2 The recommendations in this report are supported and the report is submitted to the Permanent Secretary for Water Affairs for approval.

DIRECTOR : INVESTIGATIONS AND RESEARCH

Date: 12/04/1991

8.3 The recommendations in this report have been decided upon as follows:

Approved

PERMANENT SECRETARY FOR WATER AFFAIRS

Date: 15.4.91

9 ACKNOWLEDGEMENTS

NGDC wish to express their appreciation to the following personnel for their contributions during the course of this Phase 1 programme :

9.1 Staff members of the Department of Fisheries and Water for their assistance in making available information from their records; and in particular Mr Nigel Hoad, our project liaison hydrogeologist for his professional guidance and constructive criticism.

9.2 Mr P Horn, head of the Department of Agriculture, Rundu, and his staff for invaluable support throughout the field survey. The assistance with maps, personnel and general background relating to the water supply situation in Kavango greatly helped in the implementation of this project.

9.3 Mr Ben Bytel and Dr Tom Tolmay of the Department of Nature Conservation and Veterinary Services, respectively for general environmental information on the study area and constructive discussions regarding the Phase 2 proposals;

9.4 Patricia and Volker Preuß for their hospitality at Sarasungu River Lodge which was used as a base camp during the survey of Kavango;

9.5 Dr Harry Biggs for his personal assistance in the setting up and manipulation of the database.

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APPENDICES

PHASE 1 FINAL REPORT

APPENDIX 1

MASTER LISTINGS FROM F_SURVEY.DBF

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1718AC	1001	0		66.50	0.00	BOREHOLE	ABANDONED	0	0	0	11/27/1990	TARE
1718AD	1001	2	WW22604	0.00	0.00	BOREHOLE	USED	40	0	0	11/27/1990	MBAMBI
1718AD	1002	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	11/27/1990	NAMUTUNTU
1718CA	1001	4	WW22598	0.00	0.00	BOREHOLE	USED	60	0	0	11/27/1990	SIWI
1718CA	1002	3	WW8313	0.00	0.00	BOREHOLE	USED	350	2000	2100	11/27/1990	RUNDA
1718CA	1003	2	WW8314	68.32	0.00	BOREHOLE	USED	88	2000	205	11/27/1990	MPOTO
1718CA	1004	0	WW8968	67.10	0.00	BOREHOLE	USED	150	601	30	11/27/1990	MUKEKETE
1718CA	1005	0	WW22661	0.00	0.00	BOREHOLE	USED	1000	6000	500	11/29/1990	MPUNGU VLEI
1718CB	1001	2	WW9148	0.00	0.00	BOREHOLE	USED	300	400	100	11/27/1990	ZONE
1718CB	1002	0		40.60	2.00	BOREHOLE	USED	200	900	1000	11/29/1990	RUPEHO
1718CB	1003	5	WW21452	72.30	2.88	BOREHOLE	USED	2000	3500	300	11/29/1990	SILIKUNGA
1718CB	1004	0	-	3.30	0.00	DUG WELL	USED	200	0	0	11/29/1990	KENI
1718CB	1005	0	WW4321	60.30	2.00	BOREHOLE	USED	300	830	150	11/29/1990	MUNGOMBA
1718CB	1006	9	WW8311	0.00	0.00	BOREHOLE	USED	300	650	150	11/29/1990	KAGUNI
1718CB	1007	0	-	4.00	0.00	DUG WELL	USED	500	0	0	11/29/1990	KATOPE-SIMBU
1718CC	1001	0	WW8569	70.50	2.80	BOREHOLE	USED	320	620	120	11/28/1990	KATOPE-KOMUGORO
1718CC	1002	0	WW22811	69.00	2.70	BOREHOLE	USED	300	2500	200	11/28/1990	NANDINGWE
1718CD	1001	8	WW8436	43.00	0.00	BOREHOLE	USED	900	4000	3000	11/29/1990	NEPARA
1718CD	1002	0	-	2.00	0.00	DUG WELL	USED	0	0	0	11/29/1990	NEPARA
1718CD	1003	7	WW12870	47.92	0.00	BOREHOLE	USED	0	0	0	11/29/1990	NEPARA 2
1718CD	1004	0	WW29157	73.03	4.00	BOREHOLE	USED	400	3000	200	11/29/1990	SAME
1718CD	1005	3	WW21283	68.40	0.00	BOREHOLE	USED	80	600	30	11/29/1990	NCARISE
1718CD	1006	0		0.00	3.10	BOREHOLE	USED	39	250	60	11/29/1990	NKURIVERE
1718CD	1007	0	WW23496	66.70	0.00	BOREHOLE	USED	200	2000	200	11/29/1990	KASIMBA
1718CD	1008	0	WW23500	79.74	0.00	BOREHOLE	USED	70	1100	300	11/29/1990	NGE
1718CD	1009	0	WW25519	0.00	0.00	BOREHOLE	USED	2000	4000	2000	11/29/1990	GAWA
1718CD	1020	1	WW26630	0.00	3.00	BOREHOLE	USED	340	300	200	11/29/1990	NEPARA ARMY BASE
1718DA	1001	1	WW9138	0.00	0.00	BOREHOLE	USED	100	0	0	11/27/1990	SIMANYA
1718DA	1002	2	WW9136	0.00	1.00	BOREHOLE	USED	600	0	0	11/27/1990	NKURENKURU
1718DA	1003	0		0.00	0.00	BOREHOLE	USED	377	0	0	11/27/1990	MAYARA
1718DA	1004	4	WW9137	21.20	0.00	BOREHOLE	USED	600	0	0	11/27/1990	KAHENGE
1718DA	1005	7	WW9831	0.00	1.00	BOREHOLE	USED	204	0	0	11/27/1990	KANANANA
1718DB	1001	0		0.00	0.00	BOREHOLE	USED	150	0	0	11/27/1990	SITOPOGO
1718DC	1001	2	WW8434	0.00	3.60	BOREHOLE	USED	700	1400	800	11/27/1990	YINSU
1718DC	1002	0	WW24600	0.00	0.00	BOREHOLE	USED	100	0	0	11/27/1990	YINSU
1718DC	1003	0		0.00	2.40	BOREHOLE	USED	349	1600	230	11/27/1990	MPENGE
1718DC	1004	0	-	3.85	0.00	DUG WELL	ABANDONED	0	0	0	11/27/1990	DIKWEYA
1718DC	1005	0	WW29158	0.00	0.00	BOREHOLE	USED	1000	2000	1000	11/27/1990	KANKUDI
1718DC	1006	1	WW8435	46.00	0.00	BOREHOLE	USED	400	1000	200	11/29/1990	NYEGE
1718DC	1007	0	WW25735	0.00	2.70	BOREHOLE	USED	500	1200	1200	11/30/1990	SIKAROSOMPO
1718DC	1008	0	WW27318	76.10	0.00	BOREHOLE	USED	30	105	0	11/30/1990	NAMUNGUNDU
1718DC	1009	0	WW23487	81.80	1.80	BOREHOLE	USED	300	800	150	11/30/1990	SUNI
1718DC	1010	0		67.50	0.00	BOREHOLE	USED	600	2300	200	11/30/1990	CANCHANA
1718DD	1002	0	WW4735	0.00	0.00	BOREHOLE	USED	400	2000	750	11/30/1990	MBOME
1718DD	1003	0	WW29155	45.35	0.00	BOREHOLE	USED	380	500	400	11/30/1990	KAMUPUPU
1718DD	1004	0		0.00	0.00	BOREHOLE	USED	200	0	0	11/30/1990	NKONKE (KATAR' SCHOOL)
1718DD	1005	0	WW25750	18.45	0.00	BOREHOLE	ABANDONED	0	0	0	11/30/1990	S. MPASI JEUG KAMP
1718DD	1006	4	WW9823B	20.19	0.00	BOREHOLE	USED	500	0	0	11/30/1990	NZINZE SCHOOL
1718DD	1007	7	WW9351	26.43	0.00	BOREHOLE	ABANDONED	100	1100	200	11/30/1990	POMBA
1718DD	1008	0	WW23488	79.82	0.00	BOREHOLE	USED	300	2000	200	11/30/1990	DESI
1718DD	1009	0	WW25748	0.00	0.00	BOREHOLE	USED	300	3200	210	11/30/1990	KAPARARA
1719CC	1001	1	WW9321	16.40	0.00	BOREHOLE	USED	200	300	200	12/01/1990	MAYENZERE
1719CC	1002	2	WW9135?	32.40	0.00	BOREHOLE	ABANDONED	0	0	0	12/01/1990	MAYENZERE
1719CC	1003	0	-	2.30	0.00	DUG WELL	USED	500	800	350	12/01/1990	MAYENZERE
1719CC	1004	6	WW4322	0.00	1.80	BOREHOLE	USED	900	6000	80	12/05/1990	GCANGCU
1719CD	1001	0		0.00	0.00	BOREHOLE	USED	472	0	0	12/01/1990	NTARA SCHOOL
1719CD	1002	0	WW9360	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	12/01/1990	NTARA

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1719CD	1003	0	WW32204	0.00	0.00	BOREHOLE	USED	400	0	0	12/01/1990	KASIVI SCHOOL
1719CD	1004	0		0.00	0.00	BOREHOLE	USED	500	0	0	12/01/1990	SIVARA SCHOOL
1719CD	1005	0		0.00	0.00	BOREHOLE	USED	1500	0	0	12/01/1990	BUNYA SCHOOL
1719CD	1006	3	WW8308	20.34	0.00	BOREHOLE	USED	120	300	100	12/04/1990	MBORA(HALILI)
1719CD	1007	0	WW21281	0.00	0.00	BOREHOLE	USED	40	700	8	12/04/1990	SAMASIRA
1719CD	1008	0		0.00	0.00	BOREHOLE	USED	350	500	250	12/04/1990	NSINDI
1719CD	1009	4	WW9379	0.00	0.00	BOREHOLE	USED	400	0	0	12/04/1990	HALILI LP + HP SCHOOL
1719CD	1010	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	12/01/1990	LEEUWE JEUG KAMP
1719DC	1001	14	WW9406	0.00	0.00	BOREHOLE	USED	1000	600	250	10/26/1990	MAVANZE
1719DC	1002	17	WW22802	42.10	0.00	BOREHOLE	USED	1000	500	100	12/04/1990	SAUYEMWA
1719DC	1003	0	-	1.00	0.00	DUG WELL	USED	500	300	40	12/04/1990	KASOTE
1719DC	1004	16	WW9369	40.00	0.00	BOREHOLE	USED	6000	500	700	12/04/1990	NKAZAZA
1719DC	1005	15	WW9397	40.00	0.00	BOREHOLE	USED	0	0	0	12/04/1990	NKAZAZA
1719DC	1006	10	WW3907	0.00	0.00	BOREHOLE	USED	300	500	500	12/04/1990	MUKUNDU
1719DC	1007	0	-	3.50	0.00	DUG WELL	USED	100	300	100	12/04/1990	NKUTU
1719DC	1008	7	WW9372	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	12/04/1990	SINSOGORO
1719DC	1020	0	WW25710	0.00	0.00	BOREHOLE	USED	300	0	0	12/04/1990	KAPAKO
1719DD	1001	0	-	0.00	0.00	DUG WELL	USED	200	0	0	10/20/1990	KAISOSI
1719DD	1002	0	WW23497	0.00	1.94	BOREHOLE	USED	0	0	0	10/20/1990	KAISOSI 2
1719DD	1003	9	WW9717	0.00	0.00	BOREHOLE	USED	7000	0	0	10/20/1990	KAISOSI 1
1719DD	1004	18	WW12883?	0.00	0.66	BOREHOLE	USED	120	0	0	10/20/1990	NGCANGCANA
1719DD	1005	0		38.60	0.00	BOREHOLE	NOT COMPLETE	0	0	0	10/20/1990	NGCANGCANA - NOT YET COMPLETED, 1990
1719DD	1006	16	WW8302	33.80	4.80	BOREHOLE	USED	130	280	100	10/26/1990	NGCARAMA
1719DD	1007	14	WW8303	0.00	0.00	BOREHOLE	USED	330	0	0	10/26/1990	KAMBOWO
1719DD	1008	0	WW29933	0.00	0.00	BOREHOLE	USED	250	0	0	10/26/1990	MOHOPI
1719DD	1009	13	WW9718	0.00	0.00	BOREHOLEE	USED	250	1000	100	10/27/1990	NGONE
1719DD	1010	0	WW25736	0.00	0.00	BOREHOLE	NOT USED	1000	1200	600	10/27/1990	MAYANA
1720CC	1001	0	WW25745	0.00	0.00	BOREHOLE	USED	1200	1500	67	10/26/1990	MUNGUNDA
1720CC	1002	2	WW8972	0.00	1.80	BOREHOLE	USED	0	0	0	10/26/1990	FUMBE
1720CC	1003	15	WW22600	0.00	0.00	BOREHOLE	USED	200	0	0	10/27/1990	MUPAPAMA
1720CC	1004	0	WW9430	0.00	0.00	BOREHOLE	USED	100	0	0	10/27/1990	MASHARE SCHOOL
1720CD	1001	0	WW29162	0.00	0.50	BOREHOLE	USED	1200	0	0	10/31/1990	RUNDJARARA
1720CD	1002	2	WW9370	0.00	0.60	BOREHOLE	USED	166	0	0	10/31/1990	MABUSHE
1720CD	1003	0		0.00	0.00	BOREHOLE		250	0	0	10/31/1990	MABUSHE
1720CD	1004	3	WW22801	0.00	4.80	BOREHOLE	NOT USED	150	0	0	10/31/1990	SHIGHURU
1720CD	1005	5	WW9384	8.20	0.00	BOREHOLE	USED	600	0	0	10/31/1990	NDONGA
1721CC	1001	0	WW29932	0.00	0.00	BOREHOLE	USED	278	0	0	10/31/1990	MBAMBI SCHOOL
1721CC	1002	0		0.00	0.00	BOREHOLE	USED	55	86	100	11/01/1990	MUNGANYE
1721CC	1003	0	WW25499	0.00	0.00	BOREHOLE	USED	380	0	0	11/01/1990	SHAMANGORWA
1721CC	1004	0		0.00	0.00	BOREHOLE	USED	50	0	0	11/22/1990	TYOVA SCHOOL
1721CC	1005	8	WW9720	0.00	0.00	BOREHOLE	USED	0	250	120	11/22/1990	TYOVA
1721CC	1006	4	WW9714	0.00	0.00	BOREHOLE	USED	1500	2000	1000	11/22/1990	KANGONGO
1721CC	1007	0	WW24602	0.00	0.00	BOREHOLE	USED	0	0	0	11/23/1990	MAYARA CLINIC
1721CC	1008	0		0.00	0.00	BOREHOLE	USED	300	0	0	11/23/1990	MAYARA SCHOOL
1721CD	1001	2	WW9293	0.00	0.80	BOREHOLE	USED	128	70	90	11/23/1990	BIRO SCHOOL
1721CD	1002	1	WW10143	0.00	0.00	BOREHOLE	USED	50	0	0	11/23/1990	KAYANGA
1818AB	1001	0		80.20	0.00	BOREHOLE	ABANDONED	12	25	13	11/28/1990	SIGIZI
1818AB	1002	3	WW8437	66.40	3.10	BOREHOLE	USED	152	856	102	11/28/1990	MUPARANA
1818AB	1003	0		0.00	0.00	BOREHOLE	USED	21	1600	45	11/28/1990	HAMUNE FARM
1818AB	1004	0	WW30923	0.00	0.00	BOREHOLE	USED	87	264	99	11/28/1990	SIKUMBA
1818BA	1001	0	WW12882	0.00	3.13	BOREHOLE	USED	300	2200	3000	11/30/1990	MBURURU
1818BB	1001	3	WW9449	0.00	3.30	BOREHOLE	USED	200	500	140	11/30/1990	GCARUHA
1818BB	1002	1	WW30919	75.54	0.00	BOREHOLE	USED	200	560	50	11/30/1990	MPANDA
1818CA	1001	4	WW8109	0.00	0.00	BOREHOLE	USED	9	0	0	12/27/1990	MANGETTI 23
1818CA	1002	8	WW8110	0.00	0.00	BOREHOLE	USED	16	0	0	12/27/1990	MANGETTI 27
1818CA	1003	12	WW8111	0.00	0.00	BOREHOLE	USED	13	0	0	12/27/1990	MANGETTI 28

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1818CA	1004	11	WW8112	0.00	0.00	BOREHOLE	USED	8	0	0	12/28/1990	MANGETTI 25
1818CA	1005	7	WW8113	0.00	0.00	BOREHOLE	USED	17	0	0	12/28/1990	MANGETTI 24
1818CA	1006	3	WW8114	0.00	0.00	BOREHOLE	USED	10	0	0	12/28/1990	MANGETTI 20
1818CA	1007	2	WW8115	0.00	0.00	BOREHOLE	USED	18	0	0	12/28/1990	MANGETTI 17
1818CA	1008	6	WW8116	0.00	0.00	BOREHOLE	USED	11	0	0	12/28/1990	MANGETTI 21
1818CA	1009	10	WW8117	0.00	0.00	BOREHOLE	USED	23	0	0	12/28/1990	MANGETTI 22
1818CA	1010	9	WW8118	0.00	0.00	BOREHOLE	USED	10	0	0	12/28/1990	MANGETTI 19
1818CA	1011	5	WW8119	0.00	0.00	BOREHOLE	USED	9	0	0	12/28/1990	MANGETTI 18
1818CA	1012	1	WW8120	67.71	0.00	BOREHOLE	USED	19	0	0	12/28/1990	MANGETTI 14
1818CA	1030	0		0.00	0.00	BOREHOLE	USED	35	200	110	01/20/1991	ONEPANDU(FARM16)
1818CA	1031	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/20/1991	M-CAMP
1818CA	1032	0	B25705	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/20/1991	MONGOMBI
1818CB	1001	9		32.63	2.40	BOREHOLE	USED	23	0	0	12/07/1990	MANGETTI 37
1818CB	1002	6	WW8101	0.00	0.00	BOREHOLE	USED	16	0	0	12/07/1990	MANGETTI 36
1818CB	1003	3	WW8102	0.00	0.00	BOREHOLE	USED	20	0	0	12/27/1990	MANGETTI 32
1818CB	1004	2	WW8103	0.00	0.00	BOREHOLE	USED	12	0	0	12/27/1990	MANGETTI 29
1818CB	1005	5	WW8104	0.00	0.00	BOREHOLE	USED	8	0	0	12/27/1990	MANGETTI 33
1818CB	1006	8	WW8105	0.00	0.00	BOREHOLE	USED	10	0	0	12/27/1990	MANGETTI 34
1818CB	1007	7	WW8106	0.00	0.00	BOREHOLE	USED	11	0	0	12/27/1990	MANGETTI 31
1818CB	1008	4	WW8107	40.12	0.00	BOREHOLE	USED	14	0	0	12/27/1990	MANGETTI 30
1818CB	1009	1	WW8108	0.00	0.00	BOREHOLE	USED	10	0	0	12/27/1990	MANGETTI 26
1818DA	1001	0		0.00	0.00	BOREHOLE	USED	170	16030	30	12/07/1990	MANGETTI RES. AREA
1818DA	1002	10	WW8094	0.00	0.00	BOREHOLE	USED	0	0	0	12/07/1990	MANGETTI RES. AREA
1818DA	1003	0		0.00	0.00	BOREHOLE	USED	8	0	0	12/07/1990	MANGETTI RES. AREA
1818DA	1004	0		0.00	0.00	BOREHOLE	USED	0	0	0	12/07/1990	MANGETTI QUARANTINE CAMP
1818DA	1005	9	WW8099	0.00	0.00	BOREHOLE	USED	27	0	0	12/07/1990	MANGETTI 40
1818DA	1006	5	WW8098	0.00	3.13	BOREHOLE	USED	29	0	0	12/07/1990	MANGETTI 39
1818DA	1007	7	WW8092	0.00	0.00	BOREHOLE	USED	28	0	0	12/07/1990	MANGETTI 45
1818DA	1008	11	WW8093	0.00	0.00	BOREHOLE	USED	16	0	0	12/07/1990	MANGETTI 46
1818DA	1009	1	WW8097	0.00	0.00	BOREHOLE	USED	26	0	0	12/27/1990	MANGETTI 35
1818DA	1010	0		0.00	0.00	BOREHOLE	USED	0	0	0	12/28/1990	MANGETTI QUARANTINE CAMP
1818DA	1011	6	WW8095	0.00	0.00	BOREHOLE	USED	3	0	0	12/28/1990	MANGETTI QUARANTINE CAMP
1818DA	1012	2	WW8096	0.00	0.00	BOREHOLE	USED	7	0	0	12/28/1990	MANGETTI QUARANTINE CAMP
1818DA	1013	0		0.00	0.00	BOREHOLE	USED	0	0	0	12/28/1990	MANGETTI QUARANTINE CAMP
1818DA	1014	3	WW8091	0.00	0.00	BOREHOLE	USED	10	0	0	12/29/1990	MANGETTI 41
1818DA	1015	4	WW8090	0.00	0.00	BOREHOLE	USED	10	0	0	12/29/1990	MANGETTI 44
1818DA	1016	8	WW8089	0.00	0.25	BOREHOLE	USED	10	0	0	12/31/1990	MANGETTI 48
1818DA	1017	0		0.00	0.00	BOREHOLE	USED	0	0	0	12/31/1990	MANGETTI VET. CAMP 30
1818DA	1020	0		0.00	3.27	BOREHOLE	USED	12	229	96	01/20/1991	FARM NO. 6
1818DA	1021	0		0.00	4.00	BOREHOLE	USED	5	113	0	01/20/1991	FARM NO. 7 (RUDOLF'S FARM
1818DA	1022	0		0.00	4.80	BOREHOLE	USED	8	40	0	01/20/1991	FARM NO. 8
1818DB	1001	1	WW8085	0.00	0.00	BOREHOLE	USED	10	0	0	12/29/1990	MANGETTI 47
1818DB	1002	3	WW8091	100.00	0.00	BOREHOLE	USED	22	0	0	12/29/1990	MANGETTI 50 GROOT
1818DB	1003	0		87.56	0.00	BOREHOLE	USED	5	0	0	12/29/1990	MANGETTI 50 KLEIN
1818DB	1004	0		0.00	0.00	BOREHOLE	USED	16	0	0	12/29/1990	MANGETTI 53
1818DB	1005	0		105.00	0.00	BOREHOLE	USED	14	0	0	12/29/1990	MANGETTI 57
1818DB	1006	0		0.00	0.00	BOREHOLE	USED	7	0	0	12/31/1990	MANGETTI 54 KLEIN
1818DB	1007	5	WW8083	0.00	0.28	BOREHOLE	USED	9	0	0	12/31/1990	MANGETTI 54 GROOT
1818DB	1008	4	WW8086	0.00	2.00	BOREHOLE	USED	23	0	0	12/31/1990	MANGETTI 51
1818DB	1009	6	WW8087	0.00	6.00	BOREHOLE	USED	9	0	0	12/31/1990	MANGETTI 52
1818DB	1020	2	WW9145	0.00	0.00	BOREHOLE	ABANDONED	3	0	0	01/20/1991	KASAIRA
1818DC	1001	0		34.78	4.00	BOREHOLE	USED	0	0	0	12/07/1990	MANGETTI 46 LAAIBANK
1818DC	1002	0		0.00	0.00	BOREHOLE	USED	13	0	0	12/31/1990	MANGETTI 49
1818DC	1003	0		0.00	0.00	BOREHOLE	USED	0	0	0	12/31/1990	MANGETTI QUARANTINE CAMP
1818DC	1004	0		0.00	0.00	BOREHOLE	USED	0	0	0	12/31/1990	MANGETTI VET. CAMP.2
1818DD	1001	0		0.00	0.00	BOREHOLE	USED	14	0	0	12/29/1990	MANGETTI 58
1818DD	1002	6	WW8082	0.00	2.57	BOREHOLE	USED	12	0	0	12/31/1990	MANGETTI 55 GROOT

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1818DD	1003	0		0.00	1.20	BOREHOLE	USED	7	0	0	12/31/1990	MANGETTI 55 KLEIN
1819AA	1001	2	WW9500	46.60	2.40	BOREHOLE	USED	280	400	500	12/05/1990	MPUKU
1819AA	1002	0		0.00	0.00	BOREHOLE	USED	258	348	100	12/05/1990	SAU
1819AA	1003	0		51.90	0.00	BOREHOLE	USED	100	200	40	12/05/1990	KAKUHU
1819AA	1005	0	WW4323	0.00	0.00	BOREHOLE	USED	200	800	500	12/05/1990	NAUCOVA
1819AA	1006	0		48.45	2.88	BOREHOLE	USED	60	200	0	01/18/1991	DAWARE
1819AA	1007	0	WW29930	38.88	0.00	BOREHOLE	USED	220	200	80	01/19/1991	GCAGCAWE
1819AA	1008	0	WW9356	53.70	0.00	BOREHOLE	USED	192	300	120	01/19/1991	NZOVU
1819AA	1009	0	WW28235	0.00	0.00	BOREHOLE	USED	150	350	140	11/30/1990	TJOHA
1819AB	1001	3	WW8150	0.00	0.00	BOREHOLE	USED	500	720	900	11/15/1990	MYL DERTIG
1819AB	1002	0	WW6734	0.00	0.00	BOREHOLE	USED	150	304	150	11/15/1990	CWI (QWI)
1819AB	1003	0	WW9142	33.00	0.00	BOREHOLE	USED	82	200	60	12/04/1990	NKATA
1819AB	1004	0	WW9360	35.90	4.20	BOREHOLE	USED	100	1000	40	12/04/1990	NCARA
1819AB	1005	5	WW9419	42.79	0.00	BOREHOLE	IN PROGRESS	40	200	0	12/04/1990	PUZA
1819AB	1006	7	WW8965	0.00	0.00	BOREHOLE	USED	36	6	0	12/04/1990	KARO
1819AC	1001	2	WW8146	77.20	0.00	BOREHOLE	USED	6	400	0	01/19/1991	MIN. RUDOLF NGONDO
1819AC	1002	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/19/1991	MIN. RUDOLF NGONDO
1819AC	1003	1	WW25740	0.00	0.00	BOREHOLE	USED	0	0	0	01/19/1991	MIN. RUDOLF NGONDO
1819AC	1004	0		0.00	0.00	BOREHOLE	USED	6	120	0	01/19/1991	FRANS KAMBUTA
1819AC	1005	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/19/1991	FRANS KAMBUTA
1819AC	1006	0		67.35	2.18	BOREHOLE	USED	6	0	0	01/19/1991	MYL 46 TEELSTASIE SK2
1819AC	1007	0	WW25732	66.01	0.00	BOREHOLE	USED	12	106	0	01/19/1991	MYL 46 TEELSTASIE TK2
1819AC	1008	0	WW25736	0.00	0.00	BOREHOLE	USED	14	0	0	01/19/1991	MYL 46 TEELSTASIE TK2
1819AC	1009	0		0.00	0.00	BOREHOLE	DISUSED	0	0	0	01/19/1991	MYL 46 TEELSTASIE JB 6
1819AD	1001	0	WW21762	0.00	0.00	BOREHOLE	USED	250	304	180	11/16/1990	SIHETEKERA
1819AD	1002	0		40.07	2.88	BOREHOLE	USED	120	279	44	11/16/1990	MUTOMPO
1819AD	1003	0		0.00	0.00	BOREHOLE	USED	180	2063	178	11/15/1990	SIHEPERA
1819AD	1004	5	WW8148	23.39	0.00	BOREHOLE	USED	110	210	64	11/15/1990	MBEYO (KUSEKA)
1819AD	1005	3	WW9428	34.12	0.00	BOREHOLE	USED	100	200	154	11/16/1990	EPINGIRO
1819AD	1006	0	WW8966	26.83	0.00	BOREHOLE	USED	180	1500	160	11/16/1990	MPENGU
1819AD	1007	0		0.00	0.00	BOREHOLE	USED	15	79	15	11/16/1990	MAKENA PLAAS
1819AD	1008	2	WW8147	0.00	0.00	BOREHOLE	USED	82	208	130	11/16/1990	TCOVE PLAAS
1819AD	1009	0	WW212821	0.00	0.00	BOREHOLE	USED	6	24	0	11/16/1990	L. HAKUSEMBE PLAAS
1819AD	1010	0	WW23489	57.41	0.00	BOREHOLE	USED	400	486	360	11/16/1990	MYL 46 PROJECT
1819AD	1011	0	WW23494	0.00	0.00	BOREHOLE	USED	20	100	32	11/16/1990	MPORA PLAAS
1819AD	1012	0	WW25741	0.00	0.00	BOREHOLE	USED	40	0	0	11/16/1990	MAYONGORA (MPORA NO.2)
1819AD	1013	0	WW29935	0.00	0.00	BOREHOLE	USED	10	30	0	01/19/1991	WIZENI
1819BA	1001	4	WW8145	0.00	0.00	BOREHOLE	USED	2500	4000	270	11/15/1990	TIEN MYL
1819BA	1002	3	WW21850	0.00	0.00	BOREHOLE	USED	120	0	0	11/15/1990	ARENDSNES
1819BA	1003	2	WW9398	0.00	1.00	BOREHOLE	USED	8	37	11	11/15/1990	SIPILI
1819BA	1004	1	WW25511?	0.00	0.00	BOREHOLE	USED	800	175	195	11/15/1990	BITTERSOET
1819BA	1005	5	WW8151	0.00	2.00	BOREHOLE	USED	1500	506	735	11/15/1990	MYL TWINTIG
1819BA	1006	0	WW8300	0.00	5.50	BOREHOLE	USED	500	800	300	12/04/1990	SISUNGU
1819BA	1007	0		6.30	0.00	BOREHOLE	USED	300	0	0	10/25/1990	HAMOYE
1819BB	1001	0	WW25727	0.00	0.00	BOREHOLE	USED	300	500	600	10/25/1990	HAMOYE
1819BB	1002	0	-	1.50	0.00	DUG WELL	USED	150	400	120	10/25/1990	NCECWA
1819BB	1003	0	WW25514	0.00	0.90	BOREHOLE	USED	280	500	200	10/25/1990	NCUNCUNI
1819BB	1004	0	WW16557	15.00	2.80	BOREHOLE	USED	3000	0	0	10/25/1990	CUMA (DWA-> 1820AA_3?????
1819BB	1005	0	WW21450	0.00	2.80	BOREHOLE	USED	730	0	0	10/25/1990	MATAPI
1819BB	1006	0	-	2.40	2.40	DUG WELL	USED	110	0	0	10/26/1990	KAUTI (DWA - KAPUPAHEDI)
1819BB	1007	0	-	0.00	2.00	DUG WELL	USED	200	500	650	10/26/1990	SHIKALI
1819BB	1008	0	WW25728	8.60	0.80	BOREHOLE	USED	250	400	120	10/26/1990	SHARUKWE
1819BB	1010	1	WW9414	0.00	0.00	BOREHOLE	USED	300	405	180	10/26/1990	SIMPANDA
1819BC	1001	0	-	3.80	0.00	DUG WELL	USED	18	834	0	10/24/1990	GCAMA (UPPER)
1819BD	1001	2	WW22593	0.00	0.00	BOREHOLE	USED	60	0	0	10/23/1990	DCWATCYNGA
1819BD	1002	1	WW7911	0.00	0.00	BOREHOLE		0	0	0	10/31/1991	GCWATJINGA
1819BD	1003	0	-	2.30	0.00	DUG WELL	USED	21	0	0	10/24/1990	GCARU

