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ENVIRONMENTAL IMPACT STATEMENT
BULYANHULU GOLD PROJECT

TANZANIA

May 1998

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4.0 ENVIRONMENTAL BASELINE

4.1 SCOPE AND OBJECTIVES

The scope of baseline environmental studies was set out in the terms of reference document (July 1997). The document was circulated to Tanzanian government representatives and stakeholders for information and comment. A workshop was then held to discuss comments. Revisions to the terms of reference were then made, as appropriate. Meetings to discuss the terms of reference were held at Bulyanhulu with representatives of the Village of Kakola and Ward of Bugarama, in Geita and Kahama with district representatives, in Shinyanga and Mwanza with regional representatives, and in Dar es Salaam with central government agency representatives. Following these consultations, the terms of reference document was finalised.

The objectives of the studies, as with any baseline studies, were to define the nature, abundance, and variability of existing media and biota. Intensive studies and data collection has been conducted over a period exceeding one year. A weather station has been established on site, and climatic monitoring is continuing. The data are being used to assist with project design, and are a record of conditions currently occurring against which any future changes will be measured.

4.2 CLIMATE AND AIR QUALITY

4.2.1 Regional Climate (Shinyanga)

The climate is subtropical. The closest full meteorology station to Bulyanhulu with at least 10 years of record is at Shinyanga, which is located approximately 200 km east-southeast of Bulyanhulu. Temperature, rainfall, relative humidity, and wind speed data were collected from 1984 to 1996. Although by no means should this database be considered long-term, it provides some measure of the trends experienced during the last decade, and an estimation of the probable average conditions for various climate parameters at Bulyanhulu.

4.2.1.1 Temperature

Mean daily maximum and minimum temperatures were measured at Shinyanga from 1987 through 1996.

In general, mean monthly maximum and minimum temperatures were relatively uniform from year to year (Table 4-1). Mean monthly minimum and maximum temperatures were relatively uniform, ranging from 14.9 °C in July to 20.0 °C in October for minimums, and 28.9 °C in January to 32.5 °C in October for maximums. Mean monthly minimum and maximum temperatures are plotted in Figure 4-1. The highest mean monthly maximum of 33.6 °C was recorded in October 1989, while the lowest mean monthly minimum of 11.8 °C was recorded in July 1993.

The 10-year mean annual monthly minimum and maximum temperatures were 18.1 °C and 30.3 °C, with annual ranges of 17.6 °C to 18.5 °C and 29.3 °C to 30.8 °C, respectively (Table 4-1). Slightly elevated mean annual minimum and maximum temperatures were recorded between 1991 and 1994; however, no increasing trend is evident over the monitoring period (1987 to 1996).

Daily minimum and maximum temperatures for each month are given in Table 4-2. The lowest temperature of 8.2 °C recorded during the 10-year period occurred during the dry season on July 31, 1997, and the highest temperature of 39.8 °C was recorded during the wet season on November 11, 1991. Annual minimum and maximum daily temperatures ranged from 8.2 °C to 13.2 °C, and 34.5 °C to 39.8 °C, respectively. In general, the lowest temperatures were recorded during June, July and August, while the highest temperatures were recorded during October and November.

4.2.1.2 Rainfall

Monthly rainfall amounts recorded at Shinyanga are given in Table 4-3. Total annual rainfall recorded at the Shinyanga station between January 1985 and December 1994 ranged from 592 mm in 1993 to 1066 mm in 1986. Depending on how the mean is calculated to account for missing data, the mean annual rainfall ranged from approximately 820 to 850 mm. The maximum recorded monthly rainfall of 312 mm occurred in December 1985.

Based on the monthly rainfall measurements, the region surrounding Shinyanga generally experiences one dry season (June through September) per year, with one or two very wet periods occurring between November and April. In some cases, the wet season began during early October, but in general it began during November. Similarly, the wet season lasted until early May, while at other times it ended in early March. Weather patterns for 1993 were characterised by below average rainfall accumulations, indicating the early onset of the dry season in April 1993, and the latest arrival of the wet season in January 1994.

Mean monthly precipitation for Shinyanga is plotted on Figure 4-1. In general, mean monthly rainfall during the wet season ranged between 108 and 168 mm, while mean monthly dry season accumulations of only 3.1, 0.0, 0.5, and 6.5 mm were recorded in June through September. Averages of monthly mean rainfall accumulations for May and October over the same period were 33.0 and 51.7 mm, respectively.

4.2.1.3 Wind

Wind speed was recorded at 06:00 and 12:00 Greenwich mean time (GMT) at Shinyanga from October 1987 through December 1996, with some months missing during this period. Mean monthly wind speed and monthly daily maximum wind speeds for 06:00 GMT and 12:00 GMT are summarised in Tables 4-4 and 4-5, respectively. In addition, the mean monthly wind speeds for 12:00 GMT are plotted on Figure 4-1.

In general, mean annual wind speeds at 06:00 and 12:00 were very similar, 7.1 km/hr and 7.2 km/hr, respectively. However, the 10-year mean monthly wind speeds at 06:00 had a larger range (4.2 km/hr to 10.0 km/hr) than at 12:00 (5.8 km/hr to 8.6 km/hr). Mean monthly wind speeds during a particular year were greatest during the dry season of July to September and reached a maximum in July (8.6 km/hr) and a minimum in January (5.8 km/hr). The maximum wind speeds recorded for 06:00 and 12:00 were 27.0 km/hr (in October 1988) and 30 km/hr (in November 1991), respectively.

4.2.2 Bulyanhulu

As part of environmental baseline data collection a multi-functional meteorological station was installed at the Bulyanhulu exploration camp in early February 1997. Plates 4-1 and 4-2 show the mast with climate monitoring instruments attached in the camp, and other sensors adjacent to the mast on the ground, respectively. Parameters monitored included:

PARAMETER	SAMPLING INTERVAL
Wind velocity	2 minutes
Wind direction	2 minutes
Precipitation	1 hour accumulation
Temperature	5 minutes (1 hour average)
Relative humidity	5 minutes (1 hour average)
Total irradiation	5 minutes

The wind sensor was set at 15 m height, 10 m above the tallest building within 30 meters, thus minimising the influence of turbulence from buildings. In response to a concern expressed by the Meteorology Department, all building heights near the meteorology tower were measured and plotted on a location map of the exploration camp. A copy of the map was provided to the Meteorology Department and, following constructive dialogue, acceptance of the location was received from the Department.

The automated station sensors log data at appropriate intervals to a multi-channel data logger. At the time of installation of the equipment, camp staff were trained to down load the data logger. Down loaded data was compiled and evaluated monthly to ensure data integrity and quality. Approximately a full year of data (i.e., February 9, 1997 to January 30, 1998) has been compiled to date (given in Appendix 4-1), and is summarised as monthly values in Table 4-6.

In general, the data collection with the data logger was successful for the entire period. Exceptions were as follows: 1) wind direction and wind speed after November 3, 1997 (sensor malfunction); 2) temperature data between September 19 and October 2, 1997 was inaccurate; and 3) rainfall data were missing between May 11 and May 31. The data gaps are assumed to be due to unsuccessful down loading, sensor malfunctions or data logger malfunction.

4.2.2.1 Temperature

The February 9, 1997 to January 30, 1998 temperature readings indicate a uniformity of both temperature extremes and monthly mean temperatures (Table 4-6 and Figure 4-1). Mean monthly temperatures ranged from 20.7 °C in December to a high of 24.9 °C in September (although there were only 19 days of record for September). Daily temperatures ranged from between 13 °C in June and July to 34 °C in September and October. In general, the range of temperatures was greatest from June through October (16 °C to 18 °C differences), and the least during December and January (13 °C and 14 °C differences). These seasonal temperatures and temperature ranges are consistent with a subtropical climate and those measured at the Shinyananga station between 1987 and 1996.

4.2.2.2 Rainfall

The rainfall data collected between February 9, 1997 and January 30, 1998, indicate an unusually wet year (Table 4-6). A total of 1145 mm was recorded compared to the 10-year Shinyanga mean of 820 to 850 (depending on how the mean is calculated to account for missing data). In addition, there were 29 days missing.from the full year of record (February 1 to 8, 1997, and May 11 to May 31, 1997). If rainfall totals are added to account for the missing days, based on prorating the means to the 10-year Shinyanga annual mean, then approximately 1226 mm of rainfall is predicted. This is approximately 1.4 to 1.5 times the Shinyanga mean. Thus, either 1997/98 was an exceptionally wet year or more rainfall normally occurs at Bulyanhulu, or both.

In addition, during the past year, the dry season was short-lived and atypical, in that it was broken up by 35.8 mm of rain in August. The most rainfall occurred during December (268.6 mm).

4.2.2.3 Wind

Mean wind speeds measured from February 9 to November 3, 1997 demonstrated significant variations between the typical dry (May to October) and wet (February to April) seasons (no wind data was collected from November 4, 1997 to January 29, 1998). Winds during the dry season blew to the southeast, with less directional variation and far greater frequency than winds recorded during the wet season (Figures 4-2 and 4-3). Monitoring through the wet season indicated a dominant southerly wind direction, but with fluctuations between the west and east-southeast.

Frequency data for wind speed and wind direction for Bulyanhulu are summarised in Tables 4-7 and 4-8. Wind speed is graphically represented in Figures 4-4 (May-October, 1997) and 4-5 (February-April, 1997). Wind speeds during the dry season ranged between 0.0 and 5.0 km/hr for 44% of the monitoring period, from 5.1 to 10.0 km/hr for 45% of the period, and between 10.1 and 15.0 km/hr for 10.6% of the period. Winds blew between 15.1 and 20.0 km/hr for only 0.4% of the total monitoring period. The maximum recorded wind speed of 18.9 km/hr occurred on October 4, 1997. The distribution of wind speeds during the wet season shifted to favour lower speeds, with 60% of winds measured during the monitoring period blowing between 0.0 and 5.0 km/hr. Speeds from 5.1 to 10.0 km/hr were detected 35% of the period, and 5% of the monitoring period, winds were gusting between 10.1 and 15.0 km/hr. Speeds of 20.0 km/hr and over were not recorded at any time over the monitoring period.

4.2.2.4 Air Quality

There are no significant air pollution sources at the site at this time. Air contaminants directly attributable to exploration activities are predominantly dust and exhaust fumes from vehicles, and are minor.

The primary concern during mine operation will be dust, as this will represent most of the particulate loading to ambient air. To document baseline (pre-mining) conditions, four dust fall canisters were located on the four sides of the 1 by 1.5 km project compound at its perimeter fence, corresponding to north, south, east and west locations on the property. Plate 4-3 shows a dust fall monitoring station. Dust fall measurements were made at the Bulyanhulu site between June 1997 and January 1998. This monitoring period covers most of the dry season (May to October) and the winter rainy season (November to January). Dust fall results are given in Table 4-9. Laboratory certificates are given in Appendix 4-2.

Total particulates ranged from 0.66 $mg/dm^2/day$ (Station N, December-January) to 6.83 $mg/dm^2/day$ (Station W, July-August). The median dustfall value for all data was 1.42 $mg/dm^2/day$. The highest monthly median value was reported during the October-November monitoring period (3.06 $mg/dm^2/day$). This time of year corresponds to the approximate end of the dry season.

Station E reported the highest overall median particulate concentration (2.48 $mg/dm^2/day$) and the highest particulate concentrations in three of four measurement periods. The reason for this is not clear.

Dust fall objectives are not available for Tanzania. Current dust fall objectives for British Columbia, Canada, are 1.7 $mg/dm^2/day$ to 2.9 $mg/dm^2/day$. With one exception, station and monthly dust fall medians fall below or within these objectives; individual measurements exceed the higher objective in 5 of 19 measurements. However, ambient conditions in this semi-arid region are likely characterised by higher dust concentrations than those found in British Columbia.

4.3 SURFICIAL GEOLOGY

The surficial geology of the project site is relatively simple, comprising an upper zone of transported soils overlying residual soils. In areas of high ground, the upper transported unit comprises slightly clayey, silty sands and organic topsoil, and is typically less than 1 m thick. In the low lying mbuga areas, the upper transported layer is typically replaced by expansive silty clays which are thought to be in the order of 1 to 1.5 m thick. The residual soils which underlie the transported unit have been subjected to weathering and laterization. Little laterization appears to have taken place in the vicinity of the mbugas.

The term "laterites" is used to describe all soils affected by the laterization process, and hence covers a wide variation of soil types. Laterization occurs only in tropical or subtropical environments, and involves the chemical and physico-chemical alteration and/or transformation of primary rock-forming minerals into materials rich mainly in 1:1 lattice clay minerals and laterite constituents (Fe, Al, Ti and Mn). The hydraulic conductivity of *in situ* laterite is typically 1×10^{-3} cm/s.

The three major stages of the laterization process are as follows:

- The first stage is characterised by physico-chemical breakdown of primary minerals and release of constituent elements;
- The second stage (laterization) involves leaching of combined silica and bases and relative accumulation or enrichment from outside sources of oxides and hydroxides;
- The third stage (dehydration or desiccation) involves partial or complete dehydration (sometimes involving hardening) of the sesquioxide rich minerals and secondary minerals. During the rainy season, water saturated horizons form and water flow is lateral or downward. During the dry season, there is intense desiccation of the surface horizons, resulting in upward flow and capillary rise of water which transports iron. This results in continual enrichment of the laterite crust, and the gradual cementation of the upper soil zone. Zones very close to surface are often very rich in iron and through intense desiccation have cemented to almost rock-like consistency (ironstone or ferricrete).

4.4 SURFACE WATER

4.4.1 Background

Expanding on a preliminary program initiated by KMCL in 1996, a preliminary surface water assessment of the Bulyanhulu River was undertaken in early 1997 by the Institute of Hydrology (IOH), under sub-contract to Norecol, Dames & Moore (NDM). The primary objective of that assessment was to provide semi-quantitative assessment of the potential to obtain a reliable water supply from the surface water system in the area around the site. In addition, the assessment provided useful hydrological background information for this baseline, including:

- hydrological data relating to the Bulyanhulu catchment upstream and downstream of the site;
- a characterisation of the main surface water channels;
- a description of the hydraulic characteristics of channels;
- the identification of controls/restrictions on water flows and areas subject to temporary flooding; and
- an assessment of the Upper Magogo River watershed, which is a useful reference catchment for the Bulyanhulu River Watershed because of its comparable size and location.

Reference Catchment: Magogo River Watershed

One of nearest gauged catchments, comparable size to the Bulyanhulu River watershed, is the Magogo River watershed, located approximately 150 km to the east. The river exhibits ,an ephemeral flow regime typical of this area (i.e., the flow of the river responds primarily to rainfall and less so to groundwater, so that during dry periods there is no baseflow). There was a gauging station on the Upper Magogo River at Ngudu from 1968 to 1986. The catchment area at Ngudu is nearly 300 km^2, compared to the approximate catchment area of the Bulyanhulu River at the KMCL monitoring station H2 (see Figure 4-6) of 294 km^2. Thus, the flow data from the Upper Magogo River at Ngudu provides a database to help estimate of the flow of the Bulyanhulu River at H2, given the assumption of similar physical and climatic characteristics between the two catchments.

The Upper Magogo River's 18-year (1968/69-1985/86) mean annual runoff was 23.34 Mm^3/yr or 0.74 m^3/s, and ranged from 0.0 (in 1975/76) to a maximum of 1.51 m^3/s in 1985/86 (Table 4-10). According to the Ministry of Water, Energy and Minerals (MAJI, 1995), a typical mean annual runoff for this part of Tanzania should be approximately 0.6 m^3/s. In addition, the ephemeral pattern of the annual flow regime means that for the 3 to 5 month dry season, there may be no flow in the river. Examination of the Upper Magogo mean monthly flow data indicated that river flows were absent for 18 months during a drought beginning in May 1975 and ending in November 1977.

Using the 1985-86 Shinyanga precipitation total of 1038.5 mm, and the total 1985/86 runoff from the Upper Magogo, runoff for the Upper Magogo River for 1985/86 was 14.1% of rainfall (assuming a 326 km^2 catchment). The wettest rainy season of the ten-year record (1985-1994) at Shinyanga (see Section 4.4.2) was 1985-86. Although there is only one year of overlap between the Shinyanga meteorology station and the Upper Magogo gauging station to establish a runoff percentage for the area, the calculated runoff percentage is a useful yardstick for estimating runoff during a wet year in the Bulyanhulu River watershed.

4.4.2 Bulyanhulu 1997/98 Surface Water Data Collection Program

Prior to the inception of the 1997 baseline surface water data collection program, there were no data on flows in the Bulyanhulu River. Thus, the initial objectives of the program were to:

- establish baseline water quality and streamflow conditions along the Bulyanhulu River upstream (H1), downstream (H3) and at the proposed mine site (H2) (see Figure 4-7);
- establish a continuous-recording streamflow monitoring station at H2; and,
- develop a streamflow database and information for the water management plan.

Plates 4-4, 4-5 and 4-6 show the H1, H2 and H3 gauging stations, respectively.

Methods

On February 8, 1997, three baseline gauging stations (H1, H2 and H3) were established. Streamflow data were collected by personnel from NDM, Water & Environment (T) Ltd. (WEGS, based in Arusha, Tanzania) and KMCL. KMCL personnel were instructed on how to measure discharge and collect stage data over the next year. An approximate 2.5 metre staff gauge was installed at H2. Discharge measurements were made using standard accepted practices, and staff gauge data were collected. Flow velocities were measured with a pygmy meter at low flows and a Price AA meter at the higher flows.

On February 9, 1997, a continuous-recording data logger connected to a pressure transducer was installed at H2 and set-up to record stage data every 30 minutes. Electronic stage data were calibrated to the staff gauge. The data logger was down loaded every one to two months by personnel from KMCL or WEGS. In addition, for back-up, the staff gauge was read one to two times a week.

On March 17, 1997, the gauge location at station H2 had to be moved due to downstream damming activities (related to artisinal mining) which presumably began to back water up into the gauge location as early as March 4, 1997, and make the electronic stage data invalid. Thus, the stage data for several weeks prior to March 17 could not be used. Two discharge measurements (at similar flow magnitudes) had been made prior to the ponding. Thus, the stage data from February 9, 1997 to the beginning of March was not well calibrated.

The data collected between May 10 and July 16 could not be successfully retrieved, due to problems with down loading. However, staff data collected once or twice a week are available for this period.

All hydrologic data for the Bulyanhulu monitoring station are given in Appendix 4-3.

Bulyanhulu River Discharge Measurements

Table 4-11 summarises discharge measurements and other hydraulic geometry data for station H2. Discharges were measured at ten separate occurrences. The March 4 readings were affected by the downstream dam, so are not meaningful. In general, recorded discharges ranged from a low of 0.19 m^3/s on February 8, 1997, to a high of 7.24 m^3/s on November 28, 1997. Stage data for these discharge data ranged from 0.20 to 0.80 metres. Stage data for the February measurements were comparatively higher for a similar flow, and suggest that the stage data for February need to be adjusted down to match the rest of the stage data.

Composite (manual and electronic) and adjusted (for changed locations and channel aggradation) Bulyanhulu River H2 stage data for the period of record, from February 9, 1997 through January 29, 1998, are plotted on Figure 4-8. In general, the stage hydrograph indicates that from February through April, water levels were relatively low, and increased slightly a few times in early March and April. During early May, water levels more than doubled and then remained high for the entire month, including two significant peaks to around 1.5 metres. A steady decline occurred throughout June and July, and no flow was recorded for about a week in mid-August and again throughout most of September. Stage and thus Flow did not increase appreciably until mid-November, when it remained relatively high (> 1.0 metres) throughout the remainder of the record (to January 29, 1998). The highest stages (> 2.0 metres) were recorded three times in December and once in January.

Station H2 Stage-Discharge Rating Curve

From the continuous stage data and the point discharge measurements a continuous discharge hydrograph was developed. However, the following difficulties were encountered:

- The maximum measured discharge was at a stage of 0.80 metres. There are no high end discharge measurements for most of the wet season.
- With only two data points in February, measured at relatively low and similar discharges, the rating curve for the period February 9 to March 1 is not well calibrated. The slope of the rating curve for this period was assumed to be the same as for the subsequent location, while the y-intercept was adjusted to match rated discharges at equivalent flows.
- On November 28, 1997, when discharge measurements were made, sediment was observed to have aggraded approximately 0.1 metres at the gauge location. The previous discharge measurement was made on August 18. Therefore, the stage-discharge rating between August 18 and November 28 would be affected to a small extent.