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1819BD	1004	0	-	1.90	0.00	DUG WELL	USED	30	45	20	10/24/1990	GCARU
1819BD	1005	0		10.70	4.80	BOREHOLE	USED	250	700	400	10/24/1990	DCIDCO/GCIDCO
1819BD	1006	0	WW30912	10.95	1.40	BOREHOLE	USED	100	0	0	10/24/1990	SAPIRANA
1819BD	1007	0	-	2.30	0.00	DUG WELL	USED	90	325	120	10/24/1990	SAPIRABA
1819BD	1008	4	WW7912	6.40	0.00	BOREHOLE	USED	340	1050	1500	10/24/1990	NCAUTE
1819BD	1009	5	WW22594	0.00	1.80	BOREHOLE	USED	25	120	125	10/24/1990	NCAUTE (TJOMEYAO)
1819BD	1010	0	-	0.00	0.00	DUG WELL	USED	90	150	150	10/24/1990	MAKANDINA
1819BD	1011	3	WW8815	0.00	4.20	BOREHOLE	USED	35	100	22	10/24/1990	DCANA(FARM)
1819BD	1012	0	WW29161	0.00	2.80	BOREHOLE	USED	50	150	300	10/25/1990	KAWE
1819CA	1001	0		0.00	0.00	BOREHOLE	USED	0	0	0	11/17/1990	MANGETTI WILDKAMP (OLIFANTKLIP)
1819CA	1002	0		102.40	0.00	BOREHOLE	USED	0	0	0	11/17/1990	MANGETTI WILDKAMP (ZEBRAD
1819CA	1003	4	WW7838	99.40	0.00	BOREHOLE	USED	0	0	0	11/17/1990	MANGETTI WILDKAMP (DUBBEL
1819CA	1004	1	WW7837	108.15	0.00	BOREHOLE	USED	200	261	301	11/17/1990	MYL SESTIG
1819CA	1005	0	WW30918	0.00	0.00	BOREHOLE	USED	0	0	0	11/17/1990	RUHEPO POS
1819CA	1006	0	WW29159	112.00	0.00	BOREHOLE	USED	100	73	20	11/17/1990	RUHEPO PLAAS
1819CA	1007	0		0.00	0.00	BOREHOLE	USED	25	104	138	11/17/1990	KWATOKO PLAAS
1819CA	1008	3	WW8087	0.00	0.00	BOREHOLE	USED	11	0	0	12/29/1990	MANGETTI 56
1819CA	1009	0		0.00	0.00	BOREHOLE	USED	23	0	0	12/29/1990	MANGETTI 59
1819CA	1010	2	WW22592	0.00	0.00	BOREHOLE	USED	9	0	0	12/29/1990	MANGETTI 60
1819CA	1030	0		98.80	0.00	BOREHOLE	USED	400	500	500	01/19/1991	KATJINA KATJI
1819CB	1003	0	WW25722	62.20	0.00	BOREHOLE	USED	12	115	29	01/19/1991	DONGORO
1819CC	1001	0		0.00	0.00	BOREHOLE	USED	0	0	0	11/17/1990	MANGETTI WILDKAMP (PAN)
1819DA	1001	0	-	2.64	0.00	DUG WELL	USED	20	128	10	10/23/1990	MUPARANA
1819DA	1002	0	-	1.95	0.00	DUG WELL	USED	90	40	0	10/24/1990	GCAMA
1819DA	1050	0		20.60	3.50	BOREHOLE	USED	16	0	0	10/22/1990	KONDJA
1819DA	1051	0	WW23493	5.00	1.20	BOREHOLE	USED	262	0	0	10/22/1990	NCUSHE
1819DA	1052	0	-	4.65	0.20	DUG WELL	USED	0	0	0	10/22/1990	NCUSHE
1819DA	1053	0		0.00	2.40	BOREHOLE	USED	0	0	0	10/22/1990	KANUNDA
1819DA	1054	1	WW21765	0.00	0.00	BOREHOLE		18	0	0	10/22/1990	NGCASAWA A (TUUGURA)
1819DA	1055	0		14.80	0.00	BOREHOLE	USED	9	0	0	10/23/1990	NGCASAWA
1819DA	1056	2	WW21279	0.00	2.40	BOREHOLE	USED	12	0	0	10/23/1990	NGCASAWA B
1819DA	1057	0		0.00	0.00	BOREHOLE	USED	50	0	0	10/23/1990	NGCASAWA C
1819DA	1058	0		0.00	2.18	BOREHOLE	USED	25	0	0	10/23/1990	NGCASAWA D (TJIVITJIVI)
1819DA	1059	0	-	3.80	0.00	DUG WELL	USED	13	54	30	10/23/1990	NAINGOPO
1819DA	1060	0	-	2.70	0.00	DUG WELL	USED	40	65	70	10/23/1990	NAINGOPO
1819DA	1061	0	-	2.00	0.00	DUG WELL	USED	100	180	50	10/24/1990	NAINGOPO
1819DA	1062	0	-	2.65	0.00	DUG WELL	USED	0	50	40	10/23/1990	NAINGOPE
1819DB	1001	0		0.00	3.60	BOREHOLE	USED	11	215	1	10/23/1990	MPEZO
1819DB	1002	0	WW25754	20.80	0.00	BOREHOLE		0	0	0	10/23/1990	MPENZO
1819DC	1007	0	-	8.10	0.00	DUG WELL	USED	37	608	170	10/23/1990	KARAKUWISA_1
1819DC	1008	0	WW25502	8.18	4.00	BOREHOLE	USED	55	392	202	10/23/1990	TAMTAM
1819DC	1009	0	WW29166	0.00	4.20	BOREHOLE	USED	30	151	52	10/22/1990	KARAKUWISA_2
1819DC	1010	0	-	6.45	0.00	DUG WELL	USED	45	43	26	10/22/1990	KARAKUWISA_3
1820AA	1001	1	WW4046	0.00	3.13	BOREHOLE	USED	125	537	103	10/25/1990	VIKOTA
1820AA	1002	0	WW29936	28.15	0.00	BOREHOLE	USED	154	0	0	10/25/1990	BARMASONI 1
1820AA	1003	2	WW21277	15.53	0.00	BOREHOLE	USED	0	0	0	10/25/1990	BARMASONI 1
1820AA	1004	0	WW25498	37.87	4.20	BOREHOLE	USED	0	0	0	10/25/1990	NCUMUSI
1820AA	1005	0	WW25497	29.10	0.00	BOREHOLE	ABANDONED	0	0	0	10/25/1990	NCUMUSI
1820AA	1006	0	WW25747	0.00	1.60	BOREHOLE	USED	20	40	3	10/25/1990	SAIWE
1820AA	1007	10	WW21761	0.00	0.00	BOREHOLE		300	600	230	10/26/1990	GONGWA
1820AA	1008	0		0.00	0.00	BOREHOLE	USED	140	1306	310	10/26/1990	MADCUVA
1820AA	1009	0	WW4087	26.32	4.00	BOREHOLE	USED	700	2005	80	10/26/1990	YURU
1820AB	1001	6	WW4013	14.30	0.00	BOREHOLE	USED	130	1539	215	10/25/1990	TARATARE
1820AB	1002	0		0.00	4.00	BOREHOLE	USED	100	274	303	10/30/1990	SHINUNGA
1820AB	1003	0	-	1.10	0.00	DUG WELL	USED	150	103	40	10/30/1990	KAPUPAGHEDI
1820AB	1004	4	WW22601	4.93	2.20	BOREHOLE	USED	90	124	35	10/30/1990	NCODCO

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1820AB	1005	5	WW21278	0.00	2.20	BOREHOLE	USED	0	0	0	10/30/1990	NCODCO
1820AB	1006	0	-	1.10	0.00	DUG WELL	USED	150	433	57	10/30/1990	LILIRA
1820AB	1007	0	WW29163	0.00	5.50	BOREHOLE	USED	250	509	215	10/30/1990	KORO
1820AB	1008	0		0.00	0.00	BOREHOLE	USED	200	402	88	10/31/1990	SHAVIVARE
1820AB	1010	2	WW21275	0.00	0.00	BOREHOLE	USED	10	35	20	10/30/1990	SHAMANGOMBA
1820AC	1001	0	WW25754	25.30	1.53	BOREHOLE	USED	120	784	100	10/24/1990	SHAKAMBU
1820AC	1002	0		0.00	2.40	BOREHOLE	USED	10	96	34	10/24/1990	DITAUKE PLAAS(FARM)
1820AC	1003	0		0.00	3.00	BOREHOLE	USED	11	130	120	10/24/1990	MASIVI PLAAS(FARM)
1820AC	1004	0	-	4.00	0.00	DUG WELL	USED	0	0	0	10/25/1990	MUTWEGOMBAHE
1820BA	1001	0	WW25708	16.85	2.40	BOREHOLE	USED	40	203	42	10/30/1990	SHAMWIMBI
1820BA	1002	4	WW16524	0.00	2.75	BOREHOLE	USED	14	40	28	10/30/1990	NANAZI
1820BA	1003	0	WW25707	0.00	0.00	BOREHOLE	USED	16	120	0	10/30/1990	SHAMAYEMBE
1820BA	1004	0	WW22520	0.00	2.40	BOREHOLE	USED	7	10	15	10/30/1990	SIGHO
1820BA	1005	0	WW22504	39.22	2.05	BOREHOLE	USED	8	114	50	10/30/1990	MASHINGA
1820BA	1006	0	WW25711	0.00	0.00	BOREHOLE	USED	4	41	0	10/31/1990	KANDIMBE FARM
1820BA	1007	0		0.00	0.00	BOREHOLE	USED	60	0	50	10/31/1990	KAMUNDEMA
1820BA	1008	0		0.00	0.00	BOREHOLE	U/S	60	0	0	10/31/1990	SOUTH OF SHITEMBU
1820BA	1009	7	WW22602	0.00	0.00	BOREHOLE	USED	0	0	0	10/31/1990	NYONDO SCHOOL
1820BA	1010	0		0.00	0.00	BOREHOLE	USED	0	0	0	10/31/1990	KADETERE
1820BA	1011	0	WW25529	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	10/31/1990	NYANGANA SCHOOL
1820BA	1012	10	WW9393	28.19	0.00	BOREHOLE	USED	942	310	98	10/31/1990	NDIYONA
1820BA	1013	0		0.00	0.00	BOREHOLE	USED	263	0	0	10/31/1990	RUCARA
1820BA	1014	0		23.95	4.40	BOREHOLE	USED	10	100	60	11/01/1990	MASHA
1820BA	1015	0		21.65	0.00	BOREHOLE	USED	135	200	500	11/01/1990	NCAME
1820BA	1016	0		15.70	0.00	BOREHOLE	NOT INSTALLE	0	0	0	11/01/1990	SHAMASHUA
1820BB	1001	8	WW29164	0.00	2.40	BOREHOLE	USED	60	258	95	10/31/1990	KATERE
1820BB	1002	0		5.20	0.00	BOREHOLE	ABANDONED	0	0	0	10/31/1990	LINUS YOUTH CAMP
1820BB	1003	2	WW22603	0.00	0.00	BOREHOLE	USED	500	0	0	10/31/1990	SHINYUNGWE
1820BB	1004	8	WW21764	30.83	0.00	BOREHOLE	?	0	0	0	11/01/1990	LINUS PLAAS
1820BB	1005	0	WW25524	0.00	0.00	BOREHOLE	USED	600	0	0	11/01/1990	KOROKOKO SCHOOL
1820BB	1006	10	WW12881	17.93	0.00	BOREHOLE	ABANDONED	0	0	0	11/01/1990	TWITWIMA
1820BB	1007	0		0.00	3.60	BOREHOLE	USED	170	400	150	11/01/1990	KANDJARA
1820BB	1008	0		0.00	0.00	BOREHOLE	U/S	60	800	15	11/03/1990	DUMUSHE
1820BB	1009	0		14.15	0.00	BOREHOLE	U/S	60	810	1000	11/03/1990	SHAMBURO
1820BB	1010	0	WW12884	0.00	1.30	BOREHOLE	USED	120	240	95	11/03/1990	CWA
1820BB	1011	9	WW8306	0.00	0.00	BOREHOLE	USED	380	700	100	11/03/1990	CUMA
1820BB	1012	0		0.00	2.30	BOREHOLE	USED	200	200	100	11/03/1990	LIVAYI
1820BB	1013	0	WW30930	0.00	5.00	BOREHOLE	USED	100	200	80	11/03/1990	SHAMAYEMBE
1820BB	1014	0	-	2.20	0.00	DUG WELL	USED	50	0	0	11/03/1990	ZAZASI
1820BC	1001	0	-	2.50	0.00	DUG WELL	USED	85	0	0	11/01/1990	DANCENCE
1820BC	1002	0	WW9496	0.00	3.30	BOREHOLE	USED	85	1100	140	11/01/1990	DANCENCE
1820BC	1003	0	WW29165	0.00	0.00	BOREHOLE	USED	450	700	120	11/01/1990	CUMAGCASHI
1820DA	1001	0	WW28240	0.00	0.00	BOREHOLE	USED	12	0	0	11/02/1990	CAUDUM-NATURE CONSERVATIO RESERVE CAMP
1820DA	1002	0		10.40	0.00	BOREHOLE	USED	0	0	0	11/03/1990	BATEA
1820DB	1001	0		10.03	2.65	BOREHOLE	USED	0	0	0	11/02/1990	DORINGSTRAAT
1820DB	1002	0	WW28233	0.00	1.20	BOREHOLE	USED	0	0	0	11/02/1990	LEEUPAN - KAUDOM
1820DB	1020	0		0.00	3.50	BOREHOLE	USED	0	0	0	11/02/1990	OLIFANTSPAN
1820DC	1021	0		0.00	0.00	BOREHOLE	USED	0	0	0	11/02/1990	ELANDSPAN
1820DD	1001	0		0.00	0.00	BOREHOLE	USED	0	0	0	11/02/1990	TARIKORA - KAUDOM
1820DD	1002	0		0.00	0.00	BOREHOLE	USED	0	0	0	11/02/1990	DUSI
1820DD	1003	0	WW12877	0.00	0.00	BOREHOLE	USED	25	0	0	01/10/1991	#UAG#ARU
1821AA	1001	0	WW21271	0.00	1.80	BOREHOLE	USED	230	450	140	11/03/1990	KOROKOSHU
1821AA	1002	0	WW25715	39.50	2.40	BOREHOLE	USED	20	120	30	11/21/1990	SHASHOSHO No. 2
1821AA	1003	0		0.00	2.50	BOREHOLE	USED	15	82	42	11/21/1990	SHASHOSHO No. 1
1821AA	1004	0	WW29170	47.20	0.00	BOREHOLE	USED	400	601	400	11/21/1990	SHANONDHO
1821AA	1005	0		19.70	0.00	BOREHOLE	USED	100	110	70	11/22/1990	SHAKASHI

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1821AA	1006	0	WW25720	0.00	0.00	BOREHOLE	USED	200	500	100	11/22/1990	KAMBIMBA
1821AA	1007	0		21.20	0.00	BOREHOLE	USED	80	300	156	11/22/1990	SHAMUROMBWE
1821AA	1008	0		17.98	0.00	BOREHOLE	USED	300	1600	500	11/22/1990	MUKONGOTYI
1821AA	1009	0		0.00	0.00	BOREHOLE	USED	240	0	0	11/23/1990	THIKUKUTU
1821AA	1010	0	WW25515	34.40	0.00	BOREHOLE	USED	100	200	0	11/21/1990	SHASHOSHO No. 3
1821AB	1001	0	-	17.00	0.00	DUG WELL	USED	36	93	44	11/21/1990	SHAMANBUNGU
1821AB	1002	0	-	20.80	0.00	DUG WELL	USED	220	150	280	11/21/1990	SHAMUNARO
1821AB	1003	0	-	22.86	0.00	DUG WELL	USED	0	0	0	11/21/1990	SHAMUNARO
1821AB	1004	9	WW8973	19.25	0.00	BOREHOLE	USED	120	500	200	11/21/1990	KANGUNDJA
1821AB	1005	0	WW32201	32.90	4.20	BOREHOLE	USED	150	300	200	11/21/1990	KAVITJI
1821AB	1006	0	WW25733	53.80	0.00	BOREHOLE	USED	250	0	0	11/22/1990	MANGAMBA
1821AB	1007	8	WW9510	0.00	1.60	BOREHOLE	USED	230	220	30	11/22/1990	SHAMATURU
1821AB	1008	0	-	13.20	0.00	DUG WELL	USED	20	0	0	11/22/1990	SHAIWE
1821AB	1009	0	-	9.80	0.00	DUG WELL	USED	300	20	450	11/22/1990	DIKUNDU
1821AB	1010	0	WW29168	0.00	2.80	BOREHOLE		120	300	100	11/22/1990	HAVO
1821AB	1011	7	WW21449	0.00	2.25	BOREHOLE	USED	100	200	110	11/22/1990	SHAMVU
1821AB	1012	0	WW28244	0.00	0.00	BOREHOLE	ABANDONED	60	80	50	11/22/1990	DIKUNGU
1821AB	1013	1	WW9358	14.50	0.00	BOREHOLE	USED	35	0	0	11/23/1990	MUKWE
1821AB	1020	0	WW29172	12.37	0.00	BOREHOLE	USED	272	1800	90	11/23/1990	SHAYIRUNGU
1821AD	1001	0		26.56	0.00	BOREHOLE	ABANDONED	0	0	0	11/21/1990	MIDDELPOS
1821BA	1001	0		0.00	0.00	BOREHOLE	USED	0	0	0	11/20/1990	MAHANGU GAME RES.
1821BA	1002	1	WW25604	0.00	0.00	BOREHOLE	USED	73	20	20	11/20/1990	RUPETHO
1821BA	1003	2	WW25605	0.00	0.00	BOREHOLE	USED	70	400	300	11/20/1990	TAPAUTHA
1821BA	1004	3	WW25606	34.40	3.30	BOREHOLE	USED	480	900	1000	11/20/1990	DINWAKA
1821BA	1005	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	11/20/1990	DIVUNDU
1821BA	1006	0	WW9140	12.90	0.00	BOREHOLE	USED	360	0	0	11/20/1990	BAGANI
1821BA	1007	5	WW10142	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	11/20/1990	BAGANI
1821BA	1008	0	-	17.40	0.00	DUG WELL	USED	12	30	40	11/21/1990	SHUTU
1919AA	1001	0	WW24754	126.00	3.20	BOREHOLE	USED	73	151	112	01/14/1991	GRASHOEK
1919AB	1001	0		86.03	0.00	BOREHOLE	USED	200	0	0	01/14/1991	KANOVLEI
1919AB	1002	0		0.00	0.00	BOREHOLE	STANDBY	0	0	0	01/14/1991	KANOVLEI
1919AB	1003	2	WW23456	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/14/1991	KANOVLEI NORTH
1919AC	1001	0		135.60	0.00	BOREHOLE	TO BE INSTAL	16	0	68	01/14/1991	ROOIDAG HEKPOS
1919AC	1002	5	WW8086	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/16/1991	ROOIDAGHEKPOS(E)
1919AC	1004	0		0.00	0.00	BOREHOLE	USED	430	220	200	01/14/1991	OMATAKO
1919AC	1005	6	WW23369	115.45	0.00	BOREHOLE		0	0	0	01/14/1991	OMATAKO
1919AD	1001	1	WW24753	98.80	0.00	BOREHOLE	ABANDONED	0	0	0	01/14/1991	MURASI
1919AD	1002	0		0.00	0.00	BOREHOLE	USED	6	6	35	01/14/1991	MOOIPLAAS
1919AD	1003	6	WW24838	125.00	0.00	BOREHOLE	USED	26	34	0	01/14/1991	BUBE SE POS
1919AD	1006	5	WW23340	120.00	0.00	BOREHOLE	USED	203	4	0	01/14/1991	KANDU
1919AD	1007	2	WW8810	134.90	0.00	BOREHOLE	USED	15	0	0	01/14/1991	OLIFANTSBAD
1919AD	1008	0	WW24589	85.75	0.00	BOREHOLE	ABANDONED	0	0	0	01/16/1991	ROADSIDE OMARAMBA
1919AD	1009	0		0.00	0.00	BOREHOLE	USED	5	6	0	01/16/1991	BOSBOU
1919BA	1001	0	WW29160	0.00	0.00	BOREHOLE	USED	23	36	19	10/22/1990	EHAGERO
1919BA	1002	0	WW21229*	99.55	0.00	BOREHOLE	USED	20	17	2	10/22/1990	MAPANDA (ALSO BE WW21299*
1919BC	1001	1	WW6453	89.90	0.00	BOREHOLE		0	0	0	01/15/1991	BUSCHMANLAND
1919BC	1002	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/15/1991	LOHEBU
1919BC	1003	2	WW8812	76.70	0.00	BOREHOLE	USED	40	0	0	01/15/1991	LOHEBU
1919BD	1001	3	WW8983	69.36	0.00	BOREHOLE	USED	0	0	0	01/16/1991	VELSKOEN
1919BD	1002	2	WW8813	66.80	7.00	BOREHOLE	USED	80	0	0	01/16/1991	SAWMILL
1919CA	1001	1	WW24841	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/16/1991	OMARAMBA
1919CB	1001	1	WW24839	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/16/1991	OMARAMBA
1919CB	1002	0	WW24840	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/16/1991	OMARAMBA
1919DA	1001	1	WW23191	101.40	0.00	BOREHOLE	USED	320	0	0	01/15/1991	MANGETTI DUIN
1919DA	1002	0	WW24843	128.00	0.00	BOREHOLE	USED	550	0	0	01/15/1991	MKATA
1919DA	1003	0		0.00	0.00	BOREHOLE	USED	0	0	0	01/15/1991	MKATA
1919DA	1004	2	WW23458	114.30	0.00	BOREHOLE	USED	0	0	0	01/16/1991	MANGETTI SOUTH

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1919DA	1005	0		0.00	0.00	BOREHOLE	USED	0	0	0	01/16/1991	MANGETTI DUIN
1920AA	1001	3	WW9448	16.95	2.10	BOREHOLE	USED	75	85	16	01/10/1991	SAMAGAIGAI
1920AB	1001	1	WW23467	32.60	0.00	BOREHOLE	USED	0	0	0	01/10/1991	NHOMA
1920AC	1001	5	WW23192	0.00	6.00	BOREHOLE	USED	400	0	0	01/15/1991	AASVOELNES
1920AC	1002	4	WW24756	0.00	0.00	BOREHOLE	STANDBY	0	0	0	01/15/1991	AASVOELNES (NR. PUMP HOUS DOOR = 24844)
1920AC	1003	3	WW23195	67.00	0.00	BOREHOLE	USED	63	0	0	01/15/1991	VICSRUS
1920AD	1001	3	WW16871?	13.50	0.00	BOREHOLE	USED	0	0	0	01/11/1991	CAPTAINS POST
1920AD	1002	1	WW24850	0.00	0.00	BOREHOLE	USED	0	0	0	01/11/1991	NAT. CONS. NHOMA
1920AD	1010	4	WW24852	0.00	0.00	BOREHOLE	USED	0	0	0	01/10/1991	OLIFANTSWATER
1920BA	1001	1	WW9319	6.45	2.10	BOREHOLE	USED	0	0	0	11/02/1990	TSONTSANA
1920BA	1002	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	11/02/1990	SIKERETI
1920BA	1003	0		0.00	0.00	BOREHOLE	USED	0	0	0	01/10/1991	TSONTSANA FONTEIN
1920BB	1001	0	WW29976	0.00	0.00	BOREHOLE	USED	0	0	0	01/09/1991	XAWASHE
1920BB	1002	0		60.75	0.00	BOREHOLE	USED	0	0	0	11/02/1990	BAIKIEA - KAUDOM
1920BC	1001	2	WW24849?	0.00	0.00	BOREHOLE	USED	10	0	0	01/09/1991	KLEIN DOBE PAN
1920BC	1002	4	WW21316	0.00	0.00	BOREHOLE	DISUSED/ABAN	0	0	0	01/09/1991	DOBE PAN
1920BC	1003	0		13.08	0.00	BOREHOLE	DISUSED	0	0	0	01/09/1991	DOBE
1920BC	1004	0		13.85	0.00	BOREHOLE	USED	70	18	0	01/09/1991	//XA/OBA
1920BC	1005	1	WW24848	12.00	0.00	BOREHOLE	USED	22	11	0	01/09/1991	G≠AING≠O
1920BC	1006	3	WW31836	30.00	0.00	BOREHOLE	USED	45	0	0	01/09/1991	≠OTCAKXA
1920BC	1007	6	WW16585	10.37	0.00	BOREHOLE	ABANDONED	0	0	0	01/11/1991	NW. OF KLEIN DOBE
1920BD	1001	6		0.00	0.00	BOREHOLE	DISUSED	0	0	0	01/09/1991	≠IKWA
1920BD	1002	0	WW31838	16.90	1.00	BOREHOLE	USED	21	0	0	01/09/1991	≠IKWA
1920BD	1003	I	WW12876	16.45	0.00	BOREHOLE	USED	13	0	0	01/09/1991	MIDDELPOS
1920BD	1004	0		22.30	0.00	BOREHOLE	USED	7	0	0	01/09/1991	CUM'!AO
1920BD	1007	0	WW31837	32.01	0.00	BOREHOLE	USED	38	8	0	01/09/1991	≠ABACE
1920CA	1001	2	WW24844	112.04	0.00	BOREHOLE	ABANDONED	0	0	0	01/15/1991	DUINEVELD
1920CA	1002	1		0.00	0.00	BOREHOLE	USED	35	13	0	01/15/1991	PESPEKA
1920CB	1001	12		4.41	0.00	BOREHOLE	ABANDONED	0	0	0	01/08/1991	/GOAN/UI
1920CB	1002	0		0.00	0.00	BOREHOLE	USED	33	22	0	01/08/1991	N!OM/XOM
1920CB	1003	0		23.63	0.00	BOREHOLE	USED	6	0	0	01/08/1991	NATURE CONSERVATION CDM
1920CB	1004	16	WW28593	0.00	0.00	BOREHOLE	USED	25	20	0	01/08/1991	LANDBOU PROEFPLAAS
1920CB	1005	17	WW27304	0.00	0.00	BOREHOLE	USED	25	20	0	01/08/1991	LANDBOU PROEFPLAAS
1920CB	1006	0		17.23	0.00	BOREHOLE	USED	0	0	0	01/08/1991	LANDBOU PROEFPLAAS
1920CB	1007	6	WW16587	0.00	0.00	BOREHOLE	USED	0	0	0	01/08/1991	LANDBOU PROEFPLAAS
1920CB	1008	2	WW24617	71.15	0.00	BOREHOLE	USED	41	0	0	01/11/1991	MANGETTI POS - G30112
1920CC	1001	0	WW24845	145.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/15/1991	VERGENOEG
1920CD	1001	0		0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/08/1991	!XAECA
1920CD	1002	0		5.11	0.00	BOREHOLE	USED/ABAND??	0	0	0	01/08/1991	//AO/KOKONA
1920CD	1003	0		5.05	0.00	BOREHOLE	ABANDONED	0	0	0	01/08/1991	N/UA
1920CD	1004	3	WW28300	0.00	0.00	BOREHOLE	USED	83	4	0	01/08/1991	N≠AQMTJOAA
1920DA	1001	13		4.20	0.00	BOREHOLE	ABANDONED	0	0	0	01/08/1991	QURA (GURA)
1920DA	1002	11	WW16865	0.00	0.00	BOREHOLE	USED	31	12	0	01/08/1991	DJXOKO
1920DA	1003	0		4.20	0.00	BOREHOLE	DISUSED	0	0	0	01/08/1991	DJXOKO
1920DA	1004	16	WW31828	6.40	0.00	BOREHOLE	USED	40	7	0	01/08/1991	MAKURI
1920DA	1005	0		42.70	0.00	BOREHOLE	USED	40	27	0	01/08/1991	N//OAG!OSI
1920DA	1006	7	WW24853	14.60	0.00	BOREHOLE	USED	24	15	0	01/08/1991	N≠ANEME
1920DA	1007	0		6.35	0.00	BOREHOLE	USED	60	0	0	01/09/1991	!AO≠'A
1920DA	1008	6	WW16561?	6.95	0.00	BOREHOLE	USED	0	0	0	01/11/1991	TSUMKWE
1920DA	1009	0		0.00	0.00	BOREHOLE	USED	0	0	0	01/11/1991	TSUMKWE
1920DA	1010	2	WW7789	0.00	0.00	BOREHOLE	USED	0	0	0	01/11/1991	TSUMKWE
1920DB	1001	3	WW31829	9.45	0.00	BOREHOLE	USED	35	0	0	01/08/1991	BARAKA
1920DB	1002	3	WW23140	30.80	0.00	BOREHOLE	USED	0	0	0	01/09/1991	≠UI!CWA
1920DB	1003	2	WW21317	22.00	0.00	BOREHOLE	USED	156	0	0	01/09/1991	BEN SE KAMP
1920DC	1001	10	WW21383	0.00	0.00	BOREHOLE	USED	26	0	0	01/07/1991	XAMSA
1920DC	1002	0		0.00	0.00	BOREHOLE		0	0	0	01/07/1991	//AIN≠AASI

TOPO_NO	SUR_NO	WELL	BH_NO	RWL	P_RATE	SOURCE	STATUS	POPUL	LSU	SSU	S_DATE	LOCALITY
1920DC	1003	13	WW29177	48.02	0.00	BOREHOLE	USED	30	70	0	01/07/1991	GAUTSCHA-JU/WA BUSHMAN DE FOUNDATION HQ
1920DC	1004	0		24.50	0.00	BOREHOLE	USED	38	16	0	01/07/1991	!AMA(No.1)
1920DC	1005	0		13.88	0.00	BOREHOLE	ABANDONED	0	0	0	01/07/1991	!AMA PAN
1920DC	1006	5	WW10151	23.71	0.00	BOREHOLE	USED	33	24	0	01/07/1991	N//HARU#'HAN
1920DC	1007	0		16.15	0.00	BOREHOLE	USED	23	33	0	01/07/1991	N!AICI
1920DC	1008	0		21.29	0.00	BOREHOLE	USED	20	16	0	01/07/1991	#HABACE
1920DC	1009	2	WW10155	0.00	0.00	BOREHOLE	USED	65	78	0	01/07/1991	//AURU
1920DC	1010	0		6.03	0.00	BOREHOLE	USED	36	19	0	01/07/1991	/UIDINSI
1920DC	1011	8		1.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/07/1991	!HABI
1920DC	1012	9	WW10262	0.00	0.00	BOREHOLE	ABANDONED	0	0	0	01/08/1991	GAUTSCHA
1920DD	1001	4	WW31821	50.25	1.07	BOREHOLE	USED	23	0	0	01/07/1991	//OBAHA
1920DD	1002	3	WW31820	45.90	1.00	BOREHOLE	USED	10	11	3	01/07/1991	//AQRI#AH(//ONNDI)
1920DD	1003	1	WW23989	32.60	0.00	BOREHOLE	USED	18	0	0	01/07/1991	G!UKON!A'AO

APPENDIX 2

MASTER LISTING FROM CHEMDATA.DBF

TOPO_NO	SURVEY_NO	NA	CA	MG	K	CL	NO3	TA	SO4	F	TDS	CLASS
1718AD	1001	4.0	105.0	115.0	3.0	2.0	0.5	228.0	1.0	0.1	267.0	A
1718CA	1001	16.0	117.0	235.0	13.0	10.0	0.5	388.0	1.0	0.4	471.0	B
1718CA	1002	10.0	90.0	86.0	5.0	7.0	0.5	196.0	1.0	0.1	250.0	A
1718CA	1003	62.0	128.0	225.0	9.0	7.0	0.5	354.0	1.0	0.2	422.0	A
1718CA	1005	55.0	55.0	74.0	14.0	8.0	0.5	252.0	1.0	0.3	323.0	A
1718CB	1001	7.0	150.0	148.0	5.0	1.0	0.8	368.0	1.0	0.1	368.0	A
1718CB	1002	1020.0	15.0	54.0	8.0	620.0	2.0	948.0	500.0	5.1	2917.0	D
1718CB	1003	153.0	27.0	37.0	5.0	23.0	0.5	328.0	20.0	0.7	469.0	B
1718CB	1004	30.0	67.0	41.0	75.0	40.0	27.5	82.0	50.0	0.1	400.0	C
1718CB	1005	3.0	107.0	95.0	4.0	2.0	0.5	208.0	1.0	0.2	254.0	A
1718CB	1006	6.0	115.0	119.0	4.0	2.0	0.5	244.0	1.0	0.4	297.0	A
1718CB	1007	11.0	10.0	12.0	5.0	18.0	0.5	24.0	1.0	0.1	65.0	A
1718CC	1001	153.0	97.0	148.0	13.0	48.0	0.5	496.0	21.0	0.2	689.0	B
1718CC	1002	72.0	85.0	107.0	16.0	7.0	0.5	356.0	1.0	0.1	442.0	A
1718CD	1001	290.0	182.0	165.0	11.0	240.0	13.5	550.0	127.0	0.9	1315.0	B
1718CD	1002	43.0	35.0	25.0	64.0	45.0	1.1	166.0	16.0	0.1	327.0	A
1718CD	1004	430.0	10.0	21.0	8.0	122.0	0.5	740.0	83.0	1.4	1210.0	C
1718CD	1005	330.0	25.0	25.0	5.0	9.0	0.5	764.0	18.0	1.5	928.0	B
1718CD	1006	210.0	5.0	4.0	5.0	21.0	0.1	450.0	1.0	0.4	583.0	B
1718CD	1009	210.0	32.0	33.0	10.0	2.0	0.5	546.0	1.0	1.3	650.0	B
1718CD	1020	300.0	47.0	74.0	7.0	147.0	1.0	498.0	125.0	1.1	1030.0	B
1718DA	1001	3.0	92.0	62.0	3.0	3.0	0.5	158.0	1.0	0.2	209.0	A
1718DA	1002	3.0	132.0	165.0	3.0	2.0	0.5	304.0	1.0	0.6	359.0	A
1718DA	1003	4.0	162.0	206.0	3.0	57.0	0.5	314.0	1.0	0.4	472.0	B
1718DA	1004	9.0	105.0	54.0	3.0	2.0	0.5	170.0	1.0	0.1	215.0	A
1718DA	1005	7.0	85.0	130.0	4.0	1.0	0.5	144.0	1.0	0.1	182.0	A
1718DB	1001	6.0	122.0	124.0	2.0	1.0	6.5	238.0	1.0	0.4	325.0	A
1718DC	1001	29.0	140.0	140.0	4.0	6.0	1.0	342.0	1.0	0.2	413.0	A
1718DC	1002	63.0	95.0	107.0	4.0	3.0	0.5	332.0	1.0	0.1	405.0	A
1718DC	1003	7.0	120.0	124.0	4.0	2.0	0.5	260.0	1.0	0.2	317.0	A
1718DC	1005	8.0	135.0	136.0	5.0	2.0	0.5	286.0	1.0	0.3	337.0	A
1718DC	1007	830.0	50.0	74.0	11.0	250.0	1.5	1236.0	149.0	1.7	1947.0	D
1718DC	1008	200.0	15.0	33.0	8.0	31.0	0.5	440.0	12.0	0.2	592.0	B
1718DC	1009	51.0	125.0	99.0	6.0	3.0	0.5	332.0	1.0	0.1	401.0	A
1718DC	1010	560.0	60.0	136.0	10.0	520.0	2.6	292.0	465.0	0.2	1987.0	C
1718DD	1002	176.0	32.0	33.0	4.0	41.0	0.5	350.0	34.0	1.0	546.0	B
1718DD	1003	640.0	72.0	111.0	11.0	500.0	1.5	610.0	325.0	3.4	2112.0	D
1718DD	1004	6.0	87.0	25.0	4.0	4.0	2.0	112.0	1.0	0.1	160.0	A
1718DD	1006	36.0	45.0	25.0	7.0	1.0	0.5	152.0	1.0	0.1	186.0	A
1718DD	1009	79.0	55.0	119.0	25.0	6.0	0.5	364.0	3.0	0.3	441.0	A
1719CC	1001	183.0	182.0	95.0	6.0	63.0	9.9	478.0	87.0	0.6	835.0	B
1719CC	1003	9.0	37.0	21.0	3.0	11.0	0.5	58.0	2.0	0.1	102.0	A
1719CC	1004	15.0	127.0	128.0	6.0	3.0	0.5	288.0	2.0	0.2	348.0	A
1719CD	1003	1310.0	70.0	148.0	8.0	720.0	1.9	1096.0	1020.0	0.9	3742.0	D
1719CD	1004	360.0	157.0	74.0	6.0	153.0	14.0	752.0	15.0	0.2	1257.0	B
1719CD	1005	12.0	180.0	66.0	5.0	10.0	0.5	260.0	1.0	0.3	327.0	A
1719CD	1006	14.0	157.0	95.0	6.0	5.0	1.5	264.0	1.0	0.2	336.0	A
1719CD	1007	9.0	147.0	66.0	5.0	5.0	0.5	226.0	1.0	0.3	281.0	A
1719CD	1008	8.0	162.0	78.0	7.0	5.0	0.5	254.0	1.0	0.1	316.0	A
1719DC	1001	90.0	60.0	33.0	4.0	5.0	5.0	246.0	24.0	0.5	348.0	A
1719DC	1002	390.0	20.0	12.0	4.0	88.0	1.0	522.0	215.0	0.8	1113.0	B
1719DC	1003	111.0	35.0	16.0	6.0	45.0	11.0	130.0	47.0	0.4	385.0	B
1719DC	1004	158.0	57.0	37.0	5.0	41.0	4.5	308.0	53.0	2.5	545.0	C
1719DC	1005	330.0	17.0	16.0	4.0	112.0	9.5	436.0	146.0	1.1	977.0	B
1719DC	1006	18.0	142.0	37.0	4.0	9.0	8.5	170.0	1.0	0.2	275.0	A
1719DC	1007	7.0	200.0	189.0	13.0	4.0	0.5	342.0	81.0	0.2	486.0	B
1719DC	1020	58.0	152.0	78.0	6.0	49.0	0.5	284.0	3.0	0.2	448.0	A

TOPO_NO	SURVEY_NO	NA	CA	MG	K	CL	NO3	TA	SO4	F	TDS	CLASS
1719DD	1001	1700.0	27.0	124.0	2.0	1010.0	0.5	2050.0	380.0	1.5	4528.0	D
1719DD	1002	115.0	92.0	66.0	4.0	30.0	3.0	298.0	56.0	0.6	498.0	B
1719DD	1004	190.0	72.0	144.0	21.0	6.0	5.0	658.0	2.0	1.0	785.0	B
1719DD	1006	17.0	120.0	70.0	4.0	3.0	0.5	226.0	1.0	0.3	274.0	A
1719DD	1007	275.0	15.0	8.0	2.0	50.0	0.5	414.0	165.0	2.0	791.0	B
1719DD	1008	107.0	22.0	16.0	3.0	8.0	0.5	228.0	19.0	0.7	319.0	B
1719DD	1009	176.0	12.0	4.0	3.0	19.0	0.5	324.0	50.0	0.6	475.0	B
1719DD	1010	2650.0	5.0	25.0	9.0	900.0	35.0	2764.0	2000.0	5.0	6686.0	D
1720CC	1001	75.0	55.0	54.0	5.0	4.0	0.5	254.0	10.0	0.5	323.0	A
1720CC	1002	53.0	15.0	8.0	4.0	2.0	0.5	126.0	1.0	0.2	171.0	A
1720CC	1003	21.0	67.0	70.0	3.0	5.0	0.5	180.0	1.0	0.1	215.0	A
1720CD	1001	8.0	135.0	156.0	4.0	2.0	2.0	284.0	1.0	0.4	368.0	A
1720CD	1002	26.0	105.0	128.0	5.0	6.0	0.5	282.0	5.0	0.7	344.0	A
1720CD	1003	410.0	62.0	107.0	5.0	148.0	25.0	568.0	240.0	2.4	1307.0	C
1720CD	1004	820.0	2.0	4.0	5.0	180.0	0.5	672.0	760.0	10.0	2059.0	D
1721CC	1001	800.0	180.0	535.0	7.0	510.0	11.7	132.0	1650.0	0.1	3280.0	D
1721CC	1002	21.0	147.0	78.0	5.0	13.0	0.5	228.0	20.0	0.2	327.0	A
1721CC	1003	151.0	272.0	156.0	6.0	295.0	0.5	102.0	280.0	0.2	1078.0	B
1721CC	1004	27.0	155.0	74.0	4.0	5.0	0.5	284.0	7.0	0.4	354.0	A
1721CC	1008	14.0	160.0	91.0	3.0	4.0	0.5	280.0	3.0	0.2	341.0	A
1721CD	1001	11.0	250.0	58.0	3.0	6.0	2.0	322.0	3.0	0.3	408.0	B
1721CD	1002	11.0	110.0	66.0	3.0	5.0	0.5	194.0	2.0	0.3	246.0	A
1818AB	1002	330.0	12.0	12.0	6.0	5.0	1.0	730.0	7.0	1.6	888.0	B
1818AB	1003	158.0	65.0	62.0	12.0	15.0	0.5	450.0	2.0	0.1	564.0	B
1818AB	1004	143.0	50.0	49.0	7.0	3.0	1.0	396.0	1.0	0.2	470.0	B
1818BA	1001	67.0	157.0	136.0	10.0	3.0	4.0	440.0	1.0	0.1	526.0	A
1818BB	1001	44.0	160.0	152.0	20.0	24.0	1.5	384.0	4.0	0.2	529.0	B
1818BB	1002	28.0	127.0	103.0	8.0	20.0	10.0	268.0	2.0	0.1	367.0	A
1818CA	1001	215.0	115.0	165.0	36.0	142.0	8.0	512.0	40.0	0.6	981.0	B
1818CA	1002	108.0	180.0	231.0	12.0	144.0	11.0	392.0	18.0	0.6	816.0	B
1818CA	1003	98.0	200.0	206.0	9.0	64.0	33.0	384.0	33.0	0.5	772.0	C
1818CA	1004	23.0	170.0	177.0	7.0	30.0	7.5	326.0	5.0	0.6	487.0	B
1818CA	1005	78.0	155.0	185.0	9.0	66.0	11.0	360.0	15.0	0.8	635.0	B
1818CA	1006	87.0	147.0	181.0	13.0	50.0	5.5	420.0	14.0	0.7	633.0	B
1818CA	1007	134.0	115.0	169.0	18.0	84.0	9.0	428.0	13.0	0.9	731.0	B
1818CA	1008	55.0	125.0	173.0	12.0	22.0	5.0	370.0	6.0	0.9	513.0	A
1818CA	1009	61.0	207.0	235.0	9.0	120.0	23.5	324.0	10.0	0.4	743.0	C
1818CA	1010	70.0	150.0	194.0	11.0	50.0	13.5	358.0	35.0	0.5	618.0	B
1818CA	1011	36.0	237.0	231.0	9.0	140.0	19.0	304.0	3.0	0.3	725.0	B
1818CA	1012	83.0	102.0	177.0	17.0	28.0	4.5	412.0	7.0	1.4	570.0	A
1818CA	1030	220.0	85.0	185.0	33.0	144.0	2.9	540.0	25.0	0.9	956.0	B
1818CB	1001	113.0	130.0	165.0	10.0	63.0	0.5	374.0	36.0	0.4	680.0	B
1818CB	1002	240.0	67.0	99.0	30.0	73.0	2.0	584.0	66.0	1.5	931.0	B
1818CB	1003	590.0	32.0	74.0	48.0	340.0	0.5	880.0	90.0	2.1	1775.0	C
1818CB	1004	157.0	210.0	243.0	13.0	225.0	4.5	432.0	32.0	0.4	1003.0	B
1818CB	1005	190.0	180.0	218.0	15.0	220.0	9.5	446.0	40.0	0.6	1057.0	B
1818CB	1006	78.0	287.0	288.0	10.0	270.0	8.5	320.0	21.0	0.3	985.0	B
1818CB	1007	31.0	310.0	280.0	7.0	184.0	33.5	290.0	3.0	0.2	861.0	C
1818CB	1008	121.0	242.0	255.0	13.0	265.0	22.0	358.0	1.0	0.2	979.0	C
1818CB	1009	400.0	162.0	222.0	27.0	360.0	15.0	558.0	66.0	0.6	1472.0	B
1818DA	1001	210.0	160.0	169.0	13.0	190.0	2.6	460.0	99.0	0.2	1044.0	B
1818DA	1002	220.0	165.0	169.0	13.0	200.0	2.5	488.0	113.0	0.2	1082.0	B
1818DA	1003	230.0	160.0	173.0	13.0	190.0	2.5	498.0	115.0	0.2	1106.0	B
1818DA	1004	250.0	45.0	91.0	18.0	130.0	20.5	462.0	63.0	0.9	889.0	C
1818DA	1005	180.0	307.0	325.0	16.0	370.0	5.0	498.0	64.0	0.4	1353.0	B
1818DA	1006	390.0	175.0	218.0	19.0	400.0	3.0	580.0	190.0	0.2	1650.0	B
1818DA	1007	48.0	127.0	107.0	7.0	8.0	2.5	320.0	8.0	0.1	413.0	A

TOPO_NO	SURVEY_NO	NA	CA	MG	K	CL	NO3	TA	SO4	F	TDS	CLASS
1818DA	1008	140.0	185.0	181.0	12.0	190.0	2.0	370.0	39.0	0.4	871.0	B
1818DA	1009	114.0	135.0	132.0	10.0	60.0	5.0	370.0	26.0	0.5	642.0	B
1818DA	1010	290.0	115.0	156.0	19.0	204.0	0.5	548.0	100.0	0.8	1152.0	B
1818DA	1011	222.0	82.0	86.0	15.0	144.0	1.0	412.0	45.0	1.2	836.0	B
1818DA	1012	180.0	162.0	165.0	17.0	210.0	2.5	380.0	60.0	0.5	948.0	B
1818DA	1013	187.0	147.0	165.0	28.0	164.0	2.0	474.0	46.0	0.5	939.0	B
1818DA	1014	107.0	122.0	115.0	10.0	36.0	1.5	400.0	15.0	0.4	566.0	B
1818DA	1015	19.0	157.0	140.0	7.0	20.0	0.5	316.0	1.0	1.1	416.0	A
1818DA	1016	20.0	172.0	169.0	11.0	10.0	0.5	376.0	3.0	0.6	462.0	B
1818DA	1017	7.0	142.0	173.0	12.0	4.0	0.5	338.0	3.0	1.7	405.0	B
1818DA	1020	3.0	165.0	148.0	8.0	4.0	0.5	318.0	3.0	1.4	385.0	B
1818DA	1021	2.0	132.0	136.0	11.0	2.0	0.5	276.0	3.0	1.2	338.0	A
1818DA	1022	2.0	142.0	152.0	39.0	2.0	0.5	332.0	3.0	0.7	411.0	A
1818DB	1001	4.0	177.0	124.0	6.0	10.0	1.0	292.0	1.0	1.1	375.0	A
1818DB	1002	11.0	177.0	161.0	9.0	6.0	0.5	358.0	1.0	0.5	428.0	B
1818DB	1003	37.0	132.0	132.0	10.0	8.0	0.5	340.0	1.0	0.3	418.0	A
1818DB	1004	47.0	172.0	177.0	14.0	10.0	3.0	440.0	1.0	0.2	539.0	B
1818DB	1005	49.0	145.0	173.0	12.0	16.0	6.5	382.0	1.0	0.2	514.0	B
1818DB	1006	16.0	167.0	148.0	10.0	4.0	0.5	348.0	1.0	0.5	419.0	B
1818DB	1007	8.0	142.0	132.0	9.0	4.0	1.0	290.0	3.0	0.5	354.0	A
1818DB	1008	36.0	137.0	136.0	11.0	6.0	1.0	344.0	3.0	0.7	421.0	A
1818DB	1009	148.0	150.0	140.0	11.0	60.0	2.0	492.0	25.0	0.3	719.0	B
1818DC	1001	310.0	197.0	202.0	18.0	350.0	0.5	492.0	80.0	0.5	1379.0	B
1818DC	1002	27.0	120.0	173.0	24.0	4.0	1.0	362.0	3.0	1.0	437.0	A
1818DC	1003	300.0	35.0	231.0	21.0	260.0	1.0	448.0	130.0	0.4	1187.0	B
1818DC	1004	270.0	157.0	169.0	16.0	250.0	1.5	470.0	116.0	0.5	1173.0	B
1818DD	1001	43.0	120.0	206.0	63.0	10.0	1.0	470.0	3.0	0.3	581.0	B
1818DD	1002	6.0	152.0	128.0	21.0	4.0	1.5	298.0	3.0	1.0	378.0	A
1818DD	1003	49.0	105.0	111.0	10.0	6.0	1.0	318.0	3.0	0.3	392.0	A
1819AA	1001	7.0	110.0	132.0	7.0	5.0	0.5	258.0	1.0	0.1	312.0	A
1819AA	1002	7.0	95.0	49.0	6.0	4.0	1.0	152.0	1.0	0.1	195.0	A
1819AA	1003	47.0	130.0	103.0	7.0	12.0	0.5	310.0	1.0	0.1	404.0	A
1819AA	1007	11.0	72.0	91.0	5.0	10.0	0.5	180.0	1.0	0.2	229.0	A
1819AA	1008	21.0	55.0	41.0	6.0	4.0	0.5	140.0	1.0	0.3	177.0	A
1819AA	1009	6.0	182.0	148.0	7.0	4.0	0.5	344.0	1.0	0.2	62.4	B
1819AB	1001	10.0	152.0	41.0	5.0	3.0	0.5	216.0	2.0	0.1	277.0	A
1819AB	1002	4.0	92.0	29.0	5.0	3.0	0.5	138.0	2.0	0.1	173.0	A
1819AB	1003	6.0	145.0	54.0	5.0	4.0	0.5	210.0	1.0	0.1	271.0	A
1819AB	1004	12.0	155.0	140.0	10.0	3.0	0.5	330.0	1.0	0.1	397.0	A
1819AB	1006	35.0	117.0	107.0	7.0	4.0	0.5	300.0	1.0	0.1	367.0	A
1819AC	1003	184.0	15.0	16.0	20.0	10.0	0.5	418.0	10.0	1.5	538.0	C
1819AC	1004	316.0	5.0	4.0	16.0	12.0	0.5	674.0	10.0	3.0	835.0	C
1819AC	1006	320.0	22.0	37.0	32.0	66.0	2.5	672.0	17.0	1.9	951.0	B
1819AC	1007	7.0	45.0	41.0	13.0	2.0	0.5	112.0	1.0	0.1	149.0	A
1819AC	1008	38.0	125.0	74.0	9.0	6.0	0.5	280.0	1.0	0.2	347.0	A
1819AD	1001	5.0	162.0	33.0	3.0	3.0	0.5	216.0	1.0	0.3	263.0	A
1819AD	1002	14.0	107.0	82.0	8.0	2.0	0.5	228.0	2.0	0.2	279.0	A
1819AD	1003	8.0	147.0	58.0	5.0	2.0	0.5	230.0	1.0	0.2	281.0	A
1819AD	1006	3.0	157.0	37.0	5.0	4.0	0.5	208.0	1.0	0.1	261.0	A
1819AD	1008	113.0	60.0	103.0	20.0	12.0	2.0	396.0	5.0	0.6	515.0	B
1819AD	1010	54.0	77.0	107.0	19.0	7.0	0.5	316.0	4.0	0.7	401.0	A
1819AD	1011	4.0	107.0	91.0	18.0	2.0	0.5	230.0	1.0	0.4	286.0	A
1819AD	1012	16.0	107.0	82.0	12.0	4.0	0.5	236.0	2.0	0.5	296.0	A
1819AD	1013	3.0	142.0	66.0	14.0	2.0	0.5	222.0	1.0	0.3	276.0	A
1819BA	1002	4.0	157.0	21.0	3.0	5.0	0.5	184.0	2.0	0.3	241.0	A
1819BA	1003	19.0	122.0	29.0	4.0	3.0	0.5	190.0	2.0	0.3	244.0	A
1819BA	1004	2.0	65.0	21.0	3.0	5.0	0.5	94.0	1.0	0.1	123.0	A

TOPO_NO	SURVEY_NO	NA	CA	MG	K	CL	NO3	TA	SO4	F	TDS	CLASS
1819BA	1005	5.0	130.0	25.0	4.0	3.0	0.5	170.0	2.0	0.3	214.0	A
1819BA	1006	16.0	135.0	82.0	6.0	2.0	1.0	246.0	1.0	0.1	308.0	A
1819BB	1002	26.0	155.0	243.0	17.0	12.0	0.5	0.0	1160.0	1.5	1465.0	D
1819BB	1003	4.0	72.0	21.0	2.0	3.0	0.5	94.0	1.0	0.1	119.0	A
1819BB	1004	8.0	142.0	16.0	2.0	3.0	0.5	164.0	1.0	0.3	209.0	A
1819BB	1005	21.0	170.0	86.0	7.0	6.0	0.5	304.0	1.0	0.2	366.0	A
1819BB	1006	2.0	37.0	12.0	3.0	3.0	1.0	42.0	13.0	0.3	74.0	A
1819BB	1007	3.0	135.0	25.0	4.0	4.0	0.5	122.0	36.0	0.3	207.0	A
1819BB	1008	23.0	180.0	70.0	13.0	15.0	0.5	166.0	90.0	0.3	415.0	A
1819BC	1001	9.0	40.0	16.0	7.0	32.0	0.5	30.0	10.0	0.2	114.0	A
1819BD	1001	12.0	32.0	78.0	7.0	6.0	0.5	126.0	1.0	0.1	178.0	A
1819BD	1003	11.0	22.0	33.0	9.0	3.0	0.5	46.0	38.0	0.1	121.0	A
1819BD	1004	7.0	145.0	33.0	7.0	4.0	0.5	170.0	29.0	0.1	246.0	A
1819BD	1005	5.0	140.0	37.0	4.0	2.0	0.5	194.0	1.0	0.1	234.0	A
1819BD	1006	24.0	220.0	66.0	5.0	11.0	0.5	336.0	2.0	0.1	409.0	A
1819BD	1007	62.0	449.0	58.0	4.0	40.0	0.5	348.0	240.0	0.2	773.0	B
1819BD	1008	14.0	160.0	49.0	6.0	3.0	0.5	224.0	8.0	0.1	298.0	A
1819BD	1009	11.0	115.0	25.0	4.0	2.0	0.5	164.0	3.0	0.2	208.0	A
1819BD	1010	42.0	275.0	206.0	16.0	16.0	3.0	174.0	430.0	0.6	793.0	B
1819BD	1011	7.0	162.0	29.0	4.0	3.0	0.5	202.0	1.0	0.2	254.0	A
1819BD	1012	9.0	217.0	58.0	4.0	1.0	0.5	292.0	2.0	0.1	345.0	A
1819CA	1001	93.0	122.0	107.0	16.0	33.0	1.5	386.0	3.0	0.1	536.0	A
1819CA	1002	52.0	170.0	140.0	13.0	38.0	0.5	372.0	1.0	0.1	531.0	B
1819CA	1003	25.0	150.0	165.0	14.0	7.0	3.5	374.0	1.0	0.1	454.0	B
1819CA	1004	88.0	87.0	82.0	12.0	21.0	0.5	308.0	12.0	0.2	446.0	A
1819CA	1005	860.0	105.0	218.0	46.0	1080.0	1.5	736.0	52.0	0.4	2911.0	D
1819CA	1006	270.0	55.0	86.0	37.0	200.0	5.5	488.0	7.0	0.4	957.0	B
1819CA	1007	55.0	192.0	173.0	16.0	62.0	1.0	408.0	4.0	0.2	617.0	B
1819CA	1008	116.0	135.0	181.0	21.0	84.0	1.0	464.0	3.0	0.2	706.0	B
1819CA	1009	36.0	180.0	165.0	16.0	24.0	0.5	408.0	1.0	0.1	516.0	B
1819CA	1010	162.0	65.0	136.0	29.0	54.0	1.0	500.0	5.0	0.5	682.0	B
1819CA	1030	480.0	125.0	152.0	37.0	520.0	3.0	614.0	4.0	0.2	1690.0	C
1819CB	1003	38.0	35.0	37.0	29.0	6.0	0.5	182.0	1.0	0.3	236.0	A
1819DA	1001	4.0	147.0	41.0	5.0	2.0	0.5	180.0	16.0	0.1	242.0	A
1819DA	1002	16.0	155.0	62.0	11.0	5.0	0.5	198.0	56.0	0.1	315.0	A
1819DA	1050	2.0	10.0	29.0	4.0	1.0	3.0	40.0	2.0	0.1	63.0	A
1819DA	1051	8.0	107.0	37.0	4.0	6.0	4.0	158.0	1.0	0.1	211.0	A
1819DA	1052	9.0	22.0	21.0	6.0	9.0	0.5	50.0	1.0	0.1	88.0	A
1819DA	1053	3.0	132.0	29.0	5.0	1.0	1.0	166.0	1.0	0.2	205.0	A
1819DA	1055	12.0	145.0	78.0	8.0	3.0	0.5	244.0	2.0	0.3	307.0	A
1819DA	1056	6.0	92.0	66.0	7.0	1.0	0.5	170.0	2.0	0.2	209.0	A
1819DA	1057	30.0	87.0	45.0	7.0	3.0	0.5	184.0	1.0	0.3	203.0	A
1819DA	1058	12.0	167.0	33.0	4.0	2.0	1.0	220.0	2.0	0.1	283.0	A
1819DA	1059	9.0	157.0	70.0	9.0	7.0	2.0	212.0	55.0	0.2	320.0	A
1819DA	1060	6.0	70.0	54.0	6.0	2.0	0.5	126.0	11.0	0.1	172.0	A
1819DA	1061	35.0	110.0	78.0	8.0	5.0	0.5	204.0	55.0	0.3	339.0	A
1819DA	1062	7.0	80.0	74.0	8.0	7.0	3.5	94.0	73.0	0.2	230.0	A
1819DC	1008	3.0	90.0	33.0	5.0	2.0	0.5	126.0	1.0	0.1	159.0	A
1819DC	1009	107.0	55.0	45.0	10.0	11.0	0.5	274.0	46.0	0.7	419.0	B
1819DC	1010	3.0	15.0	12.0	3.0	7.0	1.0	19.0	2.0	0.1	62.0	A
1820AA	1001	51.0	192.0	156.0	11.0	57.0	1.0	370.0	4.0	0.1	570.0	B
1820AA	1004	820.0	42.0	91.0	30.0	320.0	1.0	1308.0	210.0	3.1	2303.0	D
1820AA	1006	42.0	190.0	198.0	15.0	15.0	0.5	466.0	1.0	0.4	561.0	B
1820AA	1007	93.0	77.0	107.0	15.0	6.0	15.5	380.0	4.0	0.4	467.0	B
1820AA	1008	320.0	20.0	33.0	15.0	24.0	0.5	714.0	46.0	4.4	911.0	D
1820AA	1009	12.0	100.0	78.0	4.0	1.0	0.5	202.0	1.0	0.3	240.0	A
1820AB	1001	148.0	7.0	0.0	3.0	35.0	15.0	248.0	13.0	0.4	417.0	B