For stage heights from 0.0 to 0.80 the following stage-discharge curve (log-normal linear regression) was used: $\log Q = 2.03H - 0.75$ ($r^2 = 0.93$) (Figure 4-9). This curve could not be used for higher discharge values as it would have predicted unreasonably high discharges for the maximum observed stages in December and January, and total annual runoff of twice the annual rainfall. Also, for stages higher than 0.80, adjustments to this line had to be made to account for discharges at upper stage values increasing at a lower rate (i.e., the slope of the stage-discharge rating curve flattens). This is due to the decrease in average channel velocity that occurs when water overflows the channel and slows due to the increased roughness from vegetation. Furthermore, at station H2, average velocities will also have proportionately decreased at high flows because of the damming effect of a clump of trees just downstream of the gauging station.

The stage-discharge curve was adjusted based on the above limitations and the runoff and rainfall data from the Upper Magogo that follows. The 1984/85 streamflow data at the Upper Magogo and the precipitation recorded at Shinyanga were similar to the 1997/98 stage and rainfall data recorded at Bulyanhulu (the 1997 data for the Upper Magogo was not available at this time). They were both unusually wet years. In addition, the rainfall recorded at Bulyanhulu was at least 10% greater than Shinyanga (even though 29 days of record were missing during the wet season), and the Bulyanhulu River was likely at a much higher stage for a longer period (i.e., the Bulyanhulu had only about one total month of zero discharge in 1997/98, whereas, the Upper Magogo had three months of zero discharge in 1984/85). Thus, 1997/98 runoff for the Bulyanhulu River had to be somewhat greater than 1984/85 (14%) for the Upper Magogo River. The initial rating curve (regression line) was then iteratively adjusted (slope decreased and y-intercept increased) by simulating decreasing runoff (from 200% to 24%) until the discharge data were realistic. Thus, the resultant simulated hydrograph yields a reasonable total annual runoff and at the same time accounts for the affects of the different channel conditions at high stage.

Bulyanhulu River Hydrograph

Based on the composited staff gauge data and the regression simulations, a hydrograph covering the period February 9, 1997 to January 29, 1998 was developed for the Bulyanhulu River at H2 (Figure 4-10). The hydrograph shows the effect of the wet and dry seasons, and predicts a total volume of flow for the period of record of 84.1 Mm^3. This equated to a mean annual runoff of

2.74 m^3/s (or approximately 3.6 times greater than the mean annual runoff of the Upper Magogo River watershed). However, it is important to note that 1997 was likely a very wet year so that the estimated maximum discharges and estimated total runoff for 1997 may be significantly higher than average.

The predicted discharges ranged from no flow during periods in August and September to maximums of greater than 13.0 m^3/s in December and January. The estimated highest mean monthly flow of 9.44 m^3/s was in December 1997, and the maximum discharge of 15.71 m^3/s occurred on December 15, 1997. Although values for the high flows are not well established, the predicted values are within a reasonable magnitude. As data are still being collected, the hydrograph will be improved with higher-stage discharge measurements.

4.5 HYDROGEOLOGY

4.5.1 Introduction

The present hydrogeology of the Bulyanhulu KMCL prospecting license (PL) has been assessed and described using information gained from a variety of reference sources and field investigations. Field work was performed as an integral part of the water resources investigation and development scheme, directed and co-ordinated by Dames & Moore, and supervised by WEGS. A complete list of data sources is contained in the Section 4.15, References.

The purpose of this baseline review is to outline the existing hydrogeological setting, groundwater levels and flow regime of the Bulyanhulu Concession.

4.5.2 Geology

A detailed description of the baseline geological conditions is given in Sections 2.1 (Geology and Reserves) and 4.3 (Surficial Geology). The key aspects of the geology relevant to the site hydrogeology are summarised below.

Ferruginous and highly cemented laterite commonly occurs at shallow depths, interstratified with ferruginous clayey soils and sporadic sand/silt deposits. Below the laterite in the concession area, the thickness of the 'oxidised' saprolite (weathered zone developed at the surface of these volcanic rocks) is highly variable, between 26 to 90 m. Below the saprolite zone and associated with the main orebodies is unoxidised greenstone bedrock. The Bulyanhulu Concession active mining area is developed in the fresh bedrock, within a siliceous quartzose zone within the volcanic sequence of lavas, with minor pyroclastics (tuffs) and graphitic horizons.

The greenstone rocks are bounded by granitic rocks which occur some 2 km southwest and up to 8 km north-northeast of the mine airstrip, where they form prominent hill outcrops. The granites weather to coarse, quartzose sands at surface.

4.5.3 Groundwater Occurrence

4.5.3.1 Aquifer Types

The hydrogeology of the KMCL concession area is dominated by two major and one minor aquifer types. Figure 4-11 is an illustration of the locations of the main aquifers. The two main aquifers are:

- **Shallow Laterite Aquifer**: a shallow aquifer, typically between 5-20 m depth, in lateritic soils and silts, probably perched upon cemented laterite; and,
- **Weathered Saprolite Aquifer**: a deep aquifer controlled by fissure flow, typically between 26 and 90 m depth, developed in the weathered saprolite (or oxidised) zone in voids, discrete fissures and fractures.

The shallow, surface aquifer is comprised of predominantly laterites, which is composed of altered minerals and soils forming leached clays and silts which exhibit negligible intergranular permeability. The majority of groundwater flow is associated with localised shallow sand or gravel layers (<5 m below ground level (bgl)), and fissures within the lower hard, leached clay horizons. The fissured zones create localised pathways of higher permeability.

Below the laterites the 'oxidised' zone is defined as a zone in which groundwater circulates and therefore generally defines the base of the weathered saprolite aquifer. The saprolite is a fragmented, weathered residual rock mass, with solution-enlargement of faults, joints and shears, and solution loss of original mineral fabrics. The saprolite is clearly defined and identified by the presence of heavily iron-stained joints and fractures, which are absent in the underlying 'fresh' bedrock.

Underlying the shallow major aquifers is the unweathered, fresh bedrock, which although of low permeability can be considered as a minor aquifer. The bedrock is comprised of basement rock which is, fresh, unweathered of predominantly greenstone, with diabase and andesites from approximately below 75 to 100 m.

The main orebody mineralisation is located within the fresh bedrock, associated with tectonic faulting and fractures. The orebody mineralisation is concentrated along northwest to southeast trending fractures. These have the potential for providing conduits for groundwater flow. However, the bedrock can generally be described as 'massive' with only isolated fracture zones which appear to be poorly connected. Rotary core exploration boreholes identified isolated fractures within the bedrock at varying depths up to 1,000 m, with associated iron staining and infilling. It should be noted that no packer test information is available to quantify the potential flow along such fractures.

4.5.3.2 Aquifer Characteristics

<u>Laterite Aquifer</u>

The water resources investigation included the drilling and hydraulic testing of two production wells and two piezometers in the laterite aquifer adjacent to the Bariadi area, including the long term pump testing (5 days duration) of borehole 109. The results of the pumping tests have been analysed using a variety of standard hydrogeological analytical techniques including Theis, Cooper-Jacob and Neumann to determine aquifer transmissivity and storage characteristics. Table 4-12 contains a summary of the hydraulic testing results.

The transmissivity of the laterite aquifer measured in the vicinity of borehole 109 and the Bariadi, is estimated to vary from 154 m^2/day to 336 m^2/d, with hydraulic conductivity values of 14 m/d to 60 m/d. Aquifer storage has been estimated from the observation well curve for borehole 110 which indicates a value of 0.0173 (1.73×10^{-3}). This value is considered to be representative of a leaky confined aquifer, being one to two orders of magnitude higher than for an unconfined aquifer. It was noted during the testing of 109 that the determined transmissivity of borehole 110 was significantly higher than 109, although the yield from 110 during drilling was significantly lower. This behaviour is typical of an aquifer dominated by fracture flow. It was also noted that the analysis of the test data confirmed the absence of late time boundary effects and the presence of a relatively uniform aquifer.

The values of transmissivity derived from the analyses are higher than would be expected in the generally low permeability laterite aquifer. Away from borehole 109, the fissured aquifer would appear to be uniformly connected. The presence of a major fissure was indicated from the results of the drilling of boreholes 109 and 110, although no cores have been obtained.

<u>Saprolite Aquifer</u>

The weathered saprolite aquifer is dominated by fissure flow, and is a confined aquifer with low storage. In contrast to clastic sedimentary rocks (e.g. sandstones) with high porosity and storage, the effective porosity (connected void space) in saprolite aquifers is low, generally less than 1 percent of the rock volume. As a result, since groundwater flow paths are controlled by the interconnections, aquifer properties are generally non-uniform and show a high level of heterogeneity.

The water resources investigation also included the drilling and hydraulic testing of nine production wells and two piezometers in the saprolite, including the long-term pump testing of two further wells. The results of the pumping tests were analysed using similar methods as to the laterite aquifer. Table 4-12 also contains a summary of the hydraulic testing results for the deeper aquifer.

Using the test data, the transmissivity of the saprolite aquifer is estimated to vary from 1 m^2/day to 5 m^2/day, with hydraulic conductivity values of 0.05 m/d to 0.2 m/d. The estimate of aquifer storage is typical of a confined aquifer. The calculated values for transmissivity and hydraulic conductivity are generally two orders of magnitude lower than for the fissured laterite aquifer due principally to the increased depth, infilling of fissures and fractures by weathering products such as clay and iron staining, and poorer interconnection of water-bearing fractures. The calculated values are generally within the average range for saprolite type aquifers.

The pumping test data for the wells constructed in the saprolite aquifer, indicated a high level of heterogeneity in aquifer properties. These variations are typical of a fissured aquifer, whose flow geometry is often controlled by the complex connections. The indication of various flow zones is coincident with the different levels of water strikes observed during drilling.

The variation in the distribution of storage has been assessed from the analysis of the recorded water level responses to seasonal rainfall. The cumulative rainfall over an assumed 23 km^2 catchment area for the period November and December 1997, was recorded as approximately 500 mm. Approximately 11.5 million (M) m^3 of rainfall was available for surface run-off, evaporation and aquifer recharge. Long term monitoring of evaporation and surface run-off characteristics indicates averages for the period of 450 mm for evaporation, and 0.002 $m^3/s/km^2$ for surface run-off. Taking these factors into account over the catchment area, it is calculated that approximately 0.9 Mm^3 is available for aquifer recharge, equating to a water depth of 0.04 m.