TOPO_NO	SURVEY_NO	NA	CA	MG	K	CL	NO3	TA	SO4	F	TDS	CLASS
1820AB	1002	12.0	160.0	86.0	4.0	4.0	0.5	262.0	2.0	0.3	323.0	A
1820AB	1003	8.0	192.0	62.0	5.0	7.0	0.5	236.0	17.0	0.2	320.0	A
1820AB	1004	163.0	10.0	12.0	4.0	35.0	0.5	252.0	69.0	0.7	488.0	B
1820AB	1005	35.0	102.0	82.0	3.0	4.0	0.5	244.0	5.0	1.3	308.0	A
1820AB	1006	8.0	102.0	95.0	5.0	3.0	1.3	166.0	40.0	0.5	261.0	A
1820AB	1007	6.0	120.0	95.0	3.0	2.0	0.5	218.0	1.0	0.6	266.0	A
1820AB	1008	17.0	97.0	74.0	4.0	2.0	0.5	212.0	1.0	0.5	257.0	A
1820AC	1001	60.0	122.0	107.0	8.0	4.0	7.0	356.0	2.0	0.8	433.0	A
1820AC	1003	52.0	187.0	54.0	5.0	16.0	2.5	324.0	6.0	0.7	425.0	A
1820AC	1004	45.0	202.0	169.0	12.0	26.0	4.5	430.0	4.0	0.5	555.0	B
1820BA	1001	2.0	100.0	58.0	2.0	1.0	0.5	158.0	1.0	0.8	195.0	A
1820BA	1002	18.0	105.0	91.0	5.0	1.0	0.5	232.0	1.0	1.0	279.0	A
1820BA	1003	2.0	25.0	29.0	2.0	1.0	0.5	62.0	1.0	0.1	79.0	A
1820BA	1005	27.0	87.0	91.0	4.0	3.0	4.0	228.0	6.0	0.4	281.0	A
1820BA	1006	1.0	85.0	54.0	2.0	1.0	0.5	142.0	1.0	0.6	176.0	A
1820BA	1007	89.0	27.0	21.0	3.0	6.0	0.5	220.0	12.0	0.7	296.0	A
1820BA	1009	141.0	170.0	144.0	7.0	300.0	2.6	68.0	110.0	0.2	913.0	B
1820BA	1012	14.0	92.0	82.0	5.0	43.0	0.5	138.0	16.0	0.3	227.0	A
1820BA	1013	142.0	125.0	136.0	7.0	90.0	0.5	302.0	166.0	0.4	732.0	B
1820BA	1014	2.0	52.0	12.0	4.0	2.0	0.5	76.0	1.0	0.1	104.0	A
1820BA	1015	20.0	95.0	107.0	4.0	4.0	0.5	242.0	5.0	0.5	300.0	A
1820BB	1001	29.0	87.0	58.0	4.0	3.0	0.5	200.0	1.0	0.3	248.0	A
1820BB	1003	18.0	55.0	16.0	3.0	1.0	0.5	108.0	1.0	0.1	139.0	A
1820BB	1004	5.0	107.0	62.0	3.0	2.0	0.5	178.0	1.0	0.1	215.0	A
1820BB	1005	2180.0	45.0	115.0	8.0	1000.0	0.5	392.0	3080.0	4.0	5768.0	D
1820BB	1007	144.0	162.0	111.0	5.0	87.0	1.0	218.0	235.0	0.2	774.0	B
1820BB	1008	630.0	40.0	58.0	7.0	590.0	0.5	186.0	425.0	0.8	1987.0	C
1820BB	1008	62.0	42.0	12.0	2.0	26.0	0.5	88.0	60.0	0.4	266.0	A
1820BB	1008	126.0	40.0	12.0	2.0	52.0	0.5	106.0	148.0	0.5	463.0	B
1820BB	1008	580.0	50.0	58.0	6.0	280.0	0.5	178.0	760.0	0.8	1848.0	C
1820BB	1008	600.0	42.0	58.0	6.0	300.0	0.5	186.0	820.0	0.8	1934.0	C
1820BB	1008	610.0	42.0	62.0	5.0	300.0	0.5	190.0	820.0	0.7	1960.0	C
1820BB	1008	610.0	40.0	62.0	6.0	300.0	0.5	190.0	830.0	0.6	1967.0	C
1820BB	1008	610.0	42.0	58.0	6.0	300.0	0.5	190.0	820.0	0.6	1967.0	C
1820BB	1009	44.0	102.0	58.0	6.0	10.0	0.5	224.0	20.0	0.3	310.0	A
1820BB	1010	51.0	77.0	49.0	6.0	1.0	0.5	232.0	1.0	0.3	281.0	A
1820BB	1011	28.0	112.0	58.0	5.0	1.0	0.5	226.0	2.0	0.5	275.0	A
1820BB	1012	79.0	140.0	115.0	6.0	18.0	0.5	364.0	46.0	0.4	504.0	A
1820BB	1013	2.0	80.0	58.0	4.0	3.0	0.5	142.0	1.0	0.2	175.0	A
1820BB	1014	23.0	137.0	25.0	7.0	15.0	0.5	12.0	156.0	0.8	333.0	B
1820BC	1001	70.0	40.0	21.0	27.0	75.0	1.2	112.0	42.0	0.4	322.0	A
1820BC	1002	750.0	10.0	25.0	15.0	380.0	0.5	524.0	600.0	3.0	2105.0	C
1820BC	1003	96.0	25.0	12.0	6.0	3.0	0.5	218.0	17.0	0.8	296.0	A
1820DA	1001	24.0	47.0	12.0	2.0	2.0	0.5	104.0	2.0	0.5	139.0	A
1820DA	1002	50.0	242.0	58.0	6.0	18.0	0.5	358.0	28.0	1.1	482.0	A
1820DB	1001	89.0	30.0	4.0	4.0	22.0	0.5	192.0	5.0	1.2	283.0	A
1820DB	1002	64.0	225.0	115.0	4.0	21.0	0.5	412.0	40.0	0.4	555.0	B
1820DB	1020	21.0	200.0	37.0	4.0	6.0	0.5	268.0	1.0	0.3	333.0	A
1820DD	1002	156.0	110.0	78.0	3.0	11.0	0.5	478.0	22.0	1.0	595.0	B
1820DD	1002	37.0	195.0	119.0	4.0	10.0	1.0	358.0	17.0	0.6	458.0	B
1820DD	1003	172.0	285.0	206.0	4.0	220.0	0.5	334.0	180.0	0.4	1098.0	B
1821AA	1001	7.0	135.0	66.0	4.0	4.0	0.5	212.0	1.0	0.6	261.0	A
1821AA	1002	24.0	150.0	181.0	9.0	3.0	0.5	386.0	6.0	3.1	465.0	D
1821AA	1003	750.0	125.0	354.0	10.0	580.0	2.0	528.0	970.0	0.1	2792.0	D
1821AA	1005	2.0	12.0	8.0	2.0	2.0	0.5	24.0	1.0	0.1	36.0	A
1821AB	1001	3.0	77.0	37.0	6.0	3.0	0.5	136.0	1.0	0.1	186.0	A
1821AB	1002	8.0	150.0	103.0	7.0	8.0	0.5	270.0	1.0	0.7	347.0	A

TOPO_NO	SURVEY_NO	NA	CA	MG	K	CL	NO3	TA	SO4	F	TDS	CLASS
1821AB	1003	7.0	17.0	12.0	4.0	4.0	0.5	42.0	1.0	0.1	67.0	A
1821AB	1004	5.0	110.0	54.0	3.0	4.0	0.5	154.0	5.0	0.3	212.0	A
1821AB	1005	5.0	145.0	45.0	2.0	4.0	0.5	198.0	1.0	0.1	253.0	A
1821AB	1006	13.0	150.0	140.0	9.0	7.0	1.0	302.0	11.0	0.6	393.0	A
1821AB	1007	14.0	155.0	95.0	4.0	6.0	0.5	266.0	5.0	0.2	339.0	A
1821AB	1008	7.0	57.0	16.0	3.0	2.0	0.5	44.0	45.0	0.1	132.0	A
1821AB	1009	18.0	172.0	177.0	4.0	8.0	0.5	224.0	168.0	0.1	485.0	B
1821AB	1010	5.0	87.0	74.0	3.0	6.0	0.5	160.0	3.0	0.5	215.0	A
1821AB	1011	4.0	55.0	29.0	2.0	2.0	0.5	88.0	2.0	0.2	117.0	A
1821AB	1012	500.0	999.0	1235.0	10.0	1574.0	23.0	518.0	380.0	0.1	4039.0	D
1821AB	1013	89.0	162.0	91.0	3.0	22.0	0.5	412.0	10.0	1.1	540.0	A
1821AB	1020	4.0	127.0	74.0	2.0	5.0	0.5	208.0	1.0	0.3	262.0	A
1821BA	1001	3.0	97.0	29.0	3.0	4.0	1.0	128.0	1.0	0.1	165.0	A
1821BA	1002	11.0	150.0	66.0	4.0	3.0	0.5	238.0	1.0	0.1	163.0	A
1821BA	1003	12.0	105.0	29.0	3.0	2.0	0.5	156.0	1.0	0.1	192.0	A
1821BA	1004	6.0	107.0	33.0	3.0	3.0	0.5	150.0	1.0	0.1	260.0	A
1821BA	1006	210.0	949.0	511.0	9.0	750.0	4.5	276.0	490.0	0.1	2290.0	D
1821BA	1008	10.0	142.0	16.0	5.0	5.0	0.5	202.0	1.0	0.1	543.0	A
1919AA	1001	123.0	90.0	91.0	19.0	32.0	1.5	400.0	9.0	0.6	551.0	B
1919AB	1001	79.0	90.0	16.0	7.0	14.0	2.0	242.0	9.0	0.8	343.0	A
1919AC	1004	108.0	147.0	54.0	11.0	28.0	5.0	338.0	40.0	0.2	533.0	B
1919AD	1002	74.0	130.0	29.0	9.0	13.0	2.0	304.0	1.0	0.1	385.0	A
1919AD	1003	275.0	110.0	82.0	21.0	150.0	51.5	236.0	140.0	0.6	1100.0	D
1919AD	1006	48.0	262.0	82.0	15.0	24.0	4.0	400.0	15.0	0.3	550.0	B
1919AD	1007	22.0	175.0	12.0	7.0	4.0	0.5	236.0	1.0	0.1	294.0	A
1919AD	1009	25.0	195.0	16.0	7.0	6.0	2.5	250.0	3.0	0.1	331.0	A
1919BA	1001	9.0	190.0	33.0	7.0	2.0	0.5	236.0	1.0	0.1	303.0	A
1919BA	1002	162.0	120.0	54.0	10.0	65.0	0.5	328.0	120.0	0.2	690.0	B
1919BC	1003	12.0	195.0	37.0	13.0	18.0	5.0	228.0	3.0	0.1	343.0	A
1919BD	1001	169.0	290.0	82.0	21.0	300.0	1.5	320.0	3.0	0.2	1023.0	B
1919BD	1002	20.0	175.0	33.0	10.0	12.0	1.5	238.0	1.0	0.1	320.0	A
1919DA	1001	11.0	190.0	33.0	8.0	10.0	4.0	226.0	1.0	0.1	313.0	A
1919DA	1002	32.0	190.0	33.0	9.0	8.0	1.5	282.0	1.0	0.2	364.0	A
1919DA	1003	32.0	190.0	33.0	8.0	8.0	1.5	284.0	1.0	0.2	363.0	A
1919DA	1004	11.0	200.0	49.0	11.0	10.0	7.5	242.0	1.0	0.1	354.0	A
1919DA	1005	11.0	197.0	49.0	11.0	10.0	7.5	244.0	1.0	0.1	356.0	A
1920AA	1001	129.0	312.0	95.0	7.0	146.0	0.5	472.0	13.0	0.4	842.0	B
1920AB	1001	17.0	132.0	41.0	8.0	10.0	0.5	196.0	2.0	0.2	266.0	A
1920AC	1001	44.0	120.0	49.0	6.0	18.0	1.5	230.0	2.0	0.2	327.0	A
1920AC	1003	15.0	35.0	8.0	5.0	4.0	0.5	72.0	1.0	0.1	142.0	A
1920AD	1001	41.0	220.0	156.0	6.0	18.0	4.0	408.0	5.0	4.2	542.0	D
1920AD	1002	87.0	315.0	115.0	3.0	125.0	1.0	418.0	22.0	0.7	760.0	B
1920AD	1010	18.0	90.0	33.0	6.0	7.0	1.0	116.0	30.0	0.1	214.0	A
1920BA	1001	69.0	275.0	140.0	4.0	49.0	8.0	442.0	44.0	1.2	668.0	B
1920BA	1003	205.0	325.0	268.0	22.0	184.0	7.5	214.0	500.0	4.0	1406.0	D
1920BB	1002	21.0	225.0	255.0	3.0	16.0	0.5	440.0	52.0	0.2	585.0	B
1920BC	1001	83.0	162.0	198.0	8.0	26.0	0.5	484.0	15.0	1.5	624.0	B
1920BC	1004	10.0	187.0	231.0	4.0	4.0	0.5	436.0	2.0	1.4	506.0	B
1920BC	1005	78.0	275.0	86.0	2.0	16.0	4.0	486.0	6.0	1.7	612.0	B
1920BC	1006	176.0	120.0	185.0	3.0	56.0	0.5	602.0	1.0	2.9	796.0	C
1920BD	1002	6.0	255.0	189.0	3.0	6.0	0.5	442.0	1.0	0.4	510.0	B
1920BD	1003	160.0	180.0	218.0	4.0	66.0	5.5	602.0	22.0	0.7	854.0	B
1920BD	1007	5.0	265.0	202.0	3.0	6.0	0.5	468.0	1.0	0.4	538.0	B
1920CA	1002	31.0	132.0	37.0	12.0	34.0	7.5	176.0	2.0	0.1	330.0	A
1920CB	1002	73.0	167.0	177.0	13.0	88.0	1.0	362.0	16.0	5.2	635.0	D
1920CB	1005	50.0	87.0	165.0	8.0	50.0	0.5	266.0	24.0	1.9	449.0	B
1920CB	1008	30.0	110.0	33.0	6.0	14.0	1.5	184.0	5.0	0.1	271.0	A

E. PHYSIOGRAPHY

Nature of drainage: (seasonal/perennial/etc.)________________
Period when dry: (1-12)________________________________
Vegetation: (Grassland/thornscrub/forest etc.)________________
Topography:________________ Soils:________________
Surface geology:________________________________
Remarks:________________________________

F. DEMOGRAPHY

Source of information: (Name)________________________________
Reliability of source: (g/m/p)__ Social position:________________

Water consumption:- No of people:________
Large stock:________(units)
Small stock:________(units)
Irrigation:________(ha)

Schools: (No.)____
Name:________________classes; from______ to______ No. pupils:___
Name:________________classes; from______ to______ No. pupils:___
Name:________________classes; from______ to______ No. pupils:___
Industries: (formal or informal)________________________________
Facilities: (refer to Checklist)________________________________

Cultivation: (cash-crops or subsistence)________________

Imported water:- Method: (pipeline, tanker etc.)________________
Source: (Locality and type)________________
Access: (dry season)________ (wet season)__________

TOPO_NO	SURVEY_NO	NA	CA	MG	K	CL	NO3	TA	SO4	F	TDS	CLASS
1920CD	1002	205.0	135.0	95.0	50.0	200.0	0.5	428.0	34.0	1.2	933.0	B
1920CD	1003	53.0	187.0	152.0	26.0	130.0	0.5	298.0	8.0	2.4	638.0	C
1920CD	1004	215.0	127.0	82.0	59.0	170.0	0.5	448.0	61.0	3.0	958.0	C
1920DA	1002	17.0	215.0	62.0	5.0	14.0	0.7	292.0	2.0	1.4	385.0	A
1920DA	1004	103.0	120.0	140.0	20.0	16.0	7.5	450.0	1.0	6.4	611.0	D
1920DA	1005	49.0	220.0	86.0	3.0	34.0	3.0	364.0	9.0	0.8	525.0	B
1920DA	1006	51.0	207.0	107.0	2.0	10.0	1.5	400.0	2.0	1.0	496.0	B
1920DA	1007	56.0	227.0	74.0	7.0	38.0	1.0	362.0	10.0	1.7	524.0	B
1920DA	1008	38.0	252.0	74.0	10.0	40.0	1.0	346.0	12.0	0.6	513.0	B
1920DA	1009	680.0	207.0	119.0	38.0	900.0	1.5	336.0	220.0	0.8	2468.0	C
1920DA	1010	285.0	200.0	148.0	9.0	255.0	1.5	476.0	80.0	3.5	1179.0	D
1920DB	1001	13.0	97.0	202.0	4.0	4.0	1.0	308.0	2.0	7.0	374.0	D
1920DB	1002	33.0	177.0	280.0	4.0	24.0	0.5	486.0	7.0	1.5	606.0	B
1920DB	1003	18.0	222.0	214.0	5.0	4.0	0.5	464.0	2.0	1.7	540.0	B
1920DC	1001	41.0	140.0	173.0	5.0	14.0	10.5	344.0	6.0	1.7	496.0	B
1920DC	1003	134.0	340.0	185.0	10.0	320.0	16.5	234.0	116.0	1.3	1097.0	B
1920DC	1004	44.0	192.0	152.0	3.0	10.0	0.5	418.0	3.0	0.4	498.0	B
1920DC	1006	355.0	107.0	136.0	23.0	340.0	0.5	484.0	50.0	0.2	1320.0	B
1920DC	1007	96.0	110.0	107.0	5.0	6.0	0.5	414.0	2.0	0.9	502.0	A
1920DC	1008	12.0	205.0	169.0	2.0	6.0	0.5	376.0	2.0	0.6	453.0	B
1920DC	1009	100.0	132.0	152.0	8.0	66.0	4.5	372.0	28.0	1.4	624.0	A
1920DC	1010	465.0	117.0	95.0	8.0	230.0	6.0	708.0	140.0	3.7	1511.0	D
1920DD	1001	13.0	235.0	161.0	4.0	8.0	1.0	404.0	2.0	0.7	502.0	B
1920DD	1002	16.0	312.0	189.0	3.0	13.0	2.5	476.0	40.0	0.9	642.0	B
1920DD	1003	5.0	300.0	152.0	1.0	4.0	0.5	448.0	1.0	0.6	535.0	B

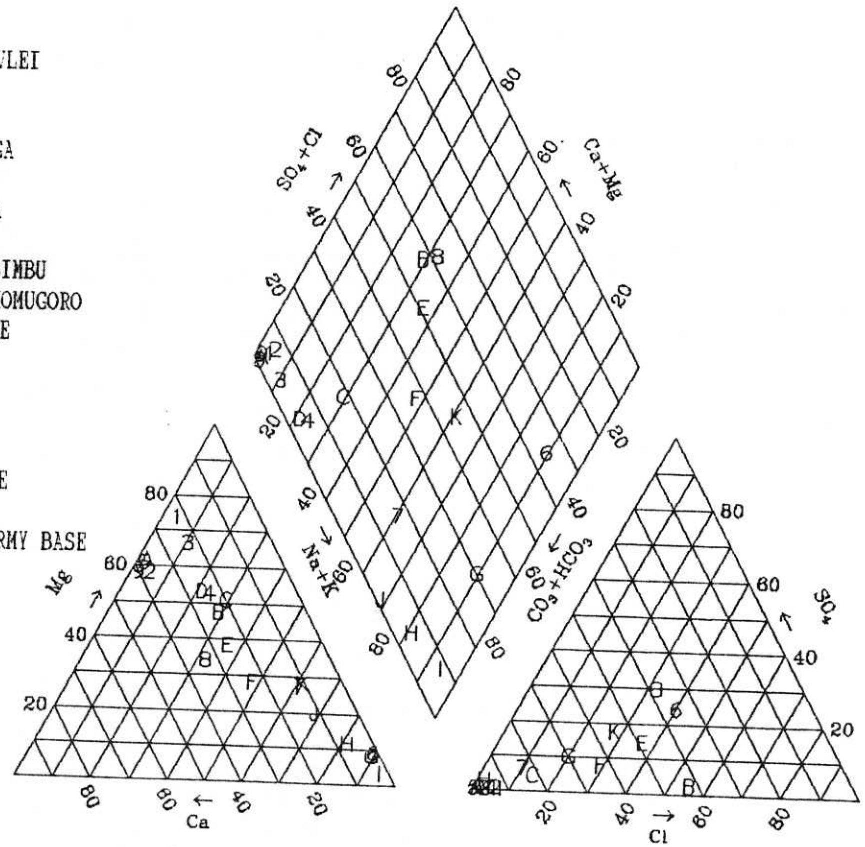
APPENDIX 3

TRILINEAR PLOTS OF HYDROCHEMISTRY

QUARTER DEGREE 1718C

LEGEND

1	1718CA 1001 BOREHOLE SIWI
2	1718CA 1002 BOREHOLE RUNDA
3	1718CA 1003 BOREHOLE MPOTO
4	1718CA 1005 BOREHOLE MPUNGU VLEI
5	1718CB 1001 BOREHOLE ZONE
6	1718CB 1002 BOREHOLE RUPEHO
7	1718CB 1003 BOREHOLE SILIKUNGA
8	1718CB 1004 DUG WELL KENI
9	1718CB 1005 BOREHOLE MUNGOMBA
A	1718CB 1006 BOREHOLE KAGUNI
B	1718CB 1007 DUG WELL KATOPE-SIMBU
C	1718CC 1001 BOREHOLE KATOPE-KOMUGORO
D	1718CC 1002 BOREHOLE NANDINGWE
E	1718CD 1001 BOREHOLE NEPARA
F	1718CD 1002 DUG WELL NEPARA
G	1718CD 1004 BOREHOLE SAME
H	1718CD 1005 BOREHOLE NCARISE
I	1718CD 1006 BOREHOLE NKURIVERE
J	1718CD 1009 BOREHOLE GAWA
K	1718CD 1020 BOREHOLE NEPARA ARMY BASE



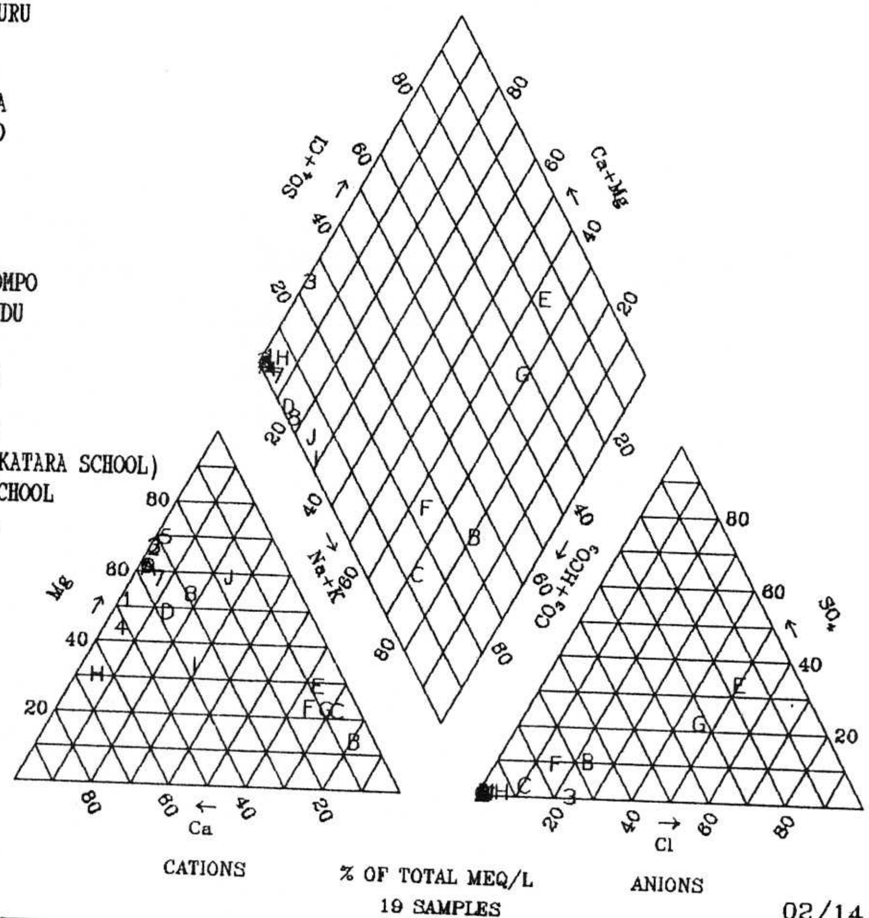
NGDC

02/14/91

QUARTER DEGREE 1718D

LEGEND

1	1718DA 1001 BOREHOLE SIMANYA
2	1718DA 1002 BOREHOLE NKURENKURU
3	1718DA 1003 BOREHOLE MAYARA
4	1718DA 1004 BOREHOLE KAHENGE
5	1718DA 1005 BOREHOLE KANANANA
6	1718DB 1001 BOREHOLE SITOPOGO
7	1718DC 1001 BOREHOLE YINSU
8	1718DC 1002 BOREHOLE YINSU
9	1718DC 1003 BOREHOLE MPENGE
A	1718DC 1005 BOREHOLE KANKUDI
B	1718DC 1007 BOREHOLE SIKAROSOMPO
C	1718DC 1008 BOREHOLE NAMUNGUNDU
D	1718DC 1009 BOREHOLE SUNI
E	1718DC 1010 BOREHOLE CANCHANA
F	1718DD 1002 BOREHOLE MBOME
G	1718DD 1003 BOREHOLE KAMUPUPU
H	1718DD 1004 BOREHOLE NKONKE (KATARA SCHOOL)
I	1718DD 1006 BOREHOLE NZINZE SCHOOL
J	1718DD 1009 BOREHOLE KAPARARA