The water level monitoring data over this period shows increases in groundwater levels of between 2 and 5 m. When related to the variation in water levels, the storage of the saprolite aquifer is calculated to be between 0.007 and 0.013. This is in general agreement with the calculated storage figures from the test pumping. It is also indicated from the variable well responses to recharge that the saprolite storage is higher at shallower depths, as expected.

Unweathered Greenstone Bedrock Aquifer

Within the greenstone bedrock, hydraulically conductive zones only occur where open fissures or shear zones are encountered. The only available hydraulic testing data on the greenstone aquifer was obtained from packer testing on the KMCL-385 shaft centre borehole. A test section between 100.9 m and 970.25 m below ground level (bgl) produced a value of permeability of 2.15×10^{-10} m/s, with a bulk transmissivity of 1.9×10^{-7} m^2/s.

Observations from rotary core drilling, and during the construction of the initial box cut and entry portal, confirm that the permeability of the unweathered bedrock is low. Groundwater inflows encountered during excavation only occurred where discrete, open fractures were found. In the situations where groundwater was encountered in the greenstone/diabase bedrock, the volumes and flow rates observed were initially high followed by a rapid reduction. The characteristics are typical of an aquifer that exhibits a low level of hydraulic connectivity.

4.5.3.3 Aquifer Recharge

Aquifer recharge is controlled by the relationship between precipitation/rainfall, surface run-off, evapotranspiration and deep regional inflow. Bulyanhulu lies within a semi-arid zone with average annual precipitation of 800 mm, and average annual evaporation of 2,000 mm (i.e. a net loss of 1,200 mm per year). Recharge to the aquifer is limited to the 'wet' season (November to

January, March and April) when precipitation is at its highest, and evaporation is at its lowest. Based on initial estimates of potential recharge during the November 1997 to January 1998 'wet' season, maximum annual recharge to the saprolite and laterite aquifer over the 23 km^2 catchment area of the concession is likely to be in the region of 1.5 to 2 Mm^3. This estimated figure does not take into account possible minor sources, such as lateral migration from 'off-site', or loss from the Bulyanhulu River.

In summary, recharge to the various aquifers is considered to occur through a combination of two main routes:

- direct rainfall and infiltration through surface soils; and,
- lateral migration of groundwater from bedrock outcrops at the margin of the groundwater catchment area.

Laterite Aquifer

Recharge to the shallow zone laterite is controlled by direct rainfall and surface run-off to the Bariadi area with subsequent infiltration through the soil surface. The rapid responses of wells 109 and 110 to rainfall, and the co-incidence of well water levels at surface with surface flooding of the Bariadi, suggest the strong link between surface water in the Bariadi and shallow groundwater in the laterite. The short delay (less than 1 week) between rainfall events and changes in water level, confirms the proximity of the recharge area, and sensitivity of the laterite groundwater reservoir to seasonal rainfall. Figure 4-12 shows a schematic illustration of the inferred groundwater recharge mechanism in the Bariadi laterite aquifer.

It is considered likely that elsewhere across the site, where fissures are developed in the laterite, recharge will be by a similar mechanism of surface infiltration and rapid movement of groundwater from the recharge area via the fissures.

Saprolite Aquifer

The mechanism of recharge to the saprolite is considered to be both directly by infiltration through the weathered profile, and more limited lateral flow from the margins of outcrop. In addition the several hundred boreholes previously drilled for mineral exploration may provide potential short circuits for the vertical movement of shallow groundwater and recharge into the saprolite.

It was noted that vertical infiltration of recharge through the superficial deposits to the saprolite, except for seepage of water perched upon laterite, was not observed in the mine box cut where the weathered profile was dry to over 30 m depth. However, the recorded responses of groundwater levels in the aquifer to rainfall, and the time period between the on-set of the 'wet' season and water level rises, confirms the presence of local recharge sources and short flowpaths.

4.5.3.4 Regional Groundwater Flow

Regional groundwater flow systems in basement aquifers such as the area around Bulyanhulu are generally complex, because of:

- significant irregularities in the thickness and properties of the laterite and saprolite aquifers; and,
- local strong structural and geological controls on water table/aquifer.

Construction of regional hydrogeological maps showing groundwater head variations for the laterite and saprolite aquifers is difficult due to the nature of the aquifers, the limited availability of borehole data, and the hydraulic disturbance induced by the present mining and water abstraction. However, Figures 4-13 and 4-14 present conceptual models of the current, inferred regional groundwater flow system, including the groundwater flow regime in the saprolite aquifer in the area of the concession. A schematic groundwater contour plan is presented in Figure 4-15. It is not possible to determine the baseline groundwater conditions prior to any site development due to the absence of hydrogeological data and the continual abstraction for exploration activities since at least 1994. It is considered that, based on water levels outside the 'dewatered' area, pre-existing rest water levels may have been between 10 and 15 m bgl. Figure 4-16 contains a possible representation of the estimated drawdown of current groundwater heads across the concession area.

On the regional scale, the groundwater flow regime is comprised of a combination of shallow groundwater in the more permeable laterite and saprolite aquifers, and the deeper greenstone bedrock. The laterite and saprolite aquifers are recharged by infiltration from rainfall and surface water from rivers. Groundwater heads within the concession area mimic the topography, with discharge to surface water bodies at lower elevations. The deeper, low permeability greenstone bedrock is expected to be recharged by the granitic outcrops at the margins of the regional catchment area creating deep, but very limited groundwater flow discharging vertically upwards in the area of the Concession. The potential is also present for localised vertical leakage from the shallow saprolite into the underlying greenstone.

The localised drawdown created by current mine abstraction has altered the flow regime in the saprolite in the area of the mine, which in conjunction with the local variations in the aquifers creates a complex local flow regime.

<u>*Bariadi Laterite Aquifer*</u>

A significant laterite aquifer has only been identified in the area of the Bariadi swamp. The groundwater levels observed in the laterite in the adjacent wells (109 and 110) are within 5 m of ground level, and during recharge periods (i.e. 'wet' seasons) recover to approximately ground level. After prolonged rainfall, the groundwater levels are generally coincident with surface water levels in the Bariadi Swamp. Groundwater flow in this area will be controlled by surface water levels with the direction of the main volume of recharge changing emphasis between 'wet' and 'dry' seasons. A schematic representation of the recharge mechanism is shown in Figure 4-12.

Recharge into the immediate area is from two sources:

- a deeper saprolite groundwater discharge from the west, driven by the fall in topography; and,
- shallow groundwater and surface water in the Bariadi area to the east.

During 'wet' seasons, the Bariadi area is observed to flood providing a significant source of recharge and flow. If abstractions are undertaken from the wells in this area, an hydraulic gradient will be induced which will draw water directly from the Bariadi.

The inferred groundwater heads for the saprolite aquifer, shown in Figures 4-15 and 4-16, illustrate the significant current influence of the long-term groundwater abstraction from the area around the exploration camp and the box cut ramp. It is reported that groundwater abstraction for domestic supply has been ongoing in this area since approximately 1995, prior to the excavation of the current mine access and ramp. As a result a 'cone of depression' and lowering of the water table over the concession area for a radius of approximately 2.5 to 3 km from the box-cut has developed. As a consequence the natural, groundwater flow direction has been significantly altered inducing a radial flow regime towards the excavation.

Construction Camp & Operational Town-site Areas

The surface elevation in the vicinity of the current exploration camp is in the region of 1196 m above sea level (asl). The abstraction of groundwater and excavation of the box-cut in the vicinity of the construction camp since 1994 has significantly altered the baseline groundwater flow regime in the immediate area. It was reported that the water level in one of the camp abstraction wells, No. 3, was 98 m bgl in October 1997, a water level in the region of 1100 m. Based on an estimated initial rest water level of approximately 20 m bgl, the abstraction drawdown was in the region of 70 to 80m, lowering the water table below the base of the saprolite and locally dewatering the greenstone. Since October 1997, the pump has been removed and installed in an adjacent borehole, No.1 (see Figure 2-14), and the water level has recovered in No.3 to 33.73 m bgl, 1162 m asl (March 1998).

One other of the 6 camp wells, No. 6, was monitored with a water level of 46.33 mbgl (1145 m above datum (AD)). It is currently not possible to record the pumping water level in the two abstraction wells due to rising main and electrical cabling. However, it is estimated that the operating levels are likely to be in the region of 1130 m AD, a drawdown of approximately 60 m, based on the operating abstraction rate of 4.5 m^3/hr and permeability data for the saprolite aquifer.

The variability of groundwater levels in the immediate area of the camp site, the box-cut and the main orebody is indicative of the significant control over transmissivity by the thickness of the saprolite aquifer, and the lateral heterogeneity of the fractured saprolite aquifer. It is known from exploration drilling records that the thickness of the saprolite varies significantly from approximately 30 m at the box-cut portal to 65 to 80 m above the main orebody, less than 100 m distant. Therefore a reduction in saprolite thickness will produce a significant reduction in aquifer transmissivity and groundwater flow without a reduction in permeability.

As shown in Figure 4-14, the saprolite to the southwest of the box-cut has restricted continuity and reduced lateral flow above the main reef and the area of the operational town-site as a result of the area of reduced thickness and transmissivity. It is therefore possible to produce the localised, steep hydraulic gradients observed between boreholes 3 and 6 (a head difference of 17 m over < 200 m), and to the surrounding water resources boreholes 104 and 112, from localised low transmissivity areas and limited saturated thickness of saprolite. It is considered that the local elevated head of approximately 1162 m AD may also be related to groundwater flowing across the base of the saprolite, with the saprolite having been dewatered above this level.

The area from the box-cut towards the operational town-site is considered to be more homogeneous and of higher transmissivity, with a saprolite thickness in the region of 50 to 60 m. This has created a broad, flatter cone of depression, with a groundwater flow direction southwards from the operational site towards the box-cut area. As such, the thicker saprolite aquifer is acting as a significant recharge source area for groundwater abstracted from the reef wells.

Kakola Village

The location of well 106 and Kakola Village are considered to be on the edge of the radius of influence from the current groundwater abstractions at the camp site. Therefore, the flow direction towards the Bulyanhulu River is considered representative of the pre-exploration flow regime, with recharge on the central area, creating radial flow to the south, and north to the Bulyanhulu River. The distribution of the groundwater head contours and the wider spacing also confirms the higher permeability in this area in comparison to the central area.

In the area of Kakola (Figure 4-15), there appears to be a groundwater 'ridge'. Hydraulic heads indicate groundwater flow northwards from well 106 to 107 (an angle oblique to the fall in topography which is northwestwards), and southwards towards the Bariadi.

The groundwater flow regime to the southwest of the box-cut, towards Kakola Village is also affected by the long term abstraction at the site creating drawdown of water levels in certain wells. Using the data obtained from the analyses of pumping tests on the groundwater abstraction wells, and the current pumping rate from the camp site boreholes, it was possible to calculate the required transmissivity to produce an estimated drawdown of 20 m in the water level in borehole 104. The calculated figure of approximately 2 m^2/d is co-incident with the test data, and tends to confirm the potential, inferred extent of the 'cone of depression' produced by groundwater abstraction at the exploration camp site.

It is considered that well 104, as evident in the pumping test analyses, is associated with another low permeability zone located between Kakola and the Construction Camp. Two boreholes, 102 and 103, were drilled on the southwestern end of the air strip, approximately 1 km west of well 104. During drilling a dioritic vertical intrusion was encountered in this area, indicated (from geophysical surveys) as running parallel to the orientation of the reef ore-bodies. The saprolite aquifer was poorly developed in this area, less than 20 m in thickness, with the boreholes recorded as dry during and on completion of drilling. It is evident from drilling observations and the steeper gradient of groundwater head contours in this area that the dioritic intrusion creates a low permeability zone between Kakola Village and the box-cut. It is expected that additional geological intrusions, such as other mineralised 'reefs' may be present, creating low permeability zones, and affecting the larger scale hydrogeological flow regime.

In the concession area, groundwater discharge occurs in spring lines and on valley margins at the boundary with mguba clay soil, and potentially as limited baseflow to the Bariadi or Bulyanhulu River when the water table has intersected their beds (resulting from groundwater recharge during wet periods increasing water levels). However, due to the general lowering of the water table in the saprolite across the concession, base flow to the rivers is likely to be insignificant from the saprolite. It is known from local shallow village supplies that surface water does interact with surface sand soils with very localised perched water tables (<5 m bgl).

4.5.4 Existing Groundwater Supplies

4.5.4.1 Existing Borehole Data

Existing regional borehole data for the Shinyanga and Mwanza Regions, and local well data for the main aquifers, the laterites and the saprolite, is generally of poor quality, lacking measured hydrogeological parameters. The data are invariably derived from boreholes drilled for rural water supply, where it is simply necessary to establish a (low) yield suitable for handpumps, of the order of 0.2 l/s or 0.72 m^3/h. Only seldom has the hydraulic performance of the borehole been adequately tested by means of standard pumping tests. Borehole yields quoted are often based on a driller estimate of water blown during airlift drilling or purging after drilling. In addition, groundwater monitoring data in terms of groundwater heads or levels are rarely recorded.

The most reliable and comprehensive existing borehole data source used in the baseline assessment has been collected and analysed from the Dames & Moore water resources investigation, and wells constructed by KMCL and Skanska for local water supply. Table 4-13 contains a summary of the existing borehole information. The data collected on existing village supplies and shallow wells has been obtained from the WEGS Village Water Supplies baseline report.

4.5.4.2 The KMCL Concession

As indicated in Table 4-12 and section 4.5.3.2, as part of the Dames & Moore water resources investigation a total of 17 boreholes (101 to 117) have been drilled in the KMCL concession area within the shallow laterites (5-20 m), and within the deeper weathered saprolite (26-98 m). Previous drilling investigations in the KMCL camp area included 8 other boreholes drilled in weathered saprolite for domestic and exploration drilling rig supply. Figure 2-14 contains a location plan for the constructed wells.

The KMCL camp well is reported to yield between 3.5-4 m^3/h. Although this supply is desalinated with ion exchange resin equipment, the natural ground water is potable with moderate conductivity (730 µS/cm), and apparently free from bacteriological contamination. The pumping water level in the camp well from the above abstraction rate was reported to be approximately 98 m below ground level (m bgl) before the borehole ceased abstraction. This level is indicated to be below the base of the saprolite aquifer, and was considered to be the result of existing over-abstraction from the camp well, dewatering the aquifer in the immediate vicinity of the well. Although the pumping water level was reported to below the base of the saprolite, the saprolite was the predominant source of the abstracted groundwater.

Deeper water supply boreholes drilled in the Bulyanhulu concession area at the KMCL and Skanska camps, and elsewhere for diamond drilling water supplies, have generally been drilled to depths between 50-100 m, a few metres into fresh bedrock, and screened opposite productive sections in the weathered volcanic rock profile.

Based on hydraulic testing carried out to date on the water resources investigation wells and piezometers, well yields are indicated to be in the region of 2 to 3 m^3/hr from the saprolite, and possibly up to 25 to 30 m^3/hr from the Bariadi laterite aquifer (to be confirmed by subsequent testing). The predicted yields from the saprolite are generally within accepted ranges for the anticipated duration of abstraction. However, the laterite aquifer, as a result of the potentially significant fissure development, could yield significantly higher than expected, but is likely to be of limited recharge.

4.5.4.3 Domestic Supplies for Local Villages

The baseline assessment included a site survey and review of the local groundwater sources and supplies to existing villages within the area of influence of the KMCL concession. The five villages both within and affected by the KMCL concession, Nyamikonze, Iyenze, Kakola, Lushimba and Busulwangili, currently obtain domestic water from a variety of groundwater sources, including protected springs, hand dug wells, well type springs and hand pumps. Lwabakanga and Nambatatu are very small settlements and not significant groundwater users. Local water supply is discussed further in section 4.14.2.

4.6 WATER QUALITY

4.6.1 Scope and Objectives of Studies

Surface water quality data were collected for project area watercourses on a monthly basis over a one-year period. Monitoring locations were selected based on proximity to the project or potential for impact from the project. For surface water, the latter is limited to surface water removal from Smith Sound. The focus of the investigation was metals and sediment levels in water bodies, with special emphasis on metals found in the deposit and mercury used by artisanal miners, formerly working in the area.

Groundwater quality was evaluated to determine potential impacts due to de-watering and seepage loss from surface facilities, such as the waste rock pile and tailing impoundment.

4.6.2 Surface Water

4.6.2.1 Seasonal Variability

Five stations were sampled up to 11 times through 1997 and 1998 (see Figure 4-7 for station locations). Analytical results are given in Appendix 4-4. Three stations (W1, W2 and W3) are located on the Bulyanhulu River. Station W4 is in Smith Sound, and Station W5 is located at the confluence of the Bariadi Swamp and the Kabhanda River. Plate 4-7 shows a sample being collected, and Plate 4-8 shows station W4.

Results from the water sampling at Bulyanhulu are supplemented by initial results from work completed by the University of Guelph, Department of Land Resource Science (Peter van Straaten, personal communication).

Water chemistry data have been evaluated to determine seasonal and spatial variations in chemistry and variation of quality with respect to guidelines. Two types of guidelines were considered to be relevant. Drinking water guidelines defined by the World Health Organisation (WHO) and Tanzania were used to evaluate suitability of the water for consumption by humans. In addition, maximum concentrations recommended for irrigation water (NASNAE, 1972 and Tanzania) were used primarily to assess the suitability of piped water from Smith Sound for irrigation purposes. Both sets of guidelines are summarised in Table 4-14. The guidelines recommended by the various organisations are comparable. The main differences are the NASNAE (1972) guidelines. For example, the copper (Cu) guideline for irrigation is lower than any of the other guidelines, and the zinc (Zn) guideline is higher.

Figures 4-17 to 4-20 depict the seasonal variability of selected parameters at each site for all 11 sampling rounds. The charts also show water quality guidelines as dashed lines, the concentration represented being the lowest recommended by any organisation (WHO, Tanzanian or NASNAE, 1972). The parameters depicted were selected based on the following criteria:

- Heavy elements and parameters likely to be associated with the proposed mine (CN, Cu, Pb, Zn, As);
- Parameters with baseline concentrations exceeding guidelines (As, Cu, Hg, Mn, Pb);
- Parameters of interest for water quality interpretations (Al, Fe, pH, total suspended solids); and,
- Elements listed above with concentrations routinely exceeding 10 times the detection limit (Al, As, Cu, Hg, Fe, Mn, pH, TSS).

<u>Bulyanhulu River (W1, W2, W3)</u>

In general, at stations W1, W2 and W3 variations in total and dissolved concentrations can in part be related to seasonal stream flow patterns. Figure 4-21 shows the flows recorded at station H2 on the dates of water sampling. Three water flow peaks occurred through the sampling period. The first was December 1996 - January 1997, although no stream flow measurements are available (heavy precipitation was noted during the period). The second peak was April -

May 1997. The third peak was December 1997 - January 1998. Between peak flows, flows were very low (<1 m^3/s).

Total aluminum concentrations show the best overall correlation with seasonal flow variation. Three concentration peaks are apparent in January 1997, April and May 1997, and January 1998. Similar, though less distinct, peak concentrations are observed for total arsenic, total iron and total mercury.

Other concentration peaks occur in periods of low flow. These include, for example, matching peaks for total aluminum, total arsenic, total iron, and total mercury in June and July. Total and dissolved manganese and copper concentrations peak mainly during low flow periods (March and November 1997). Total suspended solids (TSS) concentrations are erratic with peaks occurring during both high and low flow periods. Elevated TSS concentrations would be expected during high flow periods due to upstream bank erosion and may persist during low flow periods due to human activities such as small-scale mining. This probably explains the elevated total and dissolved arsenic, copper, manganese, and mercury concentrations during low flow periods. Concentrations of these elements may be low during high flow periods due to dilution. In summary, seasonal trends may be divided into two categories:

- elements associated primarily with lateritic soils (Al, Fe) are expected to peak during high flow events due to bank erosion; and,
- elements associated with economic minerals (As, Cu, Fe, Hg, Pb) are expected to peak during low flow periods due to lack of dilution.

Concentrations of copper, mercury and lead all appeared to decrease through 1997 probably due to efforts made to reduce small-scale mining.

Exceedances of water quality guidelines occur at peak concentrations for arsenic (irrigation), copper, mercury and manganese (drinking and irrigation). Concentrations of arsenic and lead almost always exceeded the drinking water guideline. Copper and iron concentrations almost always exceeded the irrigation guideline.

Concentrations of lead reported by Peter van Straaten (personal communication) in October 1997 were comparable to those determined for this study.