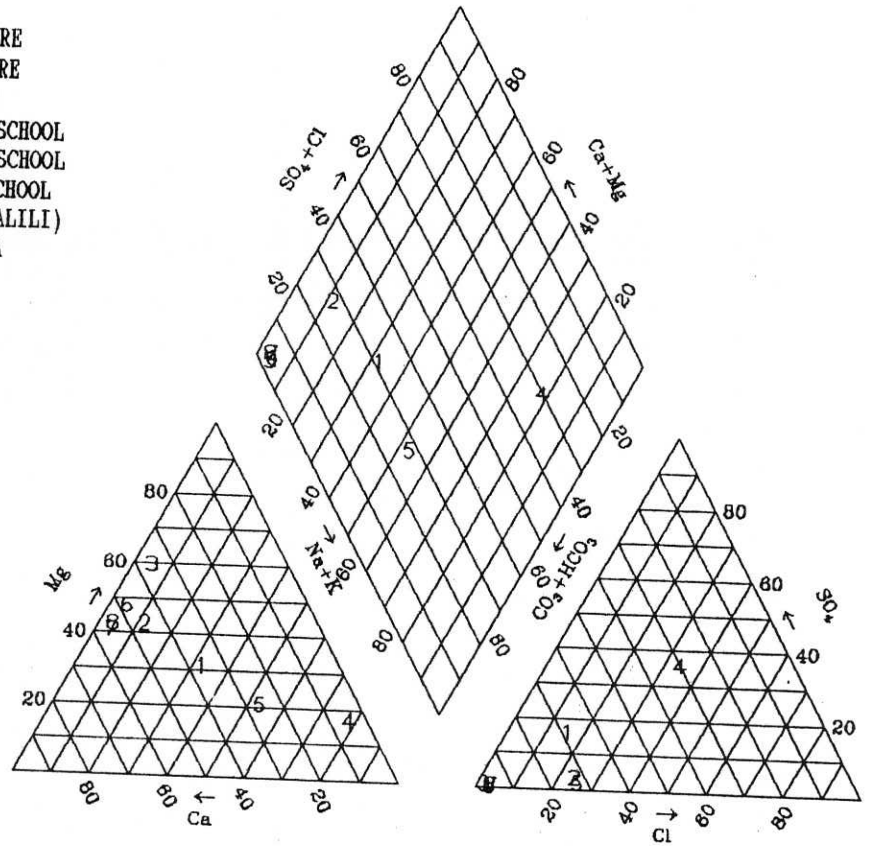
02/14/91

NGDC

QUARTER DEGREE 1719C

LEGEND

1 1719CC 1001 BOREHOLE MAYENZERE
2 1719CC 1003 DUG WELL MAYENZERE
3 1719CC 1004 BOREHOLE GCANGCU
4 1719CD 1003 BOREHOLE KASIVI SCHOOL
5 1719CD 1004 BOREHOLE SIVARA SCHOOL
6 1719CD 1005 BOREHOLE BUNYA SCHOOL
7 1719CD 1006 BOREHOLE MBORA(HALILI)
8 1719CD 1007 BOREHOLE SAMASIRA



% OF TOTAL MEQ/L
8 SAMPLES

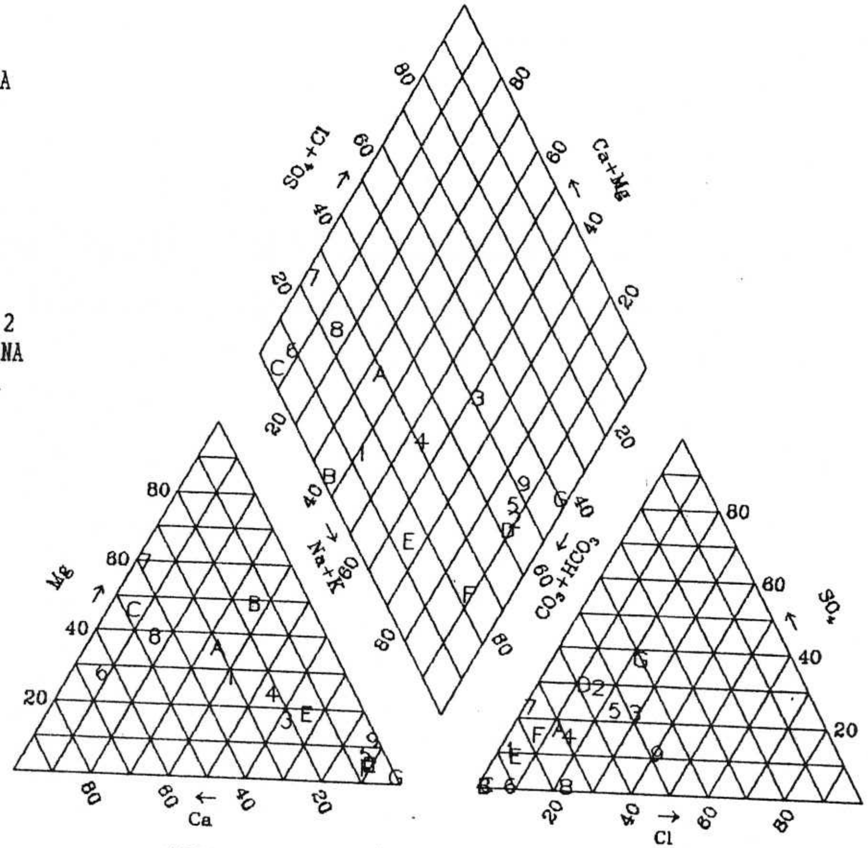
NGDC

01/02/80

QUARTER DEGREE 1719D

LEGEND

1 1719DC 1001 BOREHOLE MAVANZE
2 1719DC 1002 BOREHOLE SAUYEMWA
3 1719DC 1003 DUG WELL KASOTE
4 1719DC 1004 BOREHOLE NKAZAZA
5 1719DC 1005 BOREHOLE NKAZAZA
6 1719DC 1006 BOREHOLE MUKUNDU
7 1719DC 1007 DUG WELL NKUTU
8 1719DC 1020 BOREHOLE KAPAKO
9 1719DD 1001 DUG WELL KAISOSI
A 1719DD 1002 BOREHOLE KAISOSI 2
B 1719DD 1004 BOREHOLE NGCANGCANA
C 1719DD 1006 BOREHOLE NGCARAMA
D 1719DD 1007 BOREHOLE KAMBOWO
E 1719DD 1008 BOREHOLE MOHOPI
F 1719DD 1009 BOREHOLEE NGONE
G 1719DD 1010 BOREHOLE MAYANA



% OF TOTAL MEQ/L
16 SAMPLES

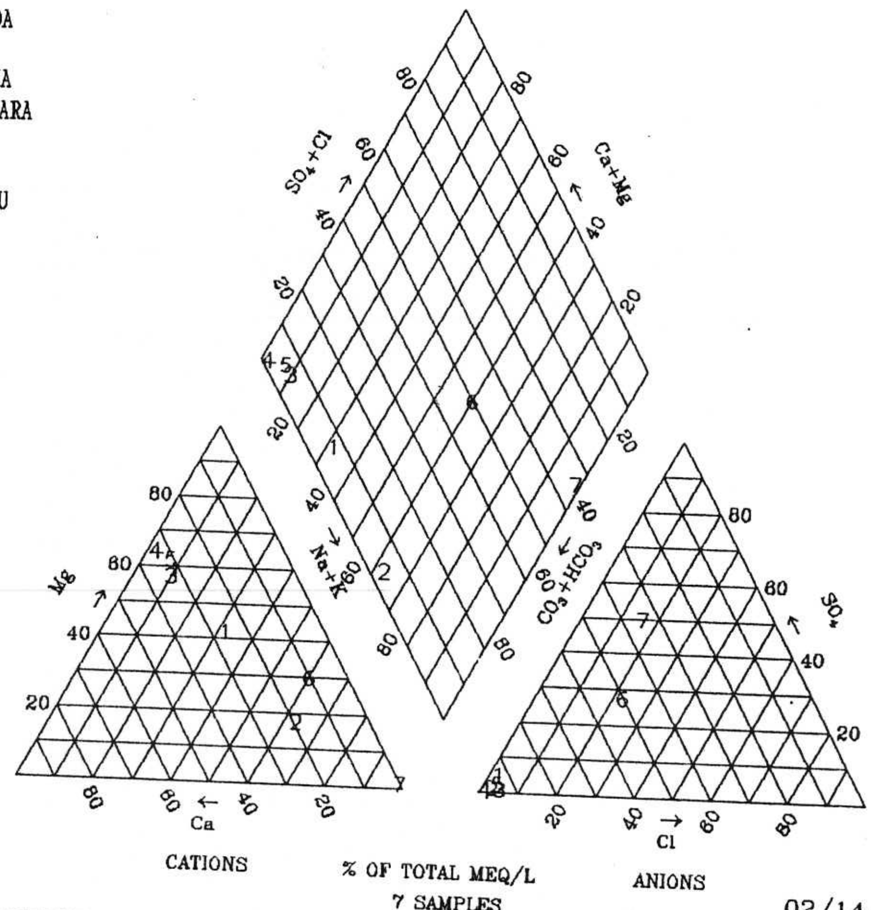
NGDC

01/02/80

QUARTER DEGREE 1720C

LEGEND

1 1720CC 1001 BOREHOLE MUNGUNDA
2 1720CC 1002 BOREHOLE FUMBE
3 1720CC 1003 BOREHOLE MUPAPAMA
4 1720CD 1001 BOREHOLE RUNDJARARA
5 1720CD 1002 BOREHOLE MABUSHE
6 1720CD 1003 BOREHOLE MABUSHE
7 1720CD 1004 BOREHOLE SHIGHURU



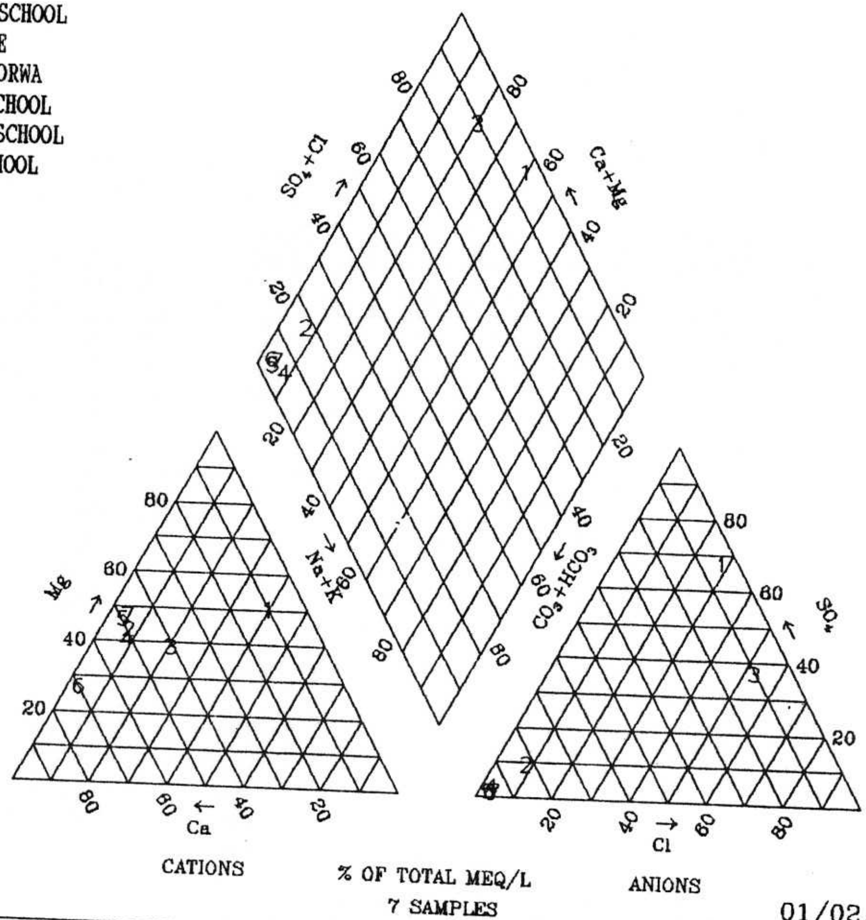
NGDC

02/14/91

QUARTER DEGREE 1721C

LEGEND

1 1721CC 1001 BOREHOLE MBAMBI SCHOOL
2 1721CC 1002 BOREHOLE MUNGANYE
3 1721CC 1003 BOREHOLE SHAMANGORWA
4 1721CC 1004 BOREHOLE TYOVA SCHOOL
5 1721CC 1008 BOREHOLE MAYARA SCHOOL
6 1721CD 1001 BOREHOLE BIRO SCHOOL
7 1721CD 1002 BOREHOLE KAYANGA



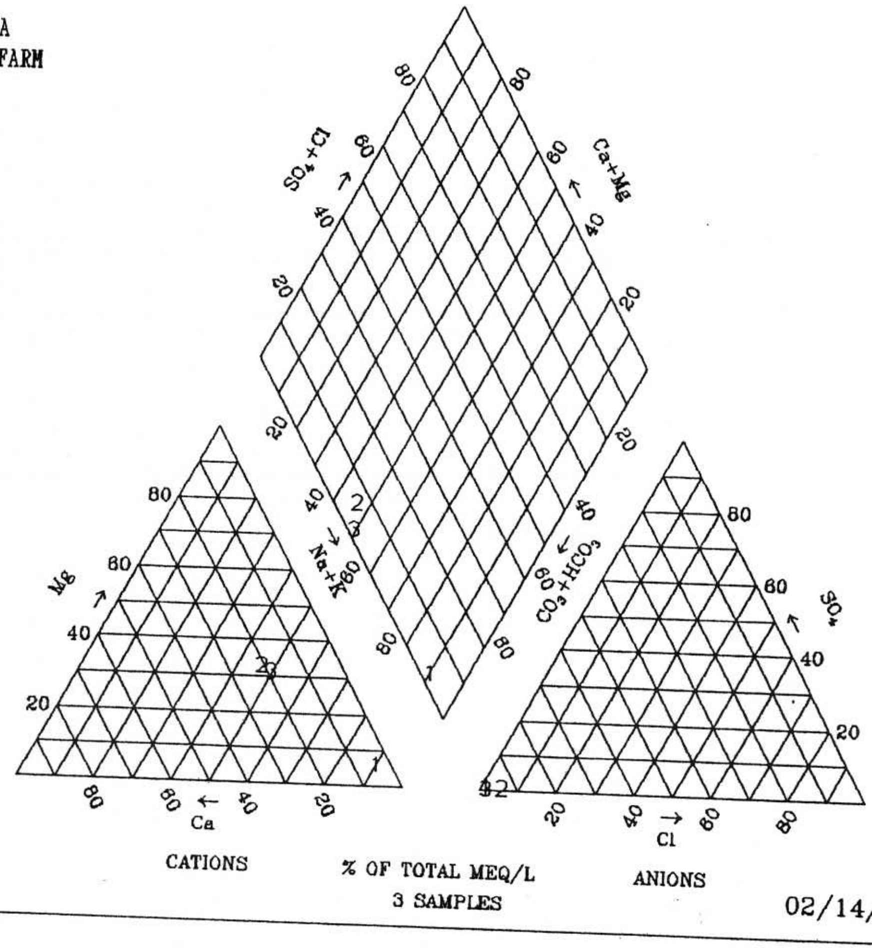
NGDC

01/02/80

QUARTER DEGREE 1818A

LEGEND

1 1818AB 1002 BOREHOLE MUPARANA
2 1818AB 1003 BOREHOLE HAMUNE FARM
3 1818AB 1004 BOREHOLE SIKUMBA



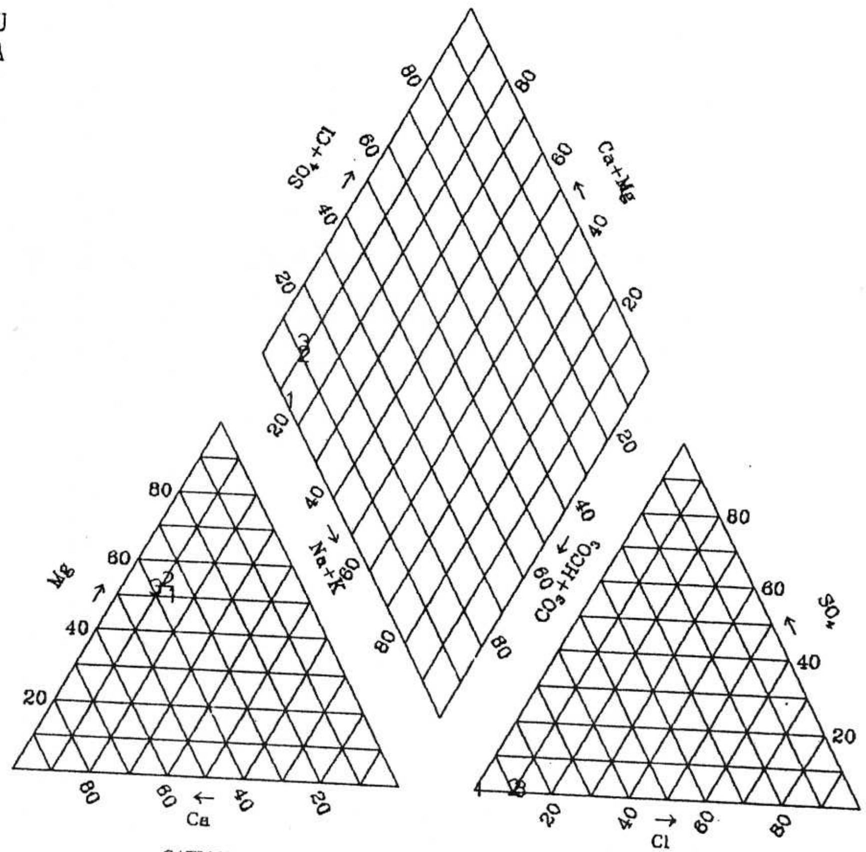
02/14/91

NGDC

QUARTER DEGREE 1818B

LEGEND

1 1818BA 1001 BOREHOLE MBURURU
2 1818BB 1001 BOREHOLE GCARUHA
3 1818BB 1002 BOREHOLE MPANDA



% OF TOTAL MEQ/L
3 SAMPLES

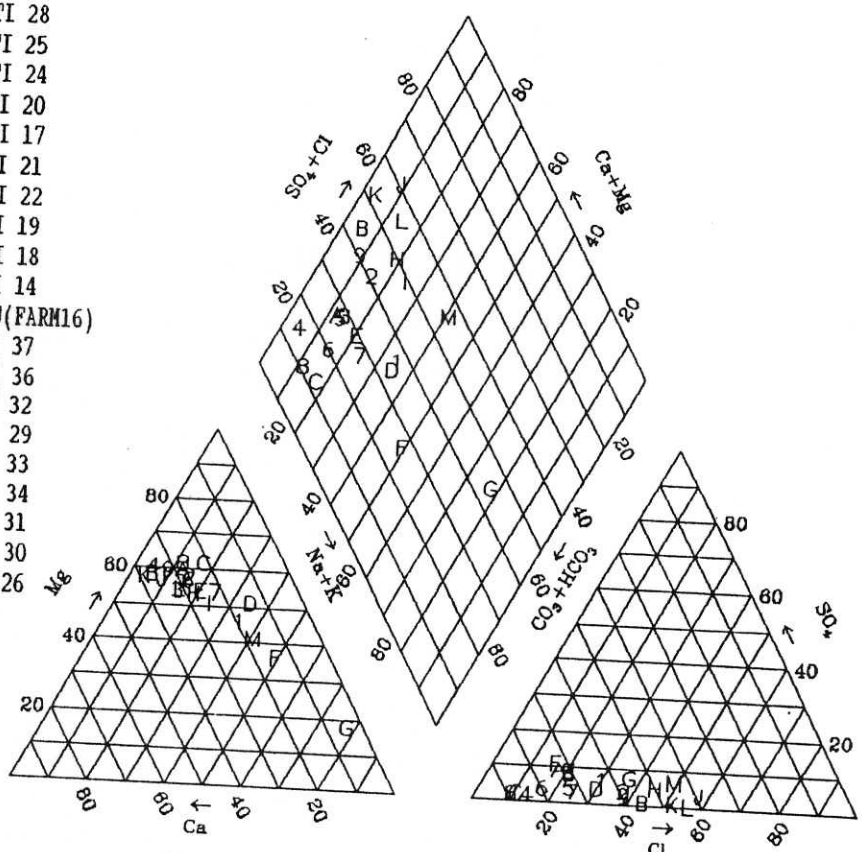
02/14/91

NGDC

QUARTER DEGREE 1818C

LEGEND

1 1818CA 1001 BOREHOLE MANGETTI 23
2 1818CA 1002 BOREHOLE MANGETTI 27
3 1818CA 1003 BOREHOLE MANGETTI 28
4 1818CA 1004 BOREHOLE MANGETTI 25
5 1818CA 1005 BOREHOLE MANGETTI 24
6 1818CA 1006 BOREHOLE MANGETTI 20
7 1818CA 1007 BOREHOLE MANGETTI 17
8 1818CA 1008 BOREHOLE MANGETTI 21
9 1818CA 1009 BOREHOLE MANGETTI 22
A 1818CA 1010 BOREHOLE MANGETTI 19
B 1818CA 1011 BOREHOLE MANGETTI 18
C 1818CA 1012 BOREHOLE MANGETTI 14
D 1818CA 1030 BOREHOLE ONEPANDU(FARM16)
E 1818CB 1001 BOREHOLE MANGETTI 37
F 1818CB 1002 BOREHOLE MANGETTI 36
G 1818CB 1003 BOREHOLE MANGETTI 32
H 1818CB 1004 BOREHOLE MANGETTI 29
I 1818CB 1005 BOREHOLE MANGETTI 33
J 1818CB 1006 BOREHOLE MANGETTI 34
K 1818CB 1007 BOREHOLE MANGETTI 31
L 1818CB 1008 BOREHOLE MANGETTI 30
M 1818CB 1009 BOREHOLE MANGETTI 26

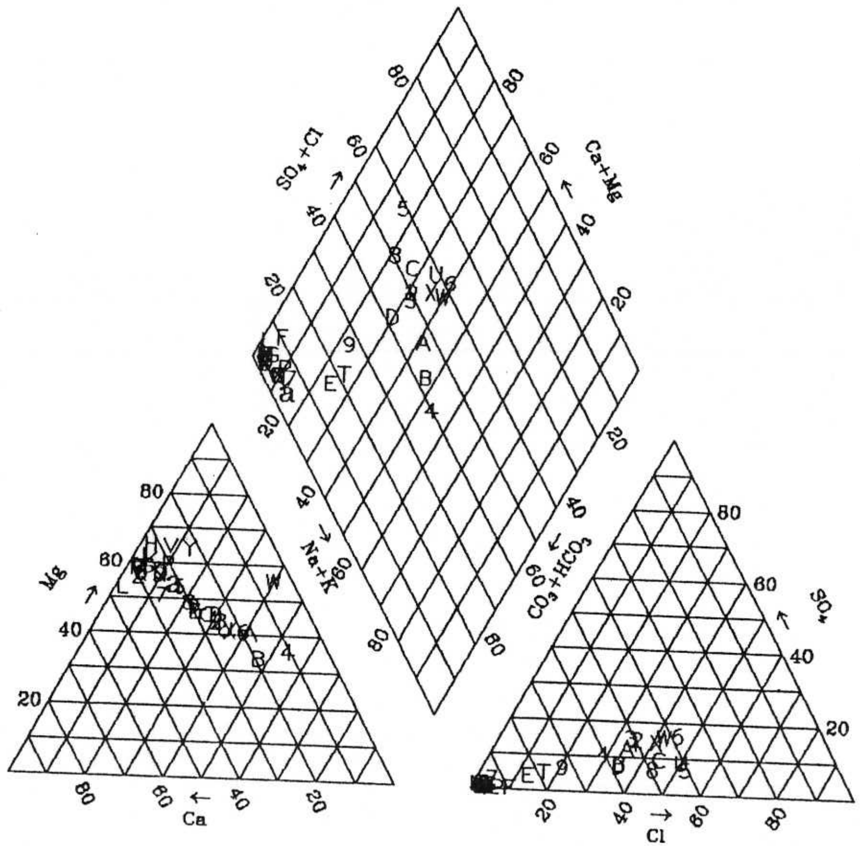


% OF TOTAL MEQ/L
22 SAMPLES

NGDC

02/18/91

QUARTER DEGREE 1818D



% OF TOTAL MEQ/L
36 SAMPLES

02/18/91

LEGEND

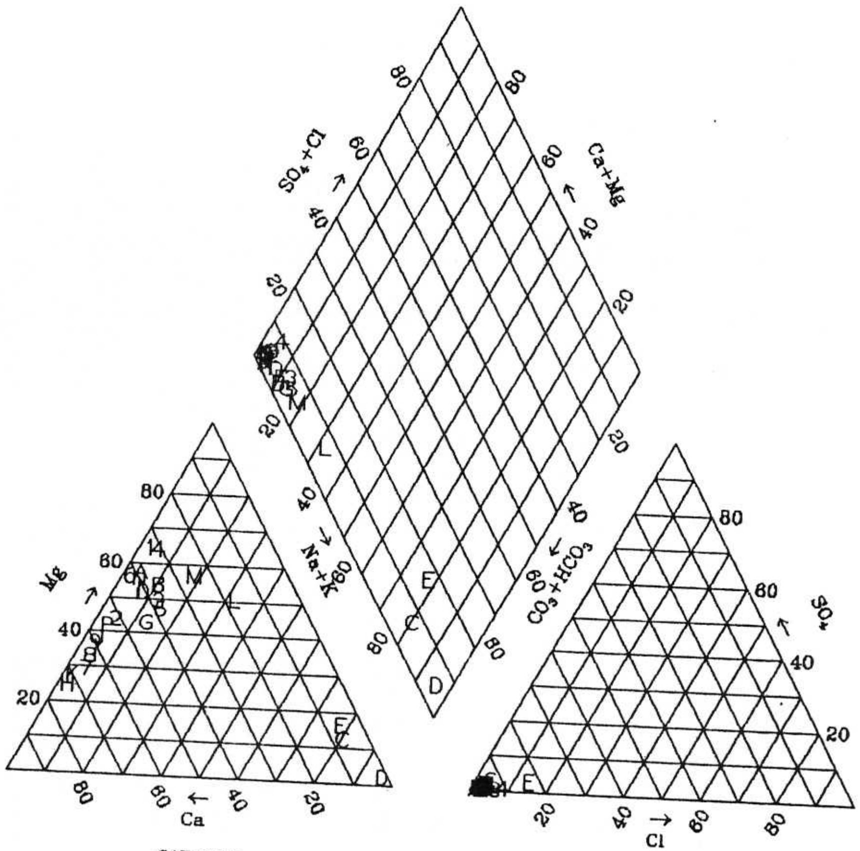
1 1818DA 1001 BOREHOLE MANGETTI RES. AREA
2 1818DA 1002 BOREHOLE MANGETTI RES. AREA
3 1818DA 1003 BOREHOLE MANGETTI RES. AREA
4 1818DA 1004 BOREHOLE MANGETTI QUARANTINE CAMP 12
5 1818DA 1005 BOREHOLE MANGETTI 40
6 1818DA 1006 BOREHOLE MANGETTI 39
7 1818DA 1007 BOREHOLE MANGETTI 45
8 1818DA 1008 BOREHOLE MANGETTI 46
9 1818DA 1009 BOREHOLE MANGETTI 35
A 1818DA 1010 BOREHOLE MANGETTI QUARANTINE CAMP 13
B 1818DA 1011 BOREHOLE MANGETTI QUARANTINE CAMP 18
C 1818DA 1012 BOREHOLE MANGETTI QUARANTINE CAMP 23
D 1818DA 1013 BOREHOLE MANGETTI QUARANTINE CAMP 28
E 1818DA 1014 BOREHOLE MANGETTI 41
F 1818DA 1015 BOREHOLE MANGETTI 44
G 1818DA 1016 BOREHOLE MANGETTI 48
H 1818DA 1017 BOREHOLE MANGETTI VET. CAMP 30
I 1818DA 1020 BOREHOLE FARM NO. 6
J 1818DA 1021 BOREHOLE FARM NO. 7 (RUDOLF'S FARM)
K 1818DA 1022 BOREHOLE FARM NO. 8
L 1818DB 1001 BOREHOLE MANGETTI 47
M 1818DB 1002 BOREHOLE MANGETTI 50 GROOT
N 1818DB 1003 BOREHOLE MANGETTI 50 KLEIN
O 1818DB 1004 BOREHOLE MANGETTI 53
P 1818DB 1005 BOREHOLE MANGETTI 57
Q 1818DB 1006 BOREHOLE MANGETTI 54 KLEIN
R 1818DB 1007 BOREHOLE MANGETTI 54 GROOT
S 1818DB 1008 BOREHOLE MANGETTI 51
T 1818DB 1009 BOREHOLE MANGETTI 52
U 1818DC 1001 BOREHOLE MANGETTI 46 LAAIBANK
V 1818DC 1002 BOREHOLE MANGETTI 49
W 1818DC 1003 BOREHOLE MANGETTI QUARANTINE CAMP 25
X 1818DC 1004 BOREHOLE MANGETTI VET. CAMP.2
Y 1818DD 1001 BOREHOLE MANGETTI 58
Z 1818DD 1002 BOREHOLE MANGETTI 55 GROOT
a 1818DD 1003 BOREHOLE MANGETTI 55 KLEIN

QUARTER DEGREE 1819A

LEGEND

1 1819AA 1001 BOREHOLE MPUKU
2 1819AA 1002 BOREHOLE SAU
3 1819AA 1003 BOREHOLE KAKUHU
4 1819AA 1007 BOREHOLE GCAGCAWE
5 1819AA 1008 BOREHOLE NZOVU
6 1819AA 1009 BOREHOLE TJOHA
7 1819AB 1001 BOREHOLE MYL DERTIG
8 1819AB 1002 BOREHOLE CWI (QWI)
9 1819AB 1003 BOREHOLE NKATA
A 1819AB 1004 BOREHOLE NCARA
B 1819AB 1006 BOREHOLE KARO
C 1819AC 1003 BOREHOLE MIN. RUDOLF NGONDO
D 1819AC 1004 BOREHOLE FRANS KAMBUTA
E 1819AC 1006 BOREHOLE MYL 46 TEELSTASIE SK2
F 1819AC 1007 BOREHOLE MYL 46 TEELSTASIE TK2
G 1819AC 1008 BOREHOLE MYL 46 TEELSTASIE TK2
H 1819AD 1001 BOREHOLE SIHETEKERA
I 1819AD 1002 BOREHOLE MUTOMPO
J 1819AD 1003 BOREHOLE SIHEPERA
K 1819AD 1006 BOREHOLE MPENGU
L 1819AD 1008 BOREHOLE TCOVE PLAAS
M 1819AD 1010 BOREHOLE MYL 46 PROJECT
N 1819AD 1011 BOREHOLE MPORA PLAAS
O 1819AD 1012 BOREHOLE MAYONGORA (MPORA NO.2)
P 1819AD 1013 BOREHOLE WIZENI