Smith Sound (W4)

A sample was collected from Smith Sound in February 1997 (Table 4-15). The water contained no detectable suspended matter. No concentrations exceeded water quality guidelines. Iron concentrations (0.72 mg/L) were close to the drinking water criteria (1 mg/L). These findings are partially substantiated by a sample collected at Sotta on the Sound on October 15, 1997 (Peter van Straaten, personal communication) (Table 4-15). The location of this and other water quality samples is shown on Figure 4-22. The filtered sample indicated very low concentrations of As, Cd, Co, Cu, Hg, Mo, Ni, Pb and Zn.

Bariadi Swamp (W5)

The Bariadi Swamp receives runoff and groundwater originating from the south side of the project. Water samples were collected when flow was present. Generally, heavy metal concentrations were lower than the Bulyanhulu River with the exception of an isolated copper concentration determined in November 1997 (Figure 4-17). TSS concentrations were higher than in the Bulyanhulu River (Figure 4-20) resulting in elevated Al concentrations (Figure 4-19). This probably reflects erosion of lateritic soils.

4.6.2.2 Spatial Variability of Seasonal Data

Erratic spatial variations were noted for most parameters. Qualitatively, the following differences were noted (with several exceptions):

- concentrations of total Al, As, Cu, Fe, Hg, Pb, Mn were generally lowest at W1; and,
- concentrations of total Al, As, Hg, Pb were greatest at W2.

4.6.2.3 Summary Characteristics of Area Streams

Other than seasonal changes in trace element concentrations, the overall characteristics of the stream waters remain generally constant from season to season. The main anions are bicarbonate and chloride (average 0.7 meq/L and 0.4 meq/L, respectively). The main cation is sodium (1 meq/L) with about equal concentrations of potassium, calcium and magnesium. Hence, the surface waters can be described as being dominated by sodium chloride and bicarbonate ions.

4.6.2.4 QA/QC

In order to monitor data quality, three measures were used:

- Duplicate samples were collected on several occasions;
- Trip blanks prepared using deionised water were shipped and analyzed using the same procedures as regular samples; and,
- All major dissolved cations and anions were measured to determine the ion balance.

Results from each of these measures are given in Appendix 4-5, and are described below.

Results for six duplicate pairs were assessed using the coefficient-of-variation (CV, Table 1, Appendix 4-5). This was calculated from the absolute value of the difference divided by the mean of the paired results. High CVs indicate that concentrations in a duplicate pair are quite different. As CVs approach 0%, the two values become very similar. CVs were low for parameters occurring in the dissolved fraction and not associated with the high suspended sediment loads (for example, Cl, F, SO4) but very high and variable for most metals in both the total and dissolved fraction (see Figure 4-23). CVs for TSS varied from 2 to 120%. Similar wide variations in CVs for total and dissolved metals were noted. The high CVs for TSS and total metals are expected because TSS can change during a sampling event. TSS is typically correlated with total metal concentrations, hence metal concentrations can vary significantly during sampling. However, the wide variation in dissolved metal concentrations is unexpected and implies that some colloidal material (<0.45 µm) probably passed through the filter. The laboratory reported visible suspended matter in the filtered samples, confirming the presence of colloidal material.

Although the duplicate samples indicated significant variability during sampling events, seasonal variability was sufficient to allow assessment of between sampling event variability.

Trip and field blanks (Table 2, Appendix 4-5) generally indicated an absence of contamination from the walls of the sample containers, preservatives or sampling practices. Isolated instances of slightly elevated copper (0.004 mg/L) and mercury (0.08 µg/L) concentrations were noted. These may have originated in the deionised water or the preservative. The concentrations measured are not considered to be significant.

Ion balances (Table 3, Appendix 4-5) varied from –2.5% to +8.4%, thereby indicating relatively reliable accounting for the major ion contents of the waters. The ion balances were mainly positive, indicating over accounting for cations. This was probably a result of uncharged colloidal particles in the filtered solutions which contributed to the concentrations of Al, Fe and Mn.

4.6.3 Groundwater Quality

Groundwater quality information has been obtained from a number of sources, including previous sampling undertaken by Golder Associates and KMCL, and more recently by the Dames & Moore water resources investigation. The primary objective of analyses undertaken has been to assess suitability for drinking. Analyses included bacteriological and physico-chemical determinants. Analytical certificates are given in Appendix 4-6.

The shallow aquifer contains fresh, low conductivity waters (less than 100 µs/cm), which enter the shallow system as annual recharge from rainfall. If treated to remove bacteria (filtration and chlorination), this water will be potable. Golder undertook an analysis for their shallow test borehole WW-2 at Bariadi village. The analysis, which is likely to be typical of the shallow zone aquifer, indicates a low salinity, hard groundwater with appreciable silicon (probably from a turbid sample).

Work done by environmental chemists in Makerere University, and by KMCL, has established mercury contamination within the Bulyanhulu River valley. The mercury appears to be concentrated within shallow river bed sediments and has been linked to mercury use by artisanal miners. Since such artisanal mining has almost stopped in the area, it can be assumed that any continuing mercury input to the shallow aquifer groundwater will diminish over time.

For the saprolite and laterite aquifer, chemical data are available for the KMCL and Skanska camp boreholes and four of the water resources wells and piezometers. These analyses indicate 'hard' groundwater of moderate conductivity in the range 550-750 µS/cm. The reported iron levels are low (<0.3 mg/L), as are nitrate levels (<4 mg/L). Fluoride concentrations were less than 0.5 mg/L. Dissolved heavy metals analyses were undertaken on three wells in the saprolite (101,104 and 106) and well 109 in the Bariadi laterite. The analyses identified only chromium and zinc in a single sample from 104 (31 and 152 mg/L respectively). All of the remaining metals were below method detection limits. Further sampling of all water supply production wells is to be undertaken for complete drinking water standard requirements.

Bacteriological sampling of the recently constructed production wells, including re-testing of well 109 has been undertaken and confirms the general absence of bacteriological contamination of the saprolite and Bariadi laterite groundwaters. Where coliforms have been detected the concentrations are in all cases less that four counts per 100 ml. The observed contamination can be attributed to contact with drilling equipment at surface and drilling operatives.

Previous bacteriological analyses by the Mwanza Water Quality Lab showed that bacteria were absent from laterite and saprolite groundwaters.

4.7 STREAM SEDIMENTS

Stream sediment samples were collected from the Bulyanhulu River water quality monitoring station locations in December 1996 by KMCL. Results are summarised in Table 4-16.

Concentrations of most parameters were within the crustal range of averages for general rock types. The exceptions were silver, arsenic, bismuth, copper and lead. Bismuth concentrations exceeded the maximum crustal average by three orders of magnitude. The measured heavy element concentrations are not likely to be natural, and probably indicate contamination related to small scale mineral processing activities upstream. Mercury concentrations were generally not elevated despite the finding from other studies that mercury contamination has occurred due to small-scale mining, although one sample (S3) exceeded the crustal maximum value (4 mg/Kg). Despite these exceedences, it was not considered worthwhile to collect additional sediment samples during the period of baseline water sampling. Sediment sampling at a later date would be appropriate if it desired to investigate the potential improvement in sediment quality, following cessation of the widespread artisanal mining and mineral processing.

Differences between sites may be due to differences in the amount of fine sediments or organic material in the samples. No inferences about changes in chemistry along the channel can be made.

Arsenic concentrations in sediments from the Bulyanhulu and Nyakadohomi Rivers were investigated by Peter van Straaten, University of Guelph, Department of Land Resource Science. Samples collected in October 1997 indicated background arsenic concentrations upstream of Kakola of 3 to 4 mg/Kg. Near the project sample site S2, concentration increased to 61 mg/Kg. These were then found to decrease to 37 mg/Kg near S3, and further decrease to less than 1 mg/Kg farther downstream in the Nyakadohomi River. These concentrations are about an order-of-magnitude less than those determined in December 1996. The reason for the difference may be the abrupt reduction in ore processing previously related to artisanal mining on the concession. Scouring of ore processing sediments between events, or dilution by natural sediments from upstream, may also have occurred.

4.8 AQUATIC RESOURCES

This section presents baseline information on aquatic resources, including aquatic habitat, fisheries, benthic macroinvertebrates, periphytic algae, and aquatic macrophytes. The assessment of aquatic habitat includes the documentation of environmental disturbance as the result of human activities, particularly those associated with artisanal mining. Fish tissue mercury analysis was conducted as an indicator of the potential ecological impacts of inorganic mercury introduced to the aquatic environment.

4.8.1 Fisheries Resources

4.8.1.1 Regional Overview

The watersheds in the vicinity of the Bulyanhulu Project are confined to sections of the Lake Victoria basin within northern Tanzania. The dominant geographic landform in the region is the Central Tanzanian Plateau, with an average elevation of approximately 1,200 m. The mine property is located on the height of land between the Bulyanhulu River, to the north, and the Kabhanda River, to the east. Surficial drainage from the area of the proposed mine facilities is largely in the direction of the Bulyanhulu River.

The Bulyanhulu River has two primary tributaries, the Bujula and Butobela, which originate in a seasonal wetland to the north, and from surface runoff to the west, respectively (Fig. 4-24). The upstream boundary of the Bulyanhulu River is at their confluence. From this point, the Bulyanhulu River flows eastward for approximately 15 km to join the Kabhanda River. The river is henceforth known as the Nyakadohomi, which flows in a northeasterly direction for approximately 50 km, before joining the Isanga River, which flows into Lake Victoria at Smith Sound. Smith Sound is located at the southern end of Mwanza Gulf, an inlet which extends over 70 km inland from the main body of Lake Victoria.

The rivers in the region are generally ephemeral, typically being dry or exhibiting low flows during the dry season from July to October. Rainfall intensifies from late March to early June, with rivers experiencing maximum flows in April or May. During this period, the land areas adjacent to the stream channels are temporarily inundated, particularly around drainage confluences. While the Kabhanda River only flows during the wet season, there is typically some flow in the Bulyanhulu River throughout the year. However, at the peak of the dry season, surface flows are intermittent and evidence of surface water is limited to isolated pools of standing water.

The stream channels in the region are poorly defined, being shallow and wide, often merging into broad floodplains. The stream beds are composed of fine textured alluvium, which lack stability and allow the stream channel to migrate between opposing banks during times of intermediate flow. Sediment loads are generally high, due to the nature of the erodable soils and the amount of human-induced soil disturbance in the region from artisanal miners. Therefore, visibility and light transmission in the water column are low.

Where the local topography is too flat to allow adequate drainage, seasonal or perennial wetlands form. Igonzela swamp, located downstream from the confluence of the Bulyanhulu and Kabhanda Rivers, retains standing water throughout the year. The presence of papyrus and water lilies is a characteristic feature of wetlands in the region.

The ephemeral nature of the Bulyanhulu and Kabhanda Rivers is a limiting factor in their potential to support commercial fish populations. Compounding this problem are high sediment loads in the water column and siltation of the stream bed, which reduce primary productivity, food sources, and the availability of spawning and rearing habitat. Fish species that are present in these streams have developed physical adaptations or behavioural patterns to live in the seasonally harsh conditions.

Local fish capture is of a subsistence nature. There is no official information available regarding the catch data of subsistence fisheries, as efforts to document fish presence and distribution in Tanzania have been focused on major commercial fisheries. Fisheries assessments conducted in the Mwanza Gulf of Lake Victoria are the most relevant studies undertaken that provide some information for comparative analysis.

Although information for riverine fish fauna for the Lake Victoria basin is lacking, the fauna of Lake Victoria proper has received world-wide attention. In particular, the impacts of introduced fish on the native species of the family Cichlidae have been well documented. Nhwani, *et al.* (1996) lists the freshwater fish families of conservation concern in the Tanzanian waters of Lake Victoria (Table 4-17). A total of 175 species in 12 families are considered threatened, including 139 species of the family Cichlidae. The Lake Victoria Environmental Management Project (LVEMP), introduced in 1996, is an ambitious project designed to address many of the ecological concerns associated with Lake Victoria and includes initiatives for fisheries research.

Human activities within the mine concession area that have likely resulted in impacts on aquatic resources include those associated with settlement, agriculture, and artisanal mining. These activities require water extraction from the local drainages, they increase sedimentation of rivers, and may contribute high levels of nutrient-rich agricultural runoff to aquatic systems. However, artisanal mining may pose the most serious local threat to the environment through the unrestricted use of mercury amalgamation in the gold extraction process. The analysis of fish tissue for mercury content has been included as part of the environmental baseline assessment.

4.8.1.2 Field Studies Program

<u>*Introduction*</u>

The fisheries component of the field studies program was conducted in the latter part of June 1997 in water bodies potentially affected by the mine development. Sampling was conducted on the Bulyanhulu River, the Kabhanda River, and on the upper reaches of the Nyakadohomi River, in a poorly drained area locally known as Igonzela swamp. The surveys were conducted:

- to assess the biophysical characteristics of the streams in and around the mine concession area;
- to characterise the fisheries habitat capability of the system;
- to obtain baseline data on the presence, use, and population characteristics of existing fish species;
- to obtain baseline data on fish tissue mercury levels, for the purpose of assessing mercury bioavailability and ecosystem health; and
- to record human activities within mine concession area that have the potential to cause impacts on aquatic resources, in particular, those activities associated with artisanal mining.

The timing of sampling corresponded to the end of the wet season, when fish were expected to be widely distributed within the local drainages. The migratory behaviour of tropical fish in ephemeral river systems is a well documented phenomenon (Leveque, 1997). Therefore, the timing of the field studies program was critical in obtaining comprehensive baseline information on fish presence. Sampling was conducted following the maximum flow period, when flood stages of the local streams had subsided. This strategy was intended to avoid the sampling complications, including safety concerns, associated with flood conditions, while still obtaining the benefits of a diverse presence of fish species. This also allowed the direct observation of fish habitat that would be unobservable during periods of peak flows.

Water is often a limiting factor in sustaining the human populations of semi-arid regions. Water from the local drainages is heavily utilised by the human population in the mine concession area. While drinking water is usually obtained from wells, water for irrigation and artisanal mining purposes is extracted directly from the local streams. During periods of low flows, temporary reservoirs are constructed to retain water, often resulting in lower than normal flows downstream.

The use of water for gold ore washing introduces large volumes of sediment to local streams. The mercury amalgamation technique, used in gold extraction, introduces inorganic mercury to the aquatic environment. The dangers of mercury contamination of aquatic systems and subsequent human mercury poisoning have been documented in other jurisdictions (Bakir *et. al.* 1973). Until 1996, the Bulyanhulu Project area was occupied by up to 10,000 artisanal miners. As the result of this intense level of activity, approximately 1,000 ha of land was deforested to supply timber for artisanal mining operations (Department of Geology, 1994).

Since human activities appear to have resulted in significant impacts to the aquatic environment, the documentation of these activities is essential to establish baseline conditions in the mine concession area. Therefore, the field studies program was designed to record physical disturbances caused by human activity and to obtain baseline levels of mercury in the tissue of the local fish fauna.

Biophysical Inventory and Habitat Characterisation

The biophysical inventory of aquatic habitat was conducted concurrently with the fisheries, benthic macroinvertebrate, periphytic algae and aquatic macrophyte investigations. A reconnaissance-level survey of the Bulyanhulu River was conducted on the first day of field investigations to determine the most appropriate locations for sampling. Sampling locations were selected on the basis of their accessibility, their representation of the range of habitat conditions, their location in relation to the mine site, and by their suitability for conducting sampling with gill nets and beach seines.

A total of five sampling locations were selected for biophysical inventory and habitat characterisation (Figure 4-24). Two sampling locations (S_1 and S_2) were selected on the Bulyanhulu River within the mine concession area, adjacent to the location of the proposed mine operations. The remaining three sampling locations were selected at downstream locations from the mine concession area. They included a third sampling location on the Bulyanhulu River (H_1), a sampling station on the Kabhanda River (S_3), and a sampling station on the Nyakadohomi River (S_4). The upper boundary of the Nyakadohomi River is defined by the confluence of the Bulyanhulu and Kabhanda Rivers. Downstream from the confluence, the upper section of the Nyakadohomi River is a poorly drained area locally known as Igonzela swamp.

The parameters measured during the biophysical inventories included stream morphology, substrate composition, wetted channel width, average depth, dominant aquatic vegetation, turbidity, and condition of the riparian vegetation. Photographs taken at the sampling locations provided a permanent record of the physical habitat conditions at each sampling location during the field studies program.

Orthophotos and topographic maps, with scales of 1:10,000 and 1:50,000, respectively, were used to define reach breaks and determine longitudinal channel slopes. A habitat map was produced showing the distribution of habitat types and the locations of reach breaks and sampling locations.

Inventory of Potential Disturbances to Aquatic Resources

Concurrent with the biophysical inventory of aquatic habitat, observations on human activities in or adjacent to the riverine habitat were recorded at each sampling location. Activities such as water withdrawal, modifications of the stream channel by tailing deposition, direct siltation of the stream as the result of gold ore washing, the use of mercury amalgamation techniques, and the construction of road crossings were considered to have the potential for negative impacts on aquatic resources. Areas where human activities appeared to have modified the aquatic and riparian vegetation were also noted. Where the composition of the riverine substrate was unusually high in fine sediments, efforts were made to determine if the its presence could be attributed to an immediate upstream source of contamination.

A 1:10,000 scale orthophoto was used to identify riparian areas that may have been devegetated as a result of human activities.

Fisheries Investigations

Fisheries investigations were conducted at a total of four sampling locations (S_1, S_2, S_3, S_4). These were identical to the location of the sampling sites utilised during the biophysical inventory of aquatic habitat, the exception being sampling site H_1, where fish sampling was not conducted (Figure 4-24).

Fish sampling was undertaken using a number of methods, including gill netting, beach seining, dip netting, and angling with baited hooks. Each method is known to be selective for particular components of the fish community and may vary considerably in their individual sampling efficiencies. The combination of methods was utilised to achieve a more accurate representation of the local fish community. The following provides a description of the fishing gear and sampling techniques used during the fisheries inventory, including an estimation of the level of effort and area sampled by gear type.

Gill Netting

Gill nets are passive devices that are suspended in the water column, capturing fish swimming into the meshes of the net. The gill net is kept suspended in the water column by a floating line, or cork line, while a sinking line, or lead line, holds the lower end of the rectangular net panel towards the substrate. While gill nets are typically used in standing water bodies such as lakes, they can be used in rivers provided that measures are undertaken to prevent debris or other obstructions from damaging or fouling the net.

Gill nets are typically constructed of strands of nylon monofilament, which are knotted together to form a grid, with each relatively square section of the grid termed a mesh. The mesh size is measured from knot to knot of a single, diagonally stretched mesh. Each mesh size is selective for a specific size of fish. Fish are captured by gilling, a process that occurs when their maxillary or opercular area is caught in a single mesh when they encounter the net. Fish may also be entangled by their teeth, spines, girth, or scales as they try to pass through or free themselves from the mesh.

The overall size of the net and the size of the mesh are important factors in determining catch efficiency. To increase the efficiency of the catch, it is beneficial for the gill net to cover a high percentage of the water column. The careful selection of mesh size will also increase the efficiency of the catch, since fish with smaller girths than the mesh can usually pass easily through the net. Gill nets also have the advantage of entangling larger fish, although larger fish may be repelled by the net or become untangled during net retrieval.

The gill nets used in the study were made of nylon monofilament and measured 7.6 m long by 1.2 m wide. The depth of the net was sufficient to reach the substrate at three of the four sampling locations. The exception occurred at sampling site S_4 (Igonzela swamp), where the average water depth was 3.9 m. Two gill nets with individual mesh sizes of 3.8 cm and 5.1 cm were used in the study. The use of two mesh sizes in the study was intended to increase the efficiency of capture of a range of fish sizes.

Local environmental conditions can also determine the level of catch efficiency. For example, water clarity and weather conditions can make the net more or less visible to fish. Since water conditions were extremely turbid during sampling, it is assumed that fish could not see the net. Therefore, the local water conditions likely increased catch efficiency.

At each sampling location, a 3.8 cm mesh gillnet and a 5.1 cm mesh gillnet were set at daylight and hauled after three hours. The nets were set parallel to the direction of current flow to prevent fouling with debris.

Beach Seining

Beach seine nets are typically moved through the water by human power and are therefore termed active devices. They are deployed from a boat or by hand and are used to encircle or enclose a specific area of a waterbody. Beach seines include a relatively small mesh size of 0.3 cm to 0.6 cm in the middle section called a bunt. The bunt is quite loose and balloons out during the set to form a pocket in which the fish become concentrated. Extending from either side of the bunt are the wings of the net which consist of larger meshes of 1.2 cm to 2.5 cm, designed to reduce drag on the net as it is hauled through the water. The wings serve to intercept fish and direct them towards the bunt. The bottom of the net is weighted with a braided leadline or rolled lead weights while the top of the net is supported by a floating corkline.