NGDC



% OF TOTAL MEQ/L
25 SAMPLES

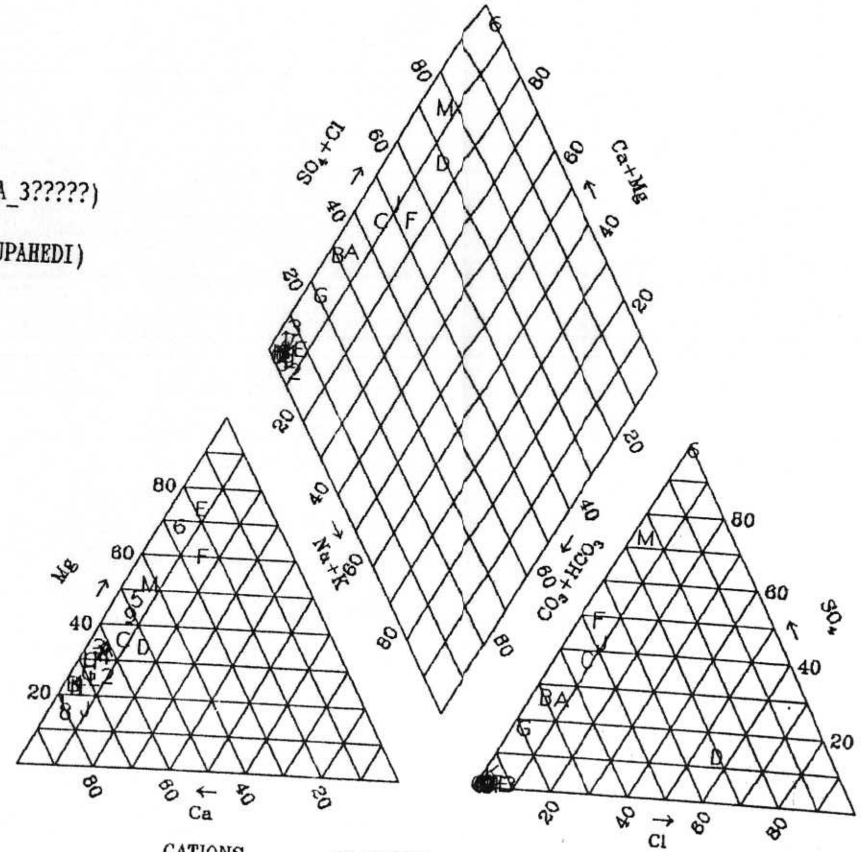
02/18/91

QUARTER DEGREE 1819B

LEGEND

1 1819BA 1002 BOREHOLE ARENDSNES
2 1819BA 1003 BOREHOLE SIPILI
3 1819BA 1004 BOREHOLE BITTERSOET
4 1819BA 1005 BOREHOLE MYL TWINTIG
5 1819BA 1006 BOREHOLE SISUNGU
6 1819BB 1002 DUG WELL NCECWA
7 1819BB 1003 BOREHOLE NCUNCUNI
8 1819BB 1004 BOREHOLE CUMA (DWA-> 1820AA_3?????)
9 1819BB 1005 BOREHOLE MATAPI
A 1819BB 1006 DUG WELL KAUTI (DWA - KAPUPAHEDI)
B 1819BB 1007 DUG WELL SHIKALI
C 1819BB 1008 BOREHOLE SHARUKWE
D 1819BC 1001 DUG WELL GCAMA (UPPER)
E 1819BD 1001 BOREHOLE DCWATCYNGA
F 1819BD 1003 DUG WELL GCARU
G 1819BD 1004 DUG WELL GCARU
H 1819BD 1005 BOREHOLE DCIDCO/GCIDCO
I 1819BD 1006 BOREHOLE SAPIRANA
J 1819BD 1007 DUG WELL SAPIRABA
K 1819BD 1008 BOREHOLE NCAUTE
L 1819BD 1009 BOREHOLE NCAUTE (TJOMEYAO)
M 1819BD 1010 DUG WELL MAKANDINA
N 1819BD 1011 BOREHOLE DCANA(FARM)
O 1819BD 1012 BOREHOLE KAWE

NGDC

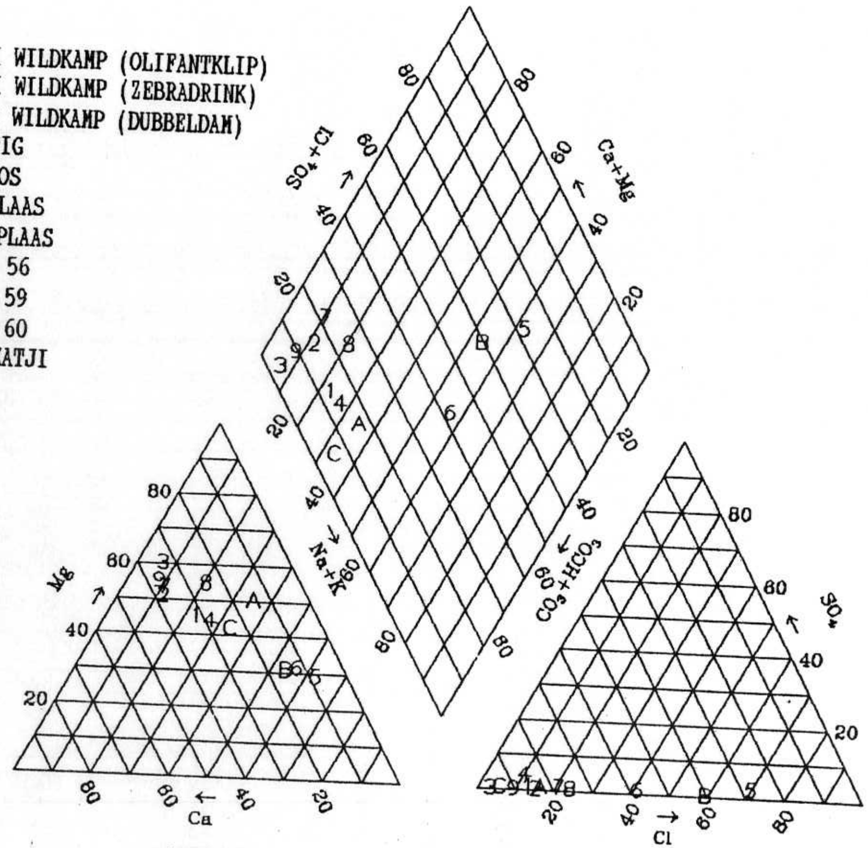


02/14/91

QUARTER DEGREE 1819C

LEGEND

1 1819CA 1001 BOREHOLE MANGETTI WILDKAMP (OLIFANTKLIP)
2 1819CA 1002 BOREHOLE MANGETTI WILDKAMP (ZEBRADRINK)
3 1819CA 1003 BOREHOLE MANGETTI WILDKAMP (DUBBELDAM)
4 1819CA 1004 BOREHOLE MYL SESTIG
5 1819CA 1005 BOREHOLE RUHEPO POS
6 1819CA 1006 BOREHOLE RUHEPO PLAAS
7 1819CA 1007 BOREHOLE KWATOKO PLAAS
8 1819CA 1008 BOREHOLE MANGETTI 56
9 1819CA 1009 BOREHOLE MANGETTI 59
A 1819CA 1010 BOREHOLE MANGETTI 60
B 1819CA 1030 BOREHOLE KATJINA KATJI
C 1819CB 1003 BOREHOLE DONGORO



% OF TOTAL MEQ/L
12 SAMPLES

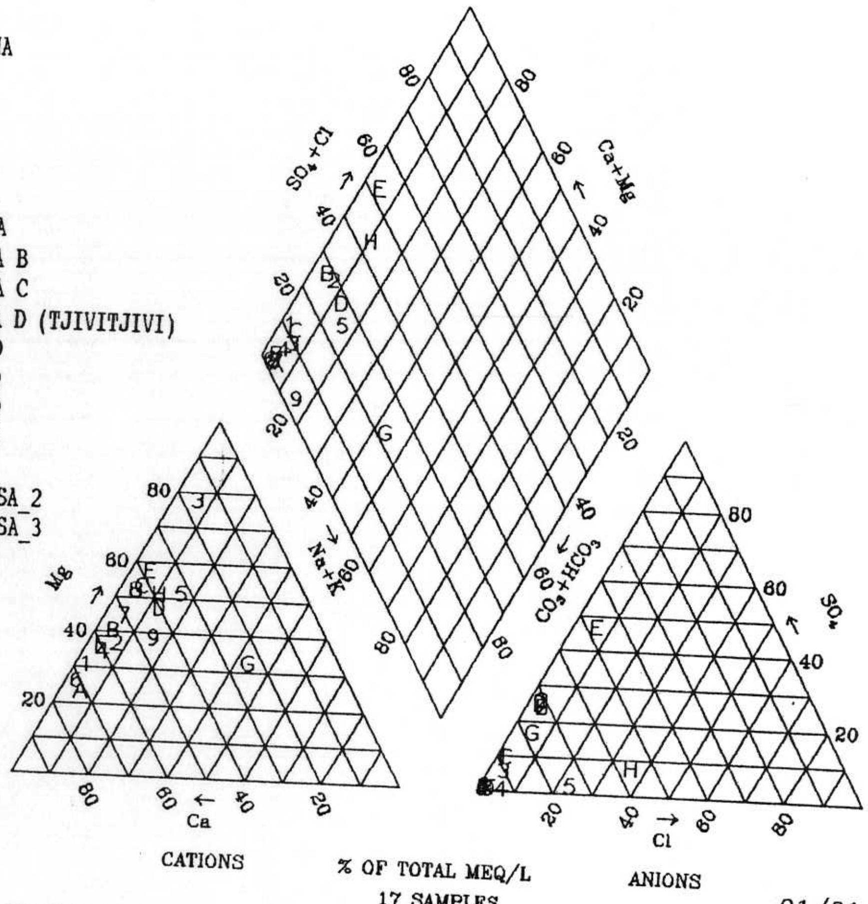
02/18/91

NGDC

QUARTER DEGREE 1819D

LEGEND

1 1819DA 1001 DUG WELL MUPARANA
2 1819DA 1002 DUG WELL GCAMA
3 1819DA 1050 BOREHOLE KONDJA
4 1819DA 1051 BOREHOLE NCUSHE
5 1819DA 1052 DUG WELL NCUSHE
6 1819DA 1053 BOREHOLE KANUNDA
7 1819DA 1055 BOREHOLE NGCASAWA
8 1819DA 1056 BOREHOLE NGCASAWA B
9 1819DA 1057 BOREHOLE NGCASAWA C
A 1819DA 1058 BOREHOLE NGCASAWA D (TJIVITJIVI)
B 1819DA 1059 DUG WELL NAINGOPO
C 1819DA 1060 DUG WELL NAINGOPO
D 1819DA 1061 DUG WELL NAINGOPO
E 1819DA 1062 DUG WELL NAINGOPE
F 1819DC 1008 BOREHOLE TAMTAM
G 1819DC 1009 BOREHOLE KARAKUWISA_2
H 1819DC 1010 DUG WELL KARAKUWISA_3



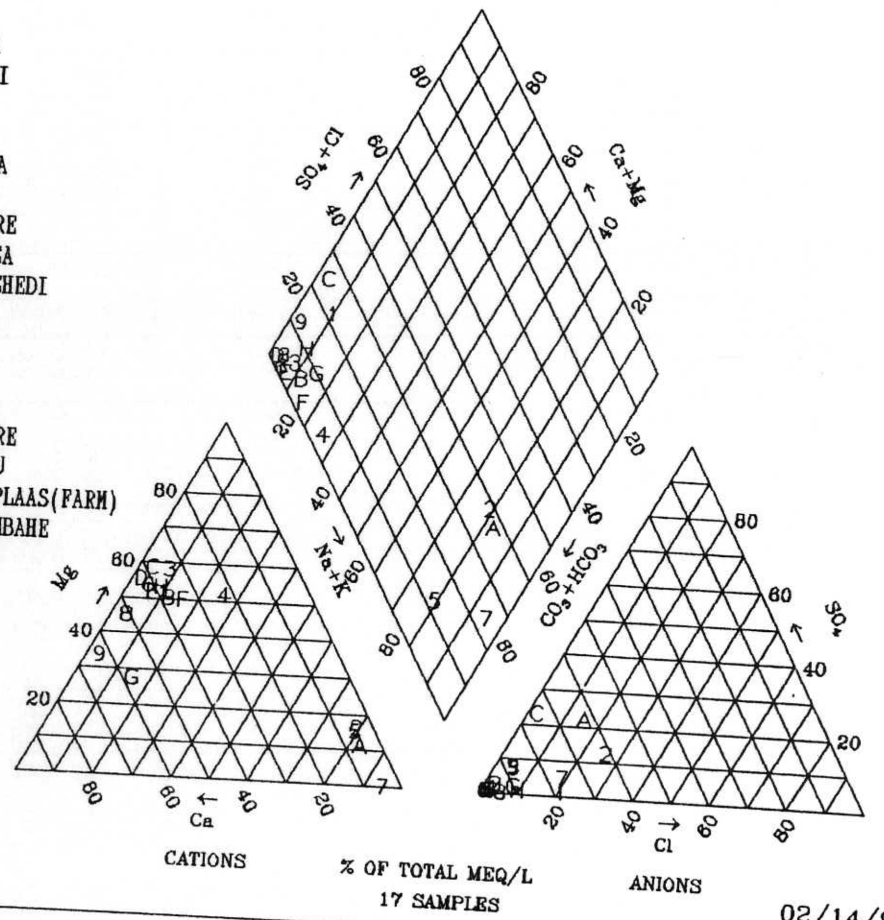
01/01/80

NGDC

QUARTER DEGREE 1820A

LEGEND

1 1820AA 1001 BOREHOLE VIKOTA
2 1820AA 1004 BOREHOLE NCUMUSI
3 1820AA 1006 BOREHOLE SAIWE
4 1820AA 1007 BOREHOLE GONGWA
5 1820AA 1008 BOREHOLE MADCUVA
6 1820AA 1009 BOREHOLE YURU
7 1820AB 1001 BOREHOLE TARATARE
8 1820AB 1002 BOREHOLE SHINUNGA
9 1820AB 1003 DUG WELL KAPUPAGHEDI
A 1820AB 1004 BOREHOLE NCODCO
B 1820AB 1005 BOREHOLE NCODCO
C 1820AB 1006 DUG WELL LILIRA
D 1820AB 1007 BOREHOLE KORO
E 1820AB 1008 BOREHOLE SHAVIVARE
F 1820AC 1001 BOREHOLE SHAKAMBU
G 1820AC 1003 BOREHOLE MASIVI PLAAS(FARM)
H 1820AC 1004 DUG WELL MUTWEGOMBAHE



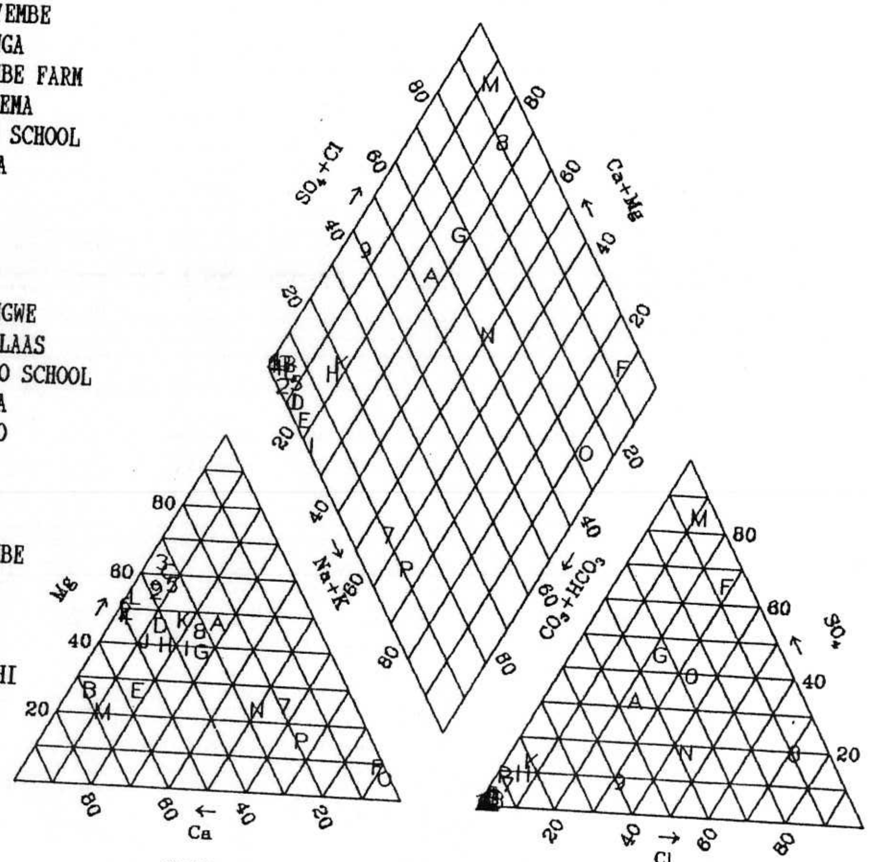
NGDC

02/14/91

QUARTER DEGREE 1820B

LEGEND

1 1820BA 1001 BOREHOLE SHAMWIMBI
2 1820BA 1002 BOREHOLE NANAZI
3 1820BA 1003 BOREHOLE SHAMAYEMBE
4 1820BA 1005 BOREHOLE MASHINGA
5 1820BA 1006 BOREHOLE KANDIMBE FARM
6 1820BA 1007 BOREHOLE KAMUNDEMA
7 1820BA 1009 BOREHOLE NYONDO SCHOOL
8 1820BA 1012 BOREHOLE NDIYONA
9 1820BA 1013 BOREHOLE RUCARA
A 1820BA 1014 BOREHOLE MASHA
B 1820BA 1015 BOREHOLE NCAME
C 1820BB 1001 BOREHOLE KATERE
D 1820BB 1003 BOREHOLE SHINYUNGWE
E 1820BB 1004 BOREHOLE LINUS PLAAS
F 1820BB 1005 BOREHOLE KOROKOKO SCHOOL
G 1820BB 1007 BOREHOLE KANDJARA
H 1820BB 1009 BOREHOLE SHAMBURO
I 1820BB 1010 BOREHOLE CWA
J 1820BB 1011 BOREHOLE CUMA
K 1820BB 1012 BOREHOLE LIVAYI
L 1820BB 1013 BOREHOLE SHAMAYEMBE
M 1820BB 1014 DUG WELL ZAZASI
N 1820BC 1001 DUG WELL DANCENCE
O 1820BC 1002 BOREHOLE DANCENCE
P 1820BC 1003 BOREHOLE CUMAGCASHI



% OF TOTAL MEQ/L
25 SAMPLES

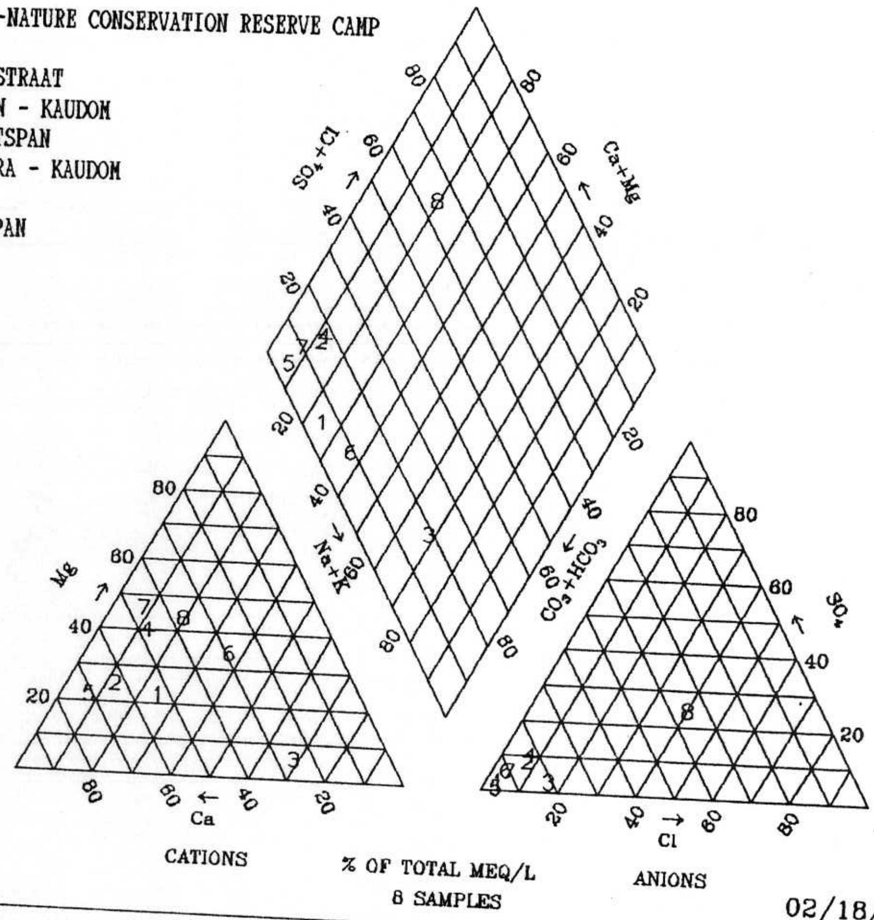
NGDC

02/14/91

QUARTER DEGREE 1820D

LEGEND

1 1820DA 1001 BOREHOLE CAUDUM-NATURE CONSERVATION RESERVE CAMP
2 1820DA 1002 BOREHOLE BATEA
3 1820DB 1001 BOREHOLE DORINGSTRAAT
4 1820DB 1002 BOREHOLE LEEUPAN - KAUDOM
5 1820DB 1020 BOREHOLE OLIFANTSPAN
6 1820DD 1001 BOREHOLE TARIKORA - KAUDOM
7 1820DD 1002 BOREHOLE DUSI
8 1820DC 1021 BOREHOLE ELANDSPAN



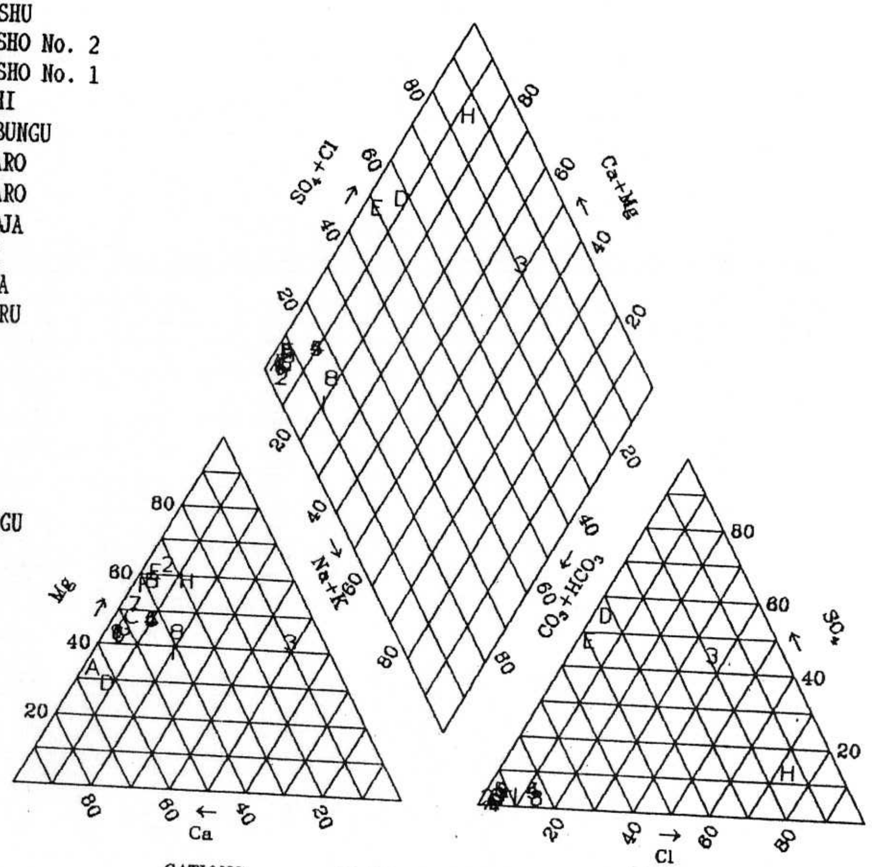
NGDC

02/18/91

QUARTER DEGREE 1821A

LEGEND

1 1821AA 1001 BOREHOLE KOROKOSHU
2 1821AA 1002 BOREHOLE SHASHOSHO No. 2
3 1821AA 1003 BOREHOLE SHASHOSHO No. 1
4 1821AA 1005 BOREHOLE SHAKASHI
5 1821AB 1001 DUG WELL SHAMANBUNGU
6 1821AB 1002 DUG WELL SHAMUNARO
7 1821AB 1003 DUG WELL SHAMUNARO
8 1821AB 1004 BOREHOLE KANGUNDJA
9 1821AB 1005 BOREHOLE KAVITJI
A 1821AB 1006 BOREHOLE MANGAMBA
B 1821AB 1007 BOREHOLE SHAMATURU
C 1821AB 1008 DUG WELL SHAIWE
D 1821AB 1009 DUG WELL DIKUNDU
E 1821AB 1010 BOREHOLE HAVO
F 1821AB 1011 BOREHOLE SHAMVU
G 1821AB 1012 BOREHOLE DIKUNGU
H 1821AB 1013 BOREHOLE MUKWE
I 1821AB 1020 BOREHOLE SHAYIRUNGU



% OF TOTAL MEQ/L
18 SAMPLES

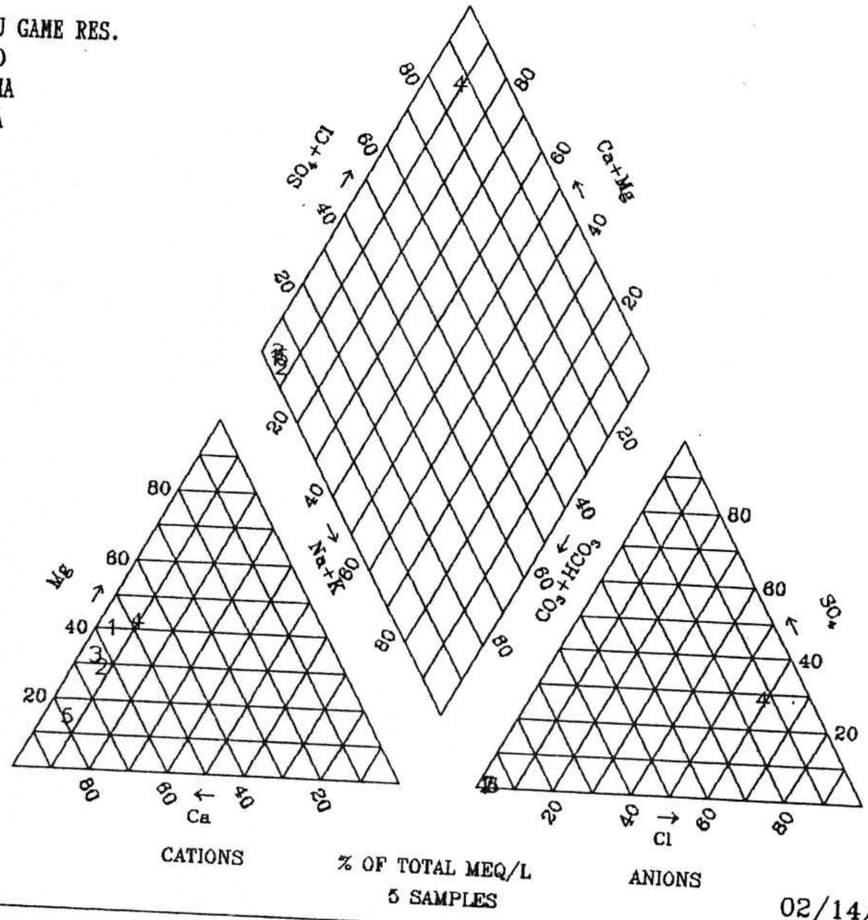
NGDC

01/01/80

QUARTER DEGREE 1821B

LEGEND

1 1821BA 1001 BOREHOLE MAHANGU GAME RES.
2 1821BA 1002 BOREHOLE RUPETHO
3 1821BA 1003 BOREHOLE TAPAUTHA
4 1821BA 1004 BOREHOLE DINWAKA
5 1821BA 1006 BOREHOLE BAGANI



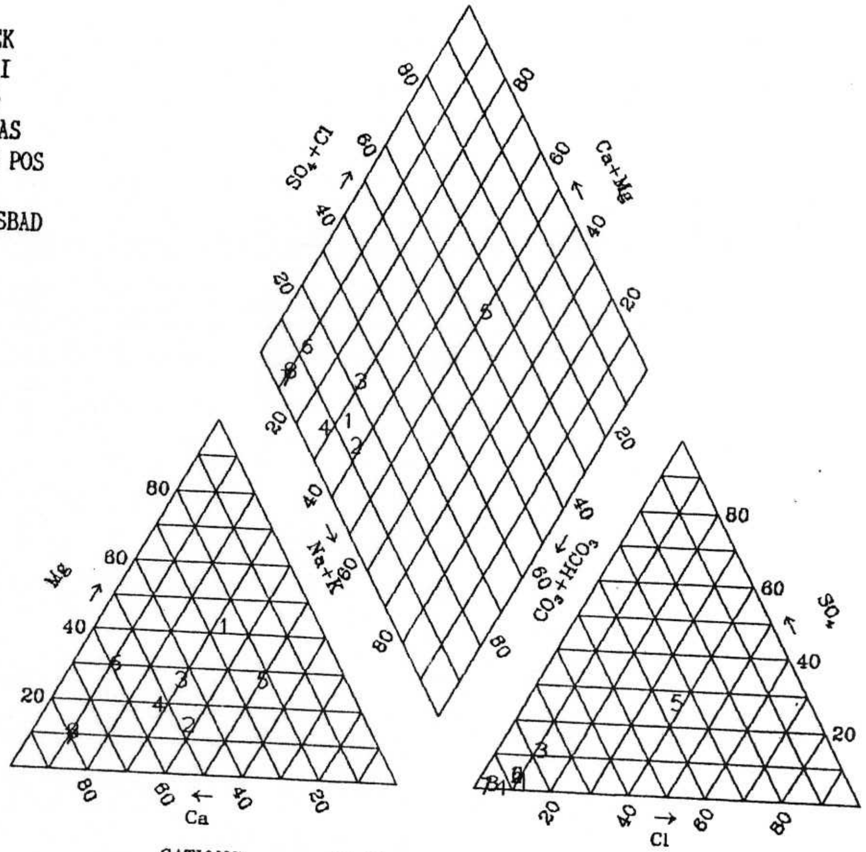
NGDC

02/14/91

QUARTER DEGREE 1919A

LEGEND

1 1919AA 1001 BOREHOLE GRASHOEK
2 1919AB 1001 BOREHOLE KANOVLEI
3 1919AC 1004 BOREHOLE OMATAKO
4 1919AD 1002 BOREHOLE MOOIPLAAS
5 1919AD 1003 BOREHOLE BUBE SE POS
6 1919AD 1006 BOREHOLE KANDU
7 1919AD 1007 BOREHOLE OLIFANTSBAD
8 1919AD 1009 BOREHOLE BOSBOU



% OF TOTAL MEQ/L
8 SAMPLES

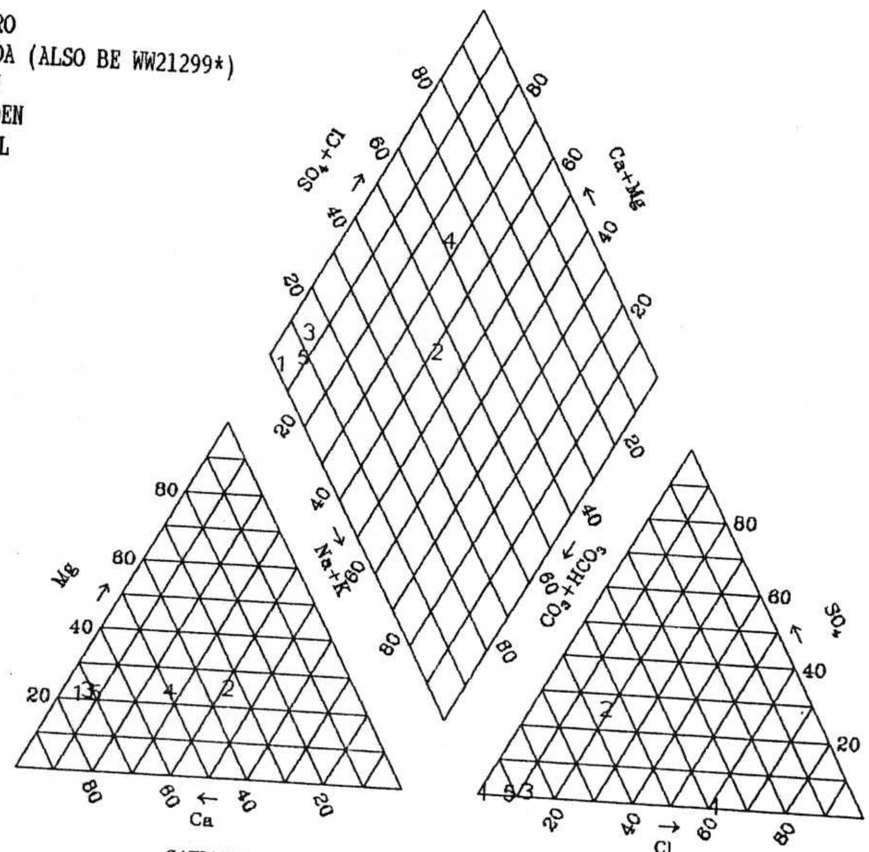
NGDC

02/18/91

QUARTER DEGREE 1919B

LEGEND

1 1919BA 1001 BOREHOLE EHAGERO
2 1919BA 1002 BOREHOLE MAPANDA (ALSO BE WW21299*)
3 1919BC 1003 BOREHOLE LOHEBU
4 1919BD 1001 BOREHOLE VELSKOEN
5 1919BD 1002 BOREHOLE SAWMILL



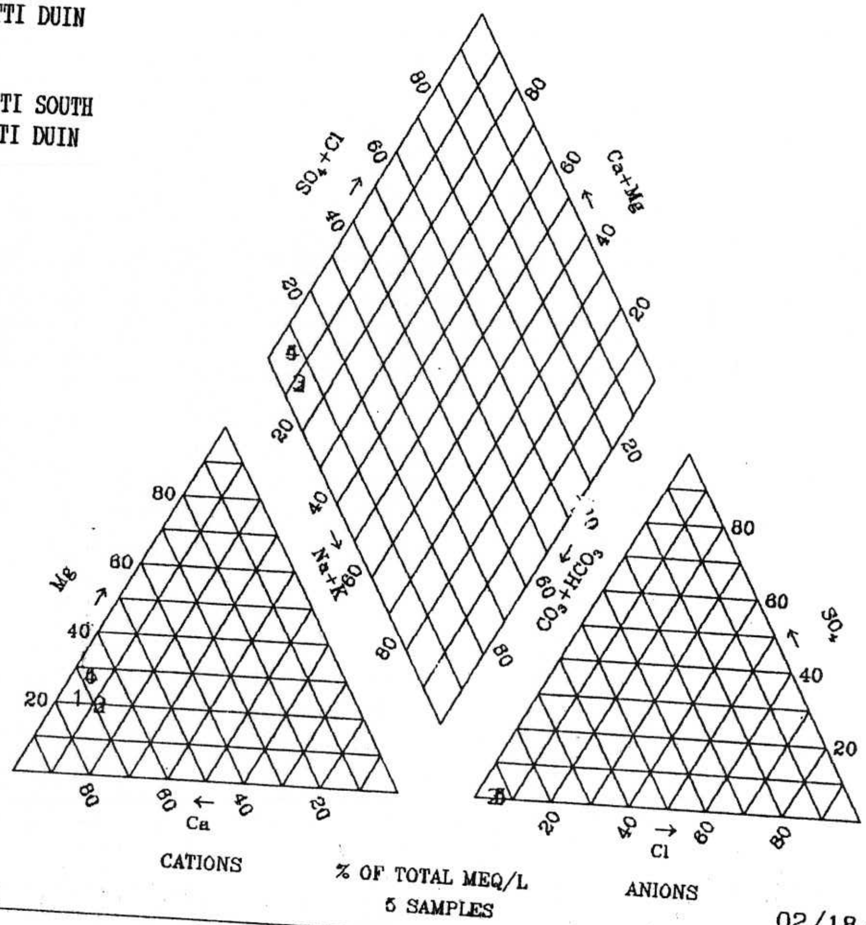
NGDC

02/18/91

QUARTER DEGREE 1919D

LEGEND

1 1919DA 1001 BOREHOLE MANGETTI DUIN
2 1919DA 1002 BOREHOLE MKATA
3 1919DA 1003 BOREHOLE MKATA
4 1919DA 1004 BOREHOLE MANGETTI SOUTH
5 1919DA 1005 BOREHOLE MANGETTI DUIN



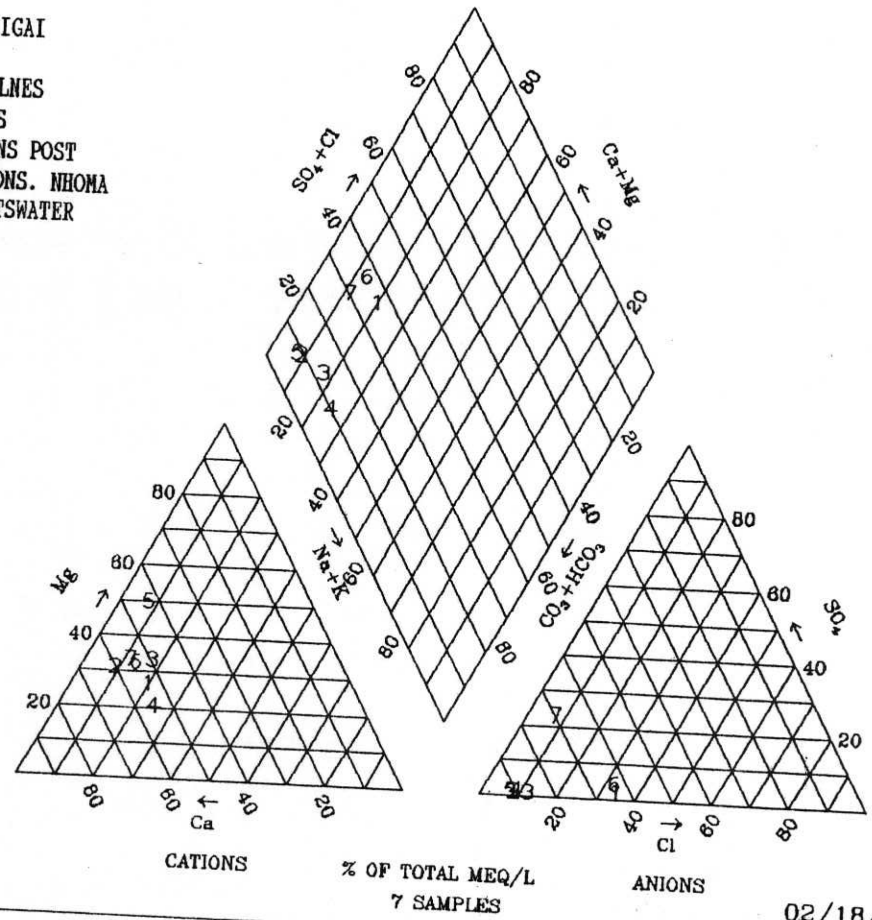
NGDC

02/18/91

QUARTER DEGREE 1920A

LEGEND

1 1920AA 1001 BOREHOLE SAMAGAIGAI
2 1920AB 1001 BOREHOLE NHOMA
3 1920AC 1001 BOREHOLE AASVOELNES
4 1920AC 1003 BOREHOLE VICSRUS
5 1920AD 1001 BOREHOLE CAPTAINS POST
6 1920AD 1002 BOREHOLE NAT. CONS. NHOMA
7 1920AD 1010 BOREHOLE OLIFANTSWATER



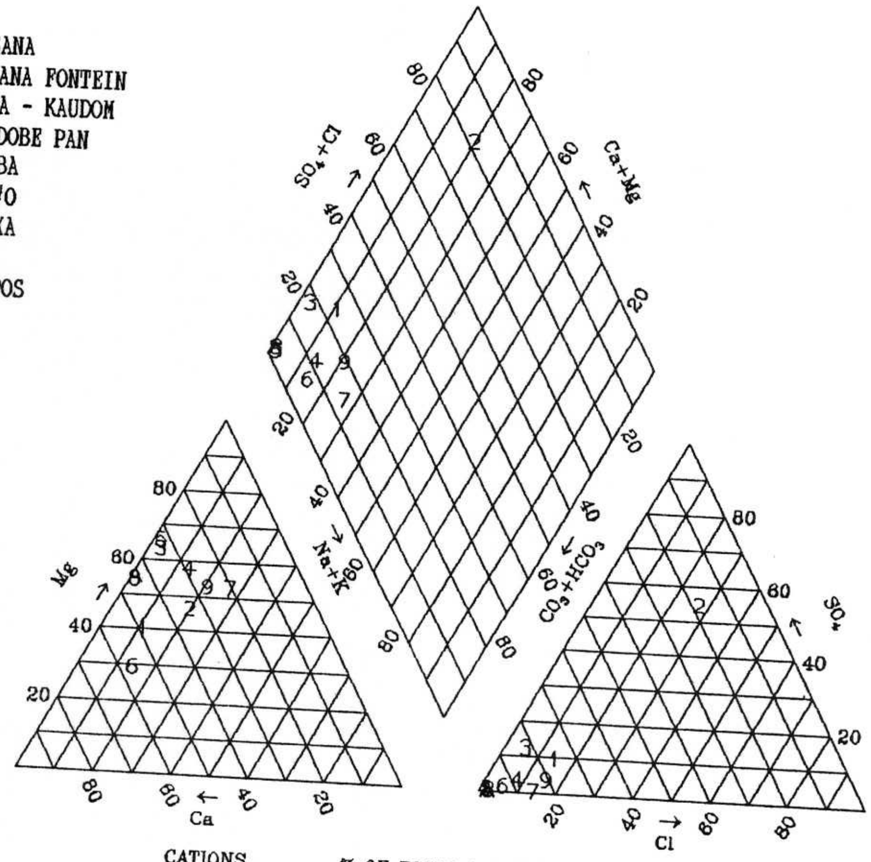
NGDC

02/18/91

QUARTER DEGREE 1920B

LEGEND

1 1920BA 1001 BOREHOLE TSONTSANA
2 1920BA 1003 BOREHOLE TSONTSANA FONTEIN
3 1920BB 1002 BOREHOLE BAIKIEA - KAUDOM
4 1920BC 1001 BOREHOLE KLEIN DOBE PAN
5 1920BC 1004 BOREHOLE //XA/OBA
6 1920BC 1005 BOREHOLE G#AING#O
7 1920BC 1006 BOREHOLE #OTCAKXA
8 1920BD 1002 BOREHOLE #IKWA
9 1920BD 1003 BOREHOLE MIDDELPOS
A 1920BD 1007 BOREHOLE #ABACE



% OF TOTAL MEQ/L
10 SAMPLES

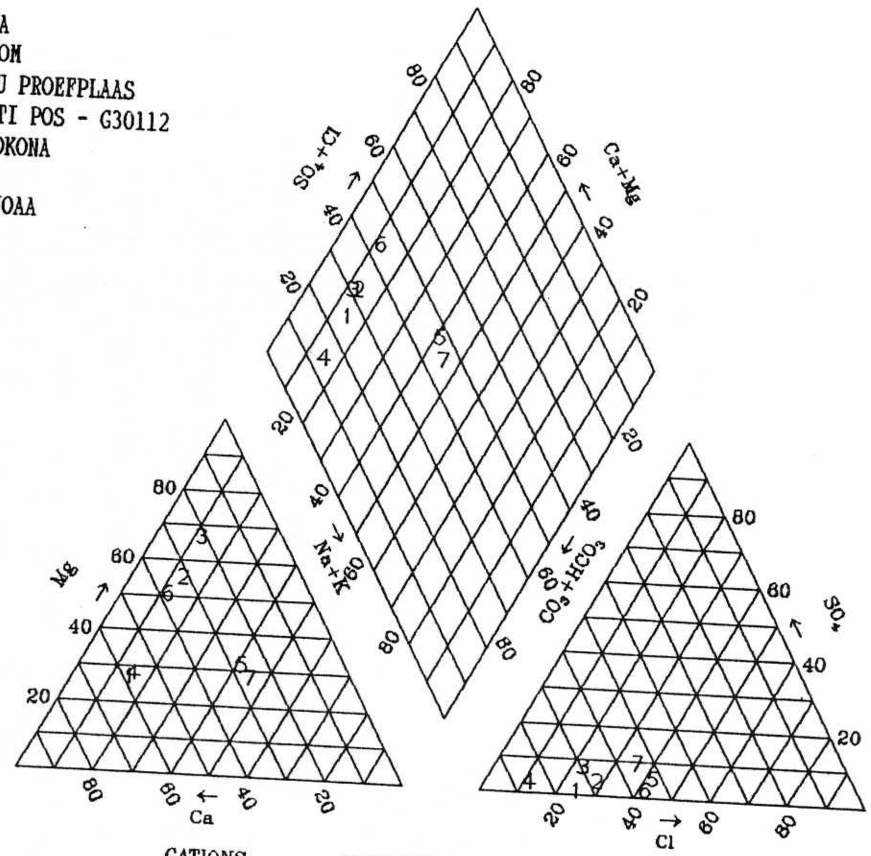
NGDC

02/18/91

QUARTER DEGREE 1920C

LEGEND

1 1920CA 1002 BOREHOLE PESPEKA
2 1920CB 1002 BOREHOLE N!OM/XOM
3 1920CB 1005 BOREHOLE LANDBOU PROEFPLAAS
4 1920CB 1008 BOREHOLE MANGETTI POS - G30112
5 1920CD 1002 BOREHOLE //AO/KOKONA
6 1920CD 1003 BOREHOLE N/UA
7 1920CD 1004 BOREHOLE N#AQMTJOAA



NGDC

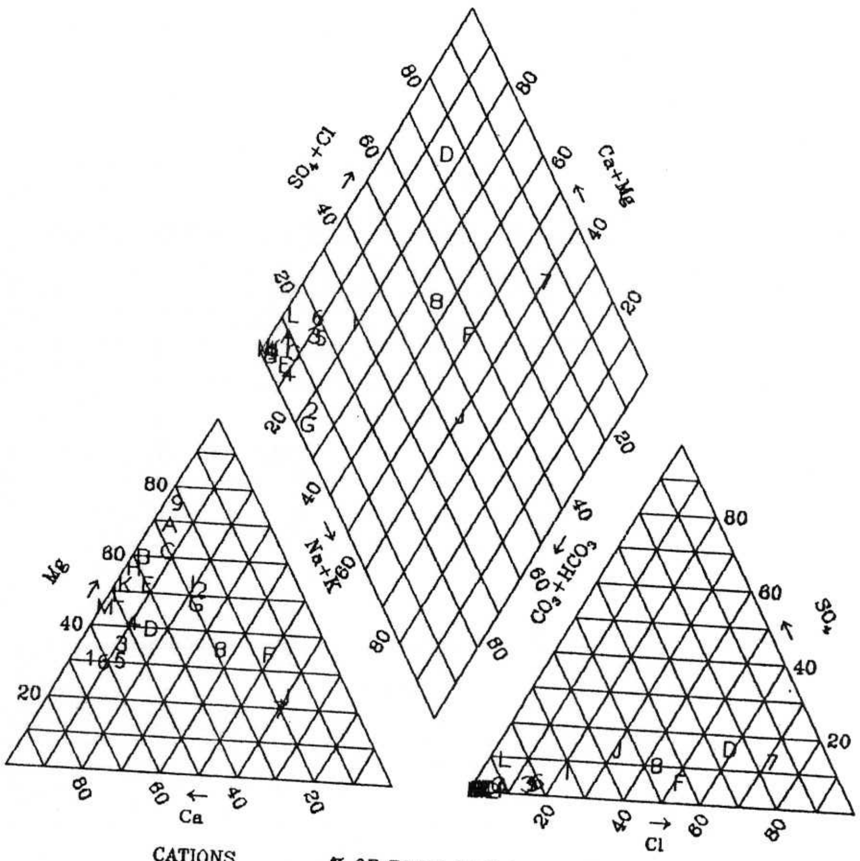
02/18/91

QUARTER DEGREE 1920D

LEGEND

1 1920DA 1002 BOREHOLE DJXOKO
2 1920DA 1004 BOREHOLE MAKURI
3 1920DA 1005 BOREHOLE N//OAG!OSI
4 1920DA 1006 BOREHOLE N#ANEME
5 1920DA 1007 BOREHOLE !AO#'A
6 1920DA 1008 BOREHOLE TSUMKWE
7 1920DA 1009 BOREHOLE TSUMKWE
8 1920DA 1010 BOREHOLE TSUMKWE
9 1920DB 1001 BOREHOLE BARAKA
A 1920DB 1002 BOREHOLE #UI!CWA
B 1920DB 1003 BOREHOLE BEN SE KAMP
C 1920DC 1001 BOREHOLE XAMSA
D 1920DC 1003 BOREHOLE GAUTSCHA PAN
E 1920DC 1004 BOREHOLE !AMA(No.1)
F 1920DC 1006 BOREHOLE N//HARU#'HAN
G 1920DC 1007 BOREHOLE N!AICI
H 1920DC 1008 BOREHOLE #HABACE
I 1920DC 1009 BOREHOLE //AURU
J 1920DC 1010 BOREHOLE /UIDINSI
K 1920DD 1001 BOREHOLE //OBAHA
L 1920DD 1002 BOREHOLE //AQRI#AH(//ONNDI)
M 1920DD 1003 BOREHOLE G!UKON!A'AO

NGDC



% OF TOTAL MEQ/L
22 SAMPLES

02/18/91

APPENDIX 4

DATABASE SPECIFICATIONS

Structure for database: D:\DBASE\GENERAL.DBF
Number of data records: 955
Date of last update : 02/22/91

Field	Field Name	Type	Width	Dec	Index
1	SOURCE	Character	10		N
2	LOC_REF	Character	40		N
3	BH_NUMBER	Character	10		Y
4	TOPO_NO	Character	6		N
5	WELL_NO	Numeric	4		N
6	LATITUDE	Numeric	7	4	N
7	LONGITUDE	Numeric	7	4	N
8	C_HEIGHT	Numeric	8	2	N
9	FUNCTION	Character	2		N
10	S_E_HEIGHT	Character	1		N
11	DATE	Character	10		N
12	DEPTH_EOH	Numeric	6	2	N
13	DIAMETER_1	Numeric	4		N
14	DIAMETER_2	Numeric	4		N
15	DIAMETER_3	Numeric	4		N
16	DIA_DEPTH1	Numeric	6	2	N
17	DIA_DEPTH2	Numeric	6	2	N
18	DIA_DEPTH3	Numeric	6	2	N
19	CASED_LINE	Logical	1		N
20	TYPE_CASIN	Character	18		N
21	SETTINGS_C	Numeric	10	2	N
22	SCREEN_TYP	Character	20		N
23	SCREEN_SET	Numeric	10	2	N
24	STRIKES_1	Numeric	6	2	N
25	STRIKES_2	Numeric	6	2	N
26	STRIKES_3	Numeric	6	2	N
27	TYPE_S_1	Character	1		N
28	TYPE_S_2	Character	1		N
29	TYPE_S_3	Character	1		N
30	DATE_WL	Character	10		N
31	LEVEL	Numeric	7	2	N
32	P_WL	Numeric	6	2	N
33	YIELD	Numeric	6	2	N
** Total **			251		

Structure for database: D:\DBASE\F_SURVEY.DBF
Number of data records: 465
Date of last update : 02/21/91

Field	Field Name	Type	Width	Dec	Index
1	SURVEY_DAT	Character	10		N
2	SOURCE	Character	10		N
3	LOC_REF	Character	40		N
4	TRIBAL	Character	10		N
5	BH_NUMBER	Character	10		N
6	JOB_NO	Numeric	3		Y
7	FLIGHT_NO	Character	3		N
8	A_PHOTO_NO	Character	4		N
9	LATITUDE	Numeric	7	4	N
10	LONGITUDE	Numeric	7	4	N
11	C_HEIGHT	Numeric	8	2	N
12	TOPO_NO	Character	6		N
13	WELL_NO	Numeric	4		N
14	SURVEY_NO	Character	4		N
15	OWNER	Character	15		N
16	TYPE	Character	30		N
17	STATUS	Character	12		N
18	RESER_TYPE	Character	15		N
19	RESER_VOL	Character	10		N
20	RESER_HEIG	Character	6		N
21	EXTENT	Character	7		N
22	AVG_DEPTH	Character	6		N
23	PERIOD_DRY	Character	11		N
24	DIAMETER_1	Numeric	5		N
25	TYPE_CASIN	Character	10		N
26	DEPTH_EOH	Numeric	6	2	N
27	LEVEL	Numeric	6	2	N
28	PARAPET	Logical	1		N
29	PAR_HEIGHT	Character	5		N
30	APRON	Logical	1		N
31	ABST_METHD	Character	12		N
32	TYPE_PUMP	Character	12		N
33	MODEL_PUMP	Character	15		N
34	YIELD	Numeric	6	2	N
35	REPAIR_INS	Character	20		N
36	REPAIR_SOU	Character	20		N
37	REMEDIAL_S	Character	35		N
38	REMEDIAL_I	Character	35		N
39	CRITERIA	Character	5		N
40	SAMPLED	Logical	1		N
41	REMARKS	Character	30		N
42	TIME_SAMPL	Character	5		N
43	DRAINAGE_1	Character	18		N
44	PHY_DRY	Character	10		N
45	VEGETATION	Character	25		N
46	TOPOGRAPHY	Character	10		N
47	SOILS	Character	10		N
48	GEOLOGY	Character	10		N
49	PHY_OBS	Character	10		N
50	INFO_NAME	Character	25		N
51	RELIA_PERS	Character	6		N
52	SOC_POSITI	Character	15		N
53	NO_CONSUME	Numeric	5		N
54	NO_EMBOS	Numeric	3		N
55	TOT_NO_LSU	Numeric	5		N
56	TOT_NO_SSU	Numeric	5		N
57	NO_CATTLE	Numeric	5		N

58	NO_DONKEYS	Numeric	5	N
59	NO_HORSES	Numeric	5	N
60	NO_GOATS	Numeric	5	N
61	NO_PIGS	Numeric	5	N
62	IRRIGATION	Numeric	5	N
63	NO_SCHOOLS	Numeric	1	N
64	SCHOOL_1	Character	20	N
65	BEGIN_ST_1	Character	1	N
66	END_ST_1	Character	1	N
67	NO_PUP_1	Numeric	5	N
68	SCHOOL_2	Character	20	N
69	BEGIN_ST_2	Character	1	N
70	END_ST_2	Character	1	N
71	NO_PUP_2	Numeric	5	N
72	INDUSTRIES	Character	30	N
73	FACILITY_1	Character	18	N
74	FACILITY_2	Character	18	N
75	FACILITY_3	Character	18	N
76	CULTIVATIO	Character	25	N
77	IMP_WATER	Character	12	N
78	ACCESS_DRY	Character	8	N
79	ACCESS_WET	Character	8	N
80	OTHER_OBS	Character	250	N
** Total **			1098	

Structure for database: D:\DBASE\CHEMDATA.DBF
Number of data records: 934
Date of last update : 02/17/91

Field	Field Name	Type	Width	Dec	Index
1	TOPO_NO	Character	6		N
2	WELL_NO	Numeric	4		N
3	STATUS	Character	1		N
4	BH_NUMBER	Character	10		N
5	LOC_REF	Character	55		N
6	SAMPLE_DAT	Character	10		N
7	REF_NUMBER	Character	10		N
8	NA	Numeric	12	4	N
9	CA	Numeric	12	4	N
10	MG	Numeric	12	4	N
11	K	Numeric	12	4	N
12	CL	Numeric	12	4	N
13	NO3	Numeric	12	4	N
14	TA	Numeric	12	4	N
15	SO4	Numeric	12	4	N
16	F	Numeric	12	4	N
17	TDS	Numeric	12	4	N
18	PH	Numeric	12	4	N
19	COND	Numeric	12	4	N
20	CLAS_DRINK	Character	1		N
21	STOCKWATER	Logical	1		N
22	CLAS_IRRIG	Character	5		N
23	LANG_INDEX	Character	2		N
24	RYZ_INDEX	Character	2		N
25	CORR_STEEL	Logical	1		N
** Total **			253		

APPENDIX 5

SPECIMEN FIELDSHEETS

A. GENERAL INFORMATION

Survey date: __/__/__ Type of water source (bh,well,etc.) _____
Location:____________________ Tribal area:____________________
Source No:(WW/T/G)________ Job/Flight/Air-photo:___/__/____
Topo-No:________ Well-No:____ Survey-No:_____
Owner:(G/P/C)_____ Use:(Dr/Do/Li/Irr)________ Status:(U/A/D)___
Water storage facilities:- Reservoir type:________ Volume:___

B. PHYSICAL SPECIFICATIONS

Open water:- Area:_______ Depth:_____ Months dry:(1-12)_______
Borehole/well specs:- Internal diam.:_____ Lining type:_____
Depth:______ Water rest level:___________
Well parapet (y/n):__ Parapet height:_____ Apron (y/n):__

C. ABSTRACTION

Method: (h/b/d/w/none):_____
Pump type:__________ model:__________ Pumping rate:______
State of repair:- Pump:_______ Source:__________________
Remedial works needed:______________________________________
____
Remarks:____
____

D.WATER QUALITY

Apparent water quality:(g/f/b)____ Sampled: (y/n)_____
Remarks:(incl. contamination or reason for not sampling)
____
____

G. ADDITIONAL REMARKS

Sketch indicating settlement layout wrt. water points:

^

N

APPENDIX 6

NATIONAL WATER CLASSIFICATION STANDARDS

NATIONAL WATER QUALITY CLASSIFICATION

Determinant	Unit	CLASSES A	B	C	D
TDS	mg/l	1500	2000	3000	>3000
Conductivity	mS/cm	150	300	400	>400
Total hardness	mg/l	300	650	1300	>1300
Ca	mg/l	150	200	400	>400
Na	mg/l	100	400	800	>800
K	mg/l	200	400	800	>800
Cl	mg/l	250	600	1200	>1200
F	mg/l	1.5	2.0	3.0	>3.0
SO4	mg/l	200	600	1200	>1200
NO3	mg/l	10	20	40	>40

APPENDIX 7

PLATES SHOWING TYPICAL WATER POINTS IN KAVAMGO AND BUSHMANLAND

LIST OF PLATES

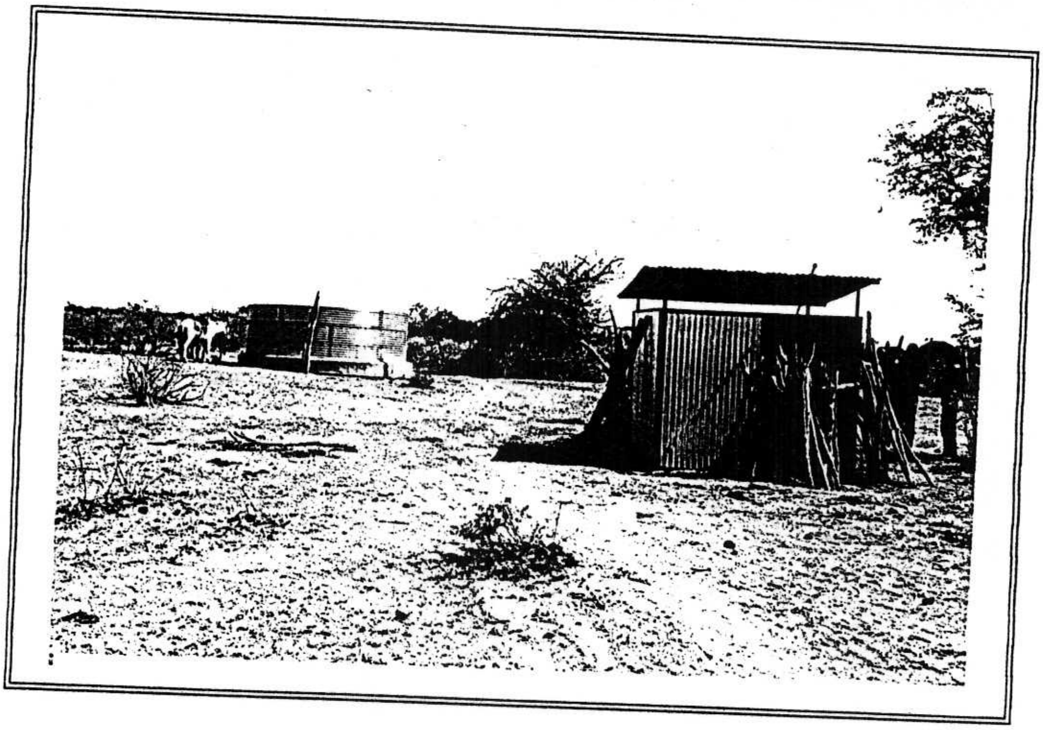


PLATE 1 Typical borehole installation maintained by Department of Agriculture, Rundu

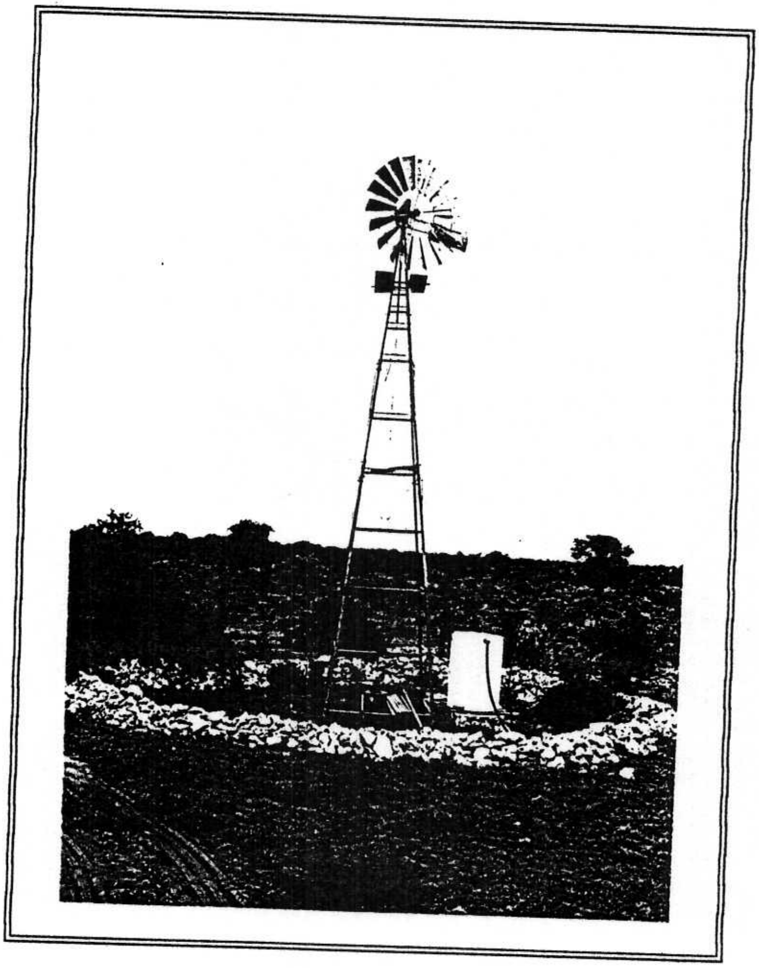


PLATE 2 Example of borehole installation maintained by Department of Nature Conservation, Bushmanland

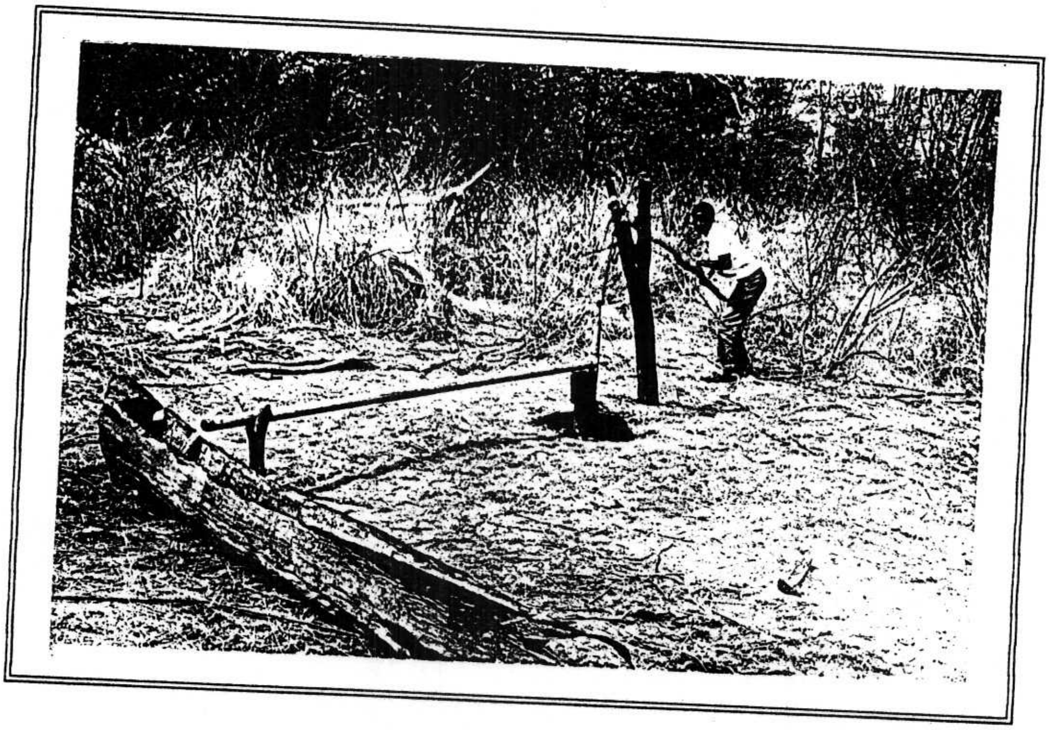


PLATE 3 Typical 'wip stok' hand-pump installed by Department of Agriculture

PLATE 4 Borehole with a 'wip stok' hand-pump in Kavango which has replaced the old abandoned borehole installation in the background

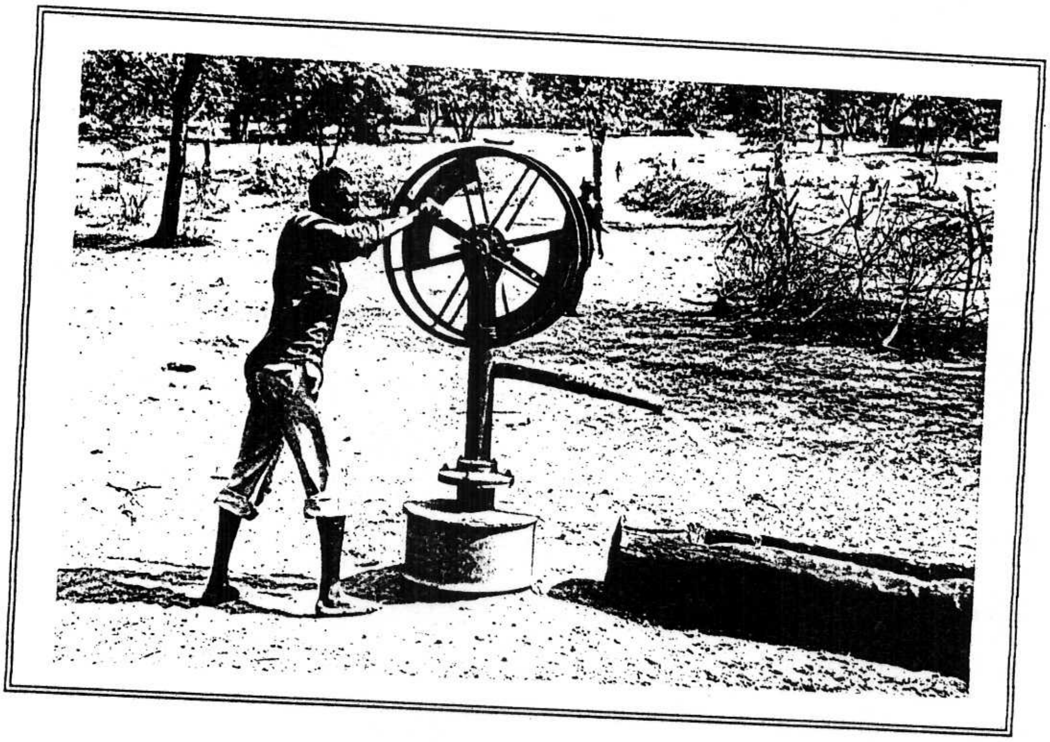


PLATE 5 'Crank' hand-pump at Department of Agriculture installation, Kavango

PLATE 6 Typical 'lever' hand-pump installed by Ju/Wasi Bushman Development Foundation, eastern Bushmanland

PLATE 7 'Mono' hand-pump installed by Department of Agriculture, Kavango

PLATE 8 Open funnel shaped well in soft unconsolidated sands, Kwangali, Kavango

PLATE 9

Partly lined well in soft, sandy sediment; Mbukushu, Kavango

PLATE 10

Unlined well in semi-self supporting sediments in Kwangali

PLATE 11 Typical surface installation for the deep wells in Mbukushu

PLATE 12 Unlined well showing typical method of water abstraction for shallow water tables, Mbunya, Kavango

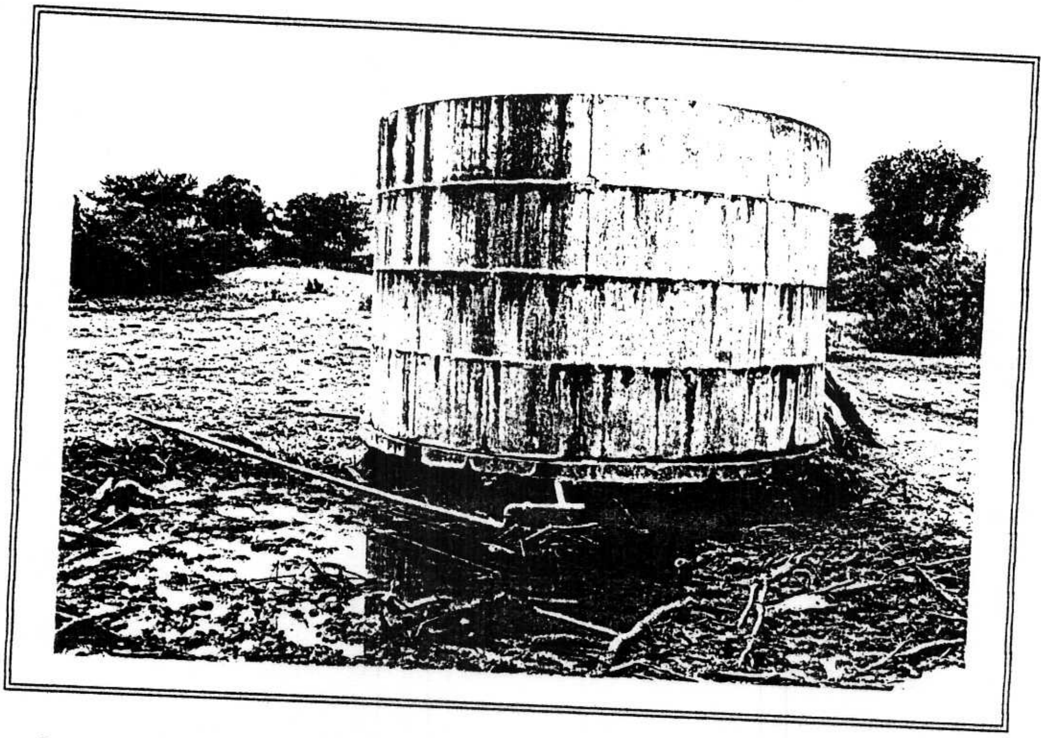


PLATE 13 Degradation and potential damage to installation caused by livestock pressure on a water point, Kavango

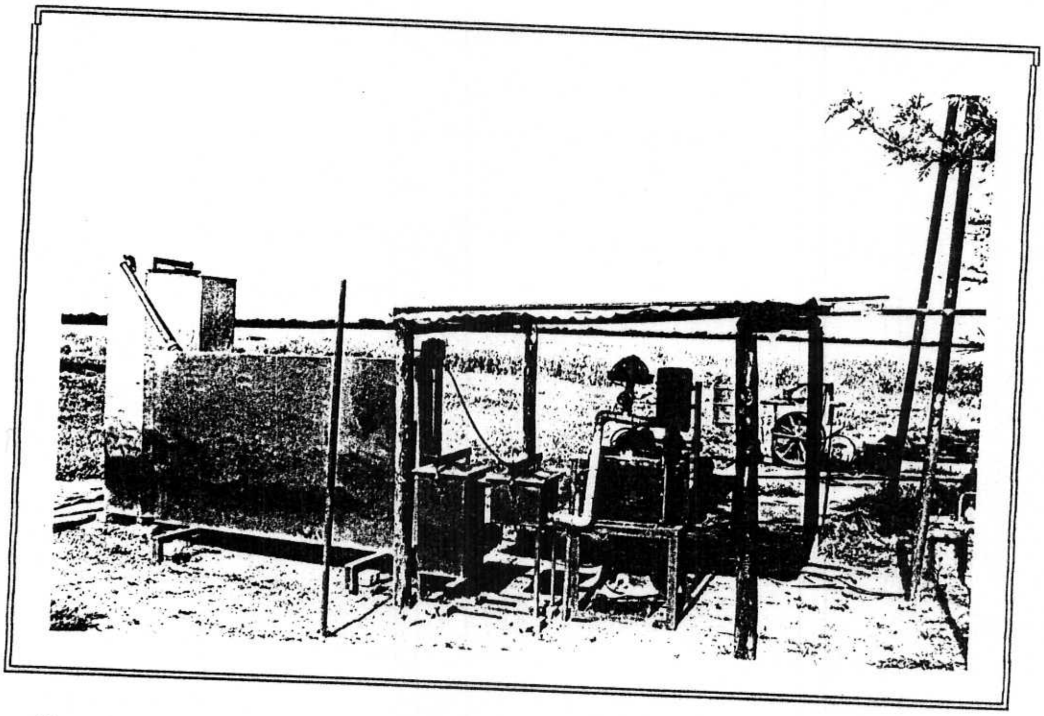


PLATE 14 Wood gas burning petrol engine driving a mono water pump, Grootfontein District

APPENDIX 8

GENERAL CONSIDERATIONS

GENERAL CONSIDERATIONS

The following considerations are the result of ideas generated during the field survey which have been discussed with and greatly benefitted from contributions from personnel who had contact with the project during the survey. These people include the regional heads of government departments, Mr P. Horn, Mr B. Bytel, Dr T. Tolmay, and the interpreter/guides.

Development schemes undertaken in Kavango and Bushmanland must consider the status of groundwater in the area. This report represents an assessment of groundwater conditions and utilization which can provide basic information for such development.

The water supply scheme organised and run by the Department of Agriculture (see Section 3.2.2) serves more than 90% of the rural groundwater dependent population. Difficulties encountered in maintenance of the scheme are outlined below.

* The scheme necessitates a complex infrastructure of semi-skilled personnel and equipment.

* It is largely run from Rundu which involves great distances to remote areas in arduous conditions.

* All water points become the nucleii of population and livestock concentration which continue to grow as the community expands. Many such centres result in serious pressure on the immediately surrounding area from overgrazing and on the waterpoint itself. Large numbers of livestock, moving from the waterpoint radially outwards to graze, cause total denudation of cover around the waterpoint and may cause damage to the installation as they jostle for water. In addition the pump and engine run long hours to ensure an adequate water supply.

* The 'pumpman' is appointed by the Department of Agriculture to operate the pump installation. He has a basic mechanical knowledge of engine maintenance (engine oil levels, fan-belt fitting etc.). The pumpman's often poor mechanical knowledge precludes his ability to diagnose problems before serious mechanical failure occurs. The maintenance of the installation with respect to operation and fuel supply is the responsibility of the Department.

* The community's total dependence on the installation for water results in total dependence on the Department of Agriculture for their water. Although run effectively, the maintenance crews cannot ensure trouble-free water supply and situations occur where the engine fails and the population have no water until the crews arrive. This is critical in large centres and serious problems result. In the case of smaller centres, the population may secure drinking water from the nearest water point which may be up to 10km away. The livestock have to move to the nearest water point to survive.

The situation described above invariably leads to a situation of false dependence to the point where the Department is blamed if disasters occur (death of livestock etc.). Suggestions to alleviate some of these problems are summarised below.

1 Short Term Recommendations

Large communities could be dispersed, where overstocking is having a serious effect on the flora. In areas of shallow water table (< 30m from surface) hand-pumps should be installed. Hand-pumps are a natural limiter on population and stock because of the effort required. However, yields from certain hand-pumps (lift pumps in particular) are no less than the engine driven equivalent. These pumps are very durable and thereby reduce maintenance and supply of fuel to an area. The manual mechanism can be constructed from local materials which can be replaced when broken. These water points can, by extension work, be made the responsibility of the community.

In areas underlain by a deep water table where engine driven pumps are essential, a cluster node system is recommended. Several boreholes or water outlet points, one to two kilometres apart, in an area accessed by a good road will result in dispersed pressure and enable easier maintenance for the crews. This is partly happening in the northwest at centres such as Mpungu where good ex-military roads are present and several boreholes serve the community. Although the boreholes are too close together to encourage dispersion, this example illustrates further advantages of this system. Secondary infrastructure such as shops, garages and service industries appear which lead to maturity of the centre.

The implementation of these systems (or a combination) can begin in priority areas rated as pressure points from the manga stock figures (re. Dept. Veterinary Services, Rundu).

2 Long Term Recommendations

The most important long term result required in these areas is the independence of the people. The communities must learn to depend on themselves for survival. This transference of responsibility from government departments to communities results in positive attitudes and a healthy economic environment, an essential aspect of a developing country.

3 Fuel Sources

As the population and the water points grow in number, the government cannot be expected to continue this scheme effectively, particularly the supply of diesel to all water installations. In addition, the present situation in the Middle East may result in fuel supply problems that cannot easily be resolved. This may have disastrous consequences to diesel dependant remote communities. Therefore it is recommended that alternative sources of power must be considered. Some of these are mentioned below.

* Hand Pumps

  As mentioned above, Point 1.

* Wood Gas

  This makes use of a standard automobile engine which consumes gas from charcoal produced from local resources. It is significantly cheaper to purchase and maintain than an imported diesel engine.

* Solar Power

  Although this method is relatively high-tech, it requires no maintenance if protected from interference.

* Steam

  Steam engines are simple and consume local fuel only.

* Electricity

  The electrification of the northern parts of the country which is being planned by the government may be utilized effectively in northwest Kavango particularly if the cluster node system reaches suitable levels of development.

In addition to the water supply scheme maintained by the Department of Agriculture (see Section 3.2.2), two regional programmes which have been examined by the government are outlined below.

* The broad retention of the areas adjacent to the Kavango river as communal land and the establishment of privately owned farms in the south of Kavango. This scheme has commened in the southwest of Kavango and with the aid of control by the Department of Veterinary Services is directed at the northward movement of the 'Red Line' to enable greater quantities of livestock to enter the open market.

* The establishment of a corridor system around the Kaudom Game Reserve in southeast Kavango and northeast Bushmanland. The objective of this is a long term scheme to maximise natural resource utilization for the area in particular and the country generally.

The various authorities (Depts. of Agriculture, Veterinary Services and Nature Conservation) have expressed great interest in the results of this report and requested that the data be made available to them for incorporation into the planning of future programmes.

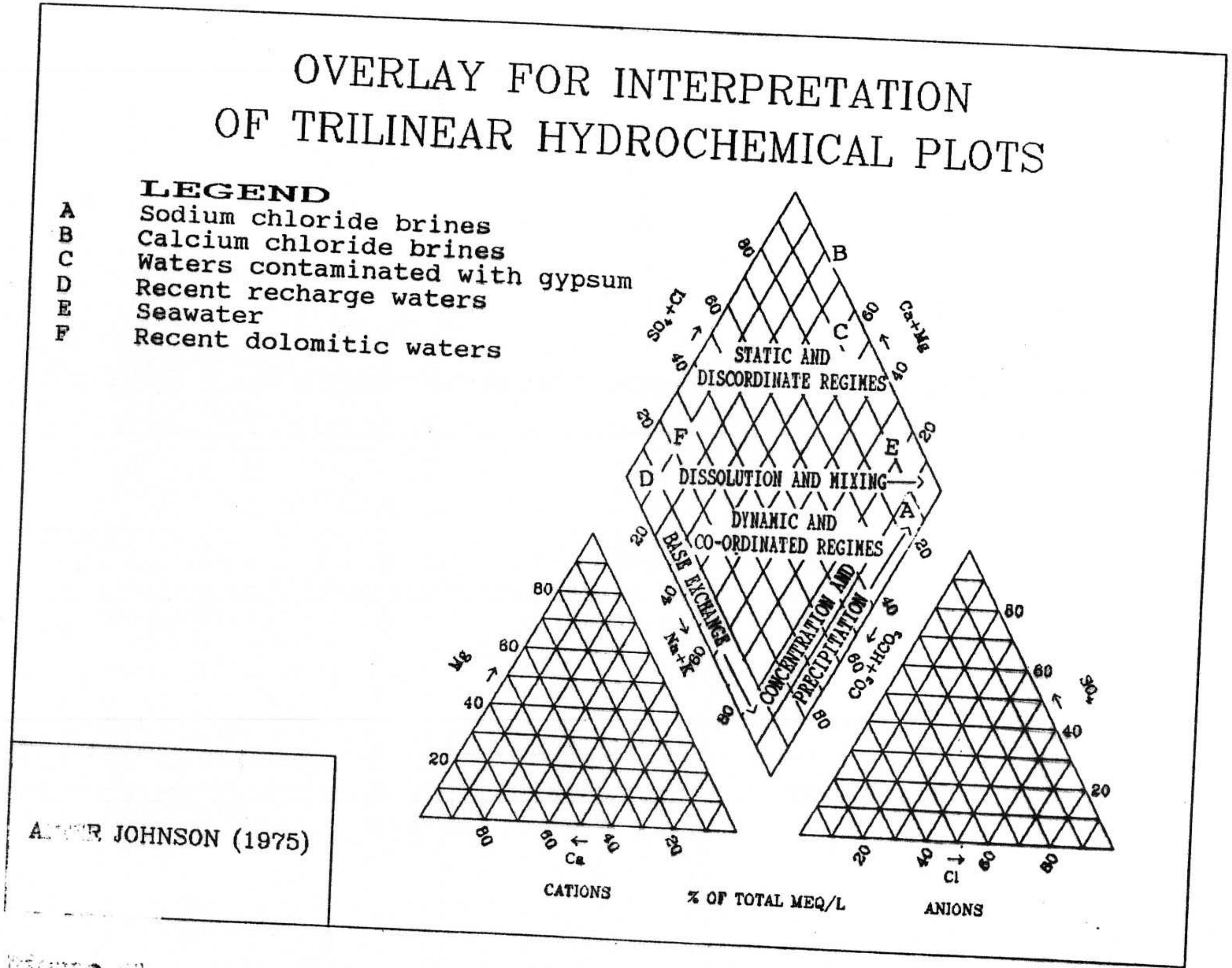


Figure 21 Overlay for interpretation of trilinear hydrochemical plots

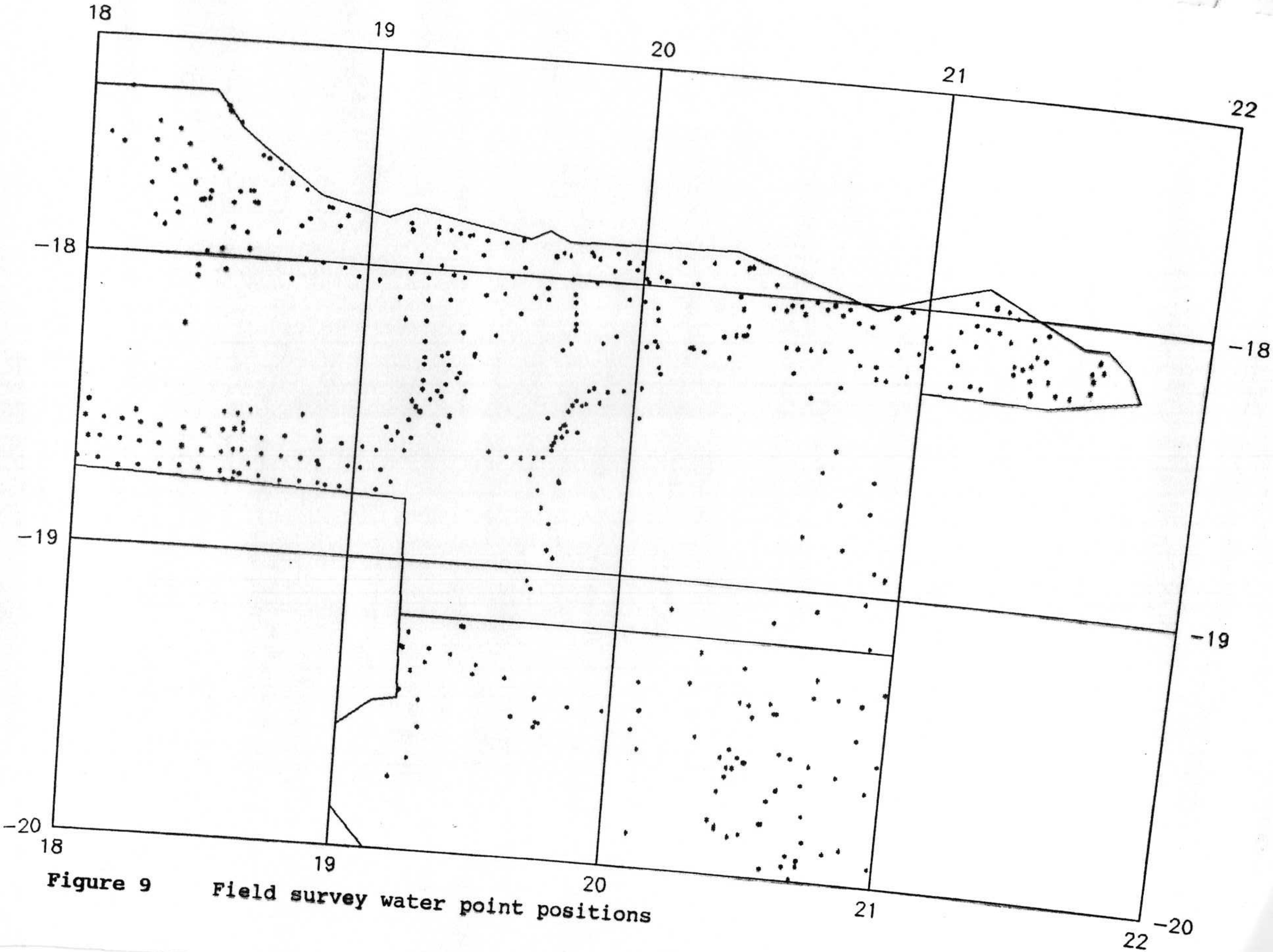


Figure 9 Field survey water point positions

KAVANGO/BUSHMANLAND – TOPO SHEET POSITIONS