The beach seine used during the study was 9.1 m long by 1.5 m wide. The beach seine was deployed once at each sampling location using a team of four men. Where seining was conducted on the Bulyanhulu and Kabhanda Rivers, gill nets were set across the stream channel at upstream and downstream locations from the sampling area. The resulting enclosure was intended to prevent fish from moving in and out of the sampling area. One end of the beach seine was tied to shore while the opposite end dragged in the direction of the opposing stream bank. The end of the seine was then pulled downstream and back toward the tie-up location on shore. This was done very slowly to prevent the leadline from lifting off the bottom and the corkline from becoming submerged. As the net was pulled toward shore by the sampling team, the corkline was lifted to prevent any fish from jumping out. The entire net and its contents were pulled onto shore and the catch was quickly sampled.

Sampling locations were selected to avoid submerged objects and allow efficient deployment of the beach seine. The locations selected for sampling had relatively flat substrate profiles, so that fish escapement caused by the leadline lifting off the bottom was minimised. Where undercut banks and submerged objects interfered with the deployment of the beach seine, dip netting was used to sample these areas instead.

Dip Netting

Dip nets are active devices that consist of a fine mesh bag trap with a single open end. They are constructed of mosquito net or nylon mesh attached to a circular metal frame on the end of a long pole. Dip nets are often utilised to sample areas that are difficult to reach with larger gill nets or seines. For example, near woody debris or aquatic vegetation in the stream channel and under cutbanks. This method is more successful in capturing smaller fish suspended in the water column. The turbid conditions of the water were thought to increase the efficiency of this method, since the net was difficult to see underwater. However, the turbid conditions prevented the selection of a "target" fish for directing the net and therefore, sampling was conducted blindly.

At each sampling location, several passes were made with the dip net in an upstream direction, through the vegetation that fringes each side of the stream channel. Fish captured in this manner were quickly deposited in buckets of water with sufficient aeration until they could be sampled.

Angling

Angling with a basic baited hook and handheld line is an active technique, since it requires the ongoing participation of the operator to be successful. While angling is an effective method for estimating angling quality, it is of limited use in providing information on fish presence and distribution since it is highly selective for individual species and size. Angling is typically a labour-intensive process and efficiency varies highly with the skill of the operator.

During the study, angling was conducted using single hooks of size 4-5 baited with fish flesh and cast from the banks of the river. At each sampling location, the process was repeated at several sites on opposing stream banks, to ensure that a high percentage of the aquatic habitat was sampled directly. The duration of angling activity was approximately one hour at each sampling location. One hook and line were used for sampling.

Treatment of Fish Samples

The fisheries sampling program was designed to collect a representative number of species for preservation and for fish tissue mercury analysis. The remaining fish captured during sampling were to be identified to species, have their individual lengths and weights recorded, and be released live after census. However, relatively low catches of adult fish required that they were all retained for analysis. At each sampling location, a minimum of one specimen of each juvenile fish species captured was retained for further study. The remaining juvenile fish were released alive.

Following fish collection, the representative fish samples were transported to the Bulyanhulu field laboratory for analysis. The fish were identified to species, where possible, using the *Field Guide to the Freshwater Fishes of Tanzania* (Eccles, 1992) and *Fish Stocks and Fisheries of Lake Victoria - A Handbook for Field Observations* (Witte and van Densen, 1995). Fork length, weight, sex, and the condition of gonads were also recorded. A reference set of identified species was preserved in 5% formalin solution and deposited at the Department of Zoology and Marine Biology, University of Dar es Salaam.

Liver and dorsal muscle samples were collected from thirteen of the medium and large sized specimens. They included three specimens of the species *Clarias liocephalus*, two specimens of *Clarias werneri*, two specimens of *Marcusenius victoriae*, and six specimens of *Protopterus aethiopicus*. Tissue samples collected from each species were deposited separately in thirteen heat treated glass jars with air tight seals. The jars were then packed in coolers containing dry ice and shipped to ADAS Consulting Ltd. in Wolverhampton, England for analysis of mercury content.

4.8.1.3 Results and Discussion

<u>Habitat Characterisation Studies</u>

The following provides a description of the aquatic habitat at five sampling locations where biophysical inventories and habitat characterisation studies were conducted:

Site S_1 (Bulyanhulu River)

Site S_1 was located within the mine concession area on the Bulyanhulu River, at the Bulyanhulu to Geita road crossing. While this sampling location was the furthest upstream on the Bulyanhulu River, it still received some surface water runoff from the principal mine operations area. The stream bed consisted of a coarse substrate of boulders and pebbles. Measurements of the channel width and average depth at this location were 6 m and 120 cm, respectively. The dominant aquatic vegetation consisted of echinochloa grass (*Echinochloa pyramidalis*), which fringed the channel along the banks of the river. Vehicles, humans, and livestock using the road crossing have caused considerable disturbance to the river substrate, and consequently, the water was highly turbid. Riparian vegetation in the vicinity of the road crossing was largely absent, due to the level of disturbance caused by the local traffic and the physical presence of the road surface.

Site S_2 (Bulyanhulu River)

Site S_2 was located approximately 1.5 km downstream from site S_2, in close proximity to a pump house constructed on the bank of the river. This site was located within the mine concession area. Evidence of artisanal mining activity in the area was extensive. The channel width of the river was approximately 3 m, due to the large volume of artisanal mine tailing that have been deposited in the channel and along the banks of the river. The average wetted depth was 50 cm, indicating a lower volume of flow than what had been recorded at site S_1 upstream. The stream substrate consisted of fine sand and silt. Like site S_1, the dominant aquatic vegetation was *Echinochloa pyramidalis*.

Site H_1 (Bulyanhulu River)

Site H_1 was located on the Bulyanhulu River approximately 0.7 km west of the mine concession area boundary, 3.5 km downstream from site S_2, and 0.6 km southwest of the village of Nyamikonze. The average wetted depth of the stream channel was approximately 60 cm. Fine sands and silt were the predominant stream substrate material. Abandoned piles of tailing lined the banks of the river. Aquatic and riparian vegetation were sparse at this location, largely as the result of the activities of the artisanal miners from the local village.

Site S_3 (Kabhanda River)

Site S_3 was located on the Kabhanda River, approximately 1.5 km upstream from its confluence with the Bulyanhulu River. While the main stem of the Kabhanda River is outside of the mine concession area, the catchment of this drainage has the potential to receive groundwater discharge or surface runoff from the principal Bulyanhulu mine operations area. Therefore, site S_3 was selected for sampling during the field investigations. Since this location is independent from the Bulyanhulu River watershed, it also acts as a potential control station for the comparison of sampling results.

During the survey, active artisanal mining operations were occurring approximately 400 m upstream from the sampling location. This activity was largely responsible for the extremely turbid condition of the river water. At site S_3, the channel width and average depth of the river were 4 m and 45 cm, respectively. Immediately downstream from the area where gold ore washing was occurring, the river had ceased flowing on the surface. The only evidence of surface water at this location was limited to stagnant pools.

Site S_4 (Nyakadohomi River/Igonzela swamp)

Site S_4 was located on the Nyakadohomi River, approximately 1.8 km downstream from the confluence of the Bulyanhulu and Kabhanda Rivers. The Nyakadohomi River is a continuation of these drainages and is defined as a distinct river by nomenclature only. The upper section of the Nyakadohomi River is also known as Igonzela swamp, due to its properties as a poorly drained area with reservoir-like characteristics.

During the study, the channel at site S_4 had a width of 32 m and an average depth of 3.9 m. Flow in this section of the "river" was not evident, as would be expected in a standing water body. The substrate consisted of alluvial mud interspersed with areas of sand and mud. The fringing aquatic vegetation included a mixture of echinochloa grass (*Echinochloa pyramidalis*), papyrus (*Cyperus involucratus* and *C. papyrus*), and water lily (*Nymphaea capensis*).

Habitat Classifications and Reach Breaks

The Central Tanzanian Plateau is a relatively flat plain with an average elevation of approximately 1200 m. The area around Bulyanhulu is also relatively flat, with elevations ranging from less than 1170 m to 1208 m within the 49 km^2 mine concession area. The lack of gradient results in very uniform landscape throughout the region. The section of river defined as the Bulyanhulu rises approximately 30 m in elevation over its 15 km length. This corresponds to a gradient of only 0.2 %. However, this is an average value and does not account for the almost zero gradient in the areas around wetlands.

In the Bulyanhulu Project area, there are two distinct types of aquatic habitat, those associated with slow flowing rivers and those associated with wetlands. In transition between these two habitat types are the seasonal floodplains associated with both rivers and wetlands, which may provide aquatic habitat for specific intervals during the wet season.

The low topographical relief, the surficial geology, and the hydrological regime in the area are major factors in determining the morphology of the local rivers. The plain-like topography has resulted in poorly defined stream channels with high width to depth ratios. The rivers in the area have meandering and slightly entrenched channels, silt-clay dominated stream beds and banks, and highly developed floodplains. The unstable nature of the stream substrate materials causes significant bed movement during moderate to high flows. Rates of lateral migration of the main stream channel are influenced by the presence and condition of the riparian vegetation, which functions to stabilise stream bank materials.

The sinuous nature of the local rivers causes a relative increase in velocity on the outside curves of meanders and a subsequent decrease in velocity on the inside curves. Thus, the outside curves of meanders are more prone to erosion and subsequently deeper. Decreased velocities on the inner curves of meanders causes deposition and the formation of point bars. When viewed in cross-section, the river presents a range of habitat conditions that provide ecological niches for different fish, plant, and invertebrate species. This range of habitat conditions is expanded during the wet season, when heavy rainfall results in flooding of the surrounding area. In particular, the areas around river confluences are frequently inundated during high flow periods. Many aquatic species, including fish, are known to colonise these flooded areas until the water recedes (Lowe-McConnell, 1987).

The wetlands in the region present a different range of habitat conditions for aquatic species. For example, Igonzela swamp is deeper than the surrounding rivers and may provide a refuge for species during the dry season. In addition, the local wetlands appear to contain a more diverse aquatic plant community, which provide food, substrate, and cover for other aquatic species. Primary productivity may also be higher in the local wetlands, due to the settling of suspended sediments and the subsequent increase of light transmission into the water column.

Based on the results of the habitat component of the field studies program and through the analysis of orthophotos and topographic maps, habitat mapping was conducted based on the following criteria:

- riverine habitat;
- perennial wetland habitat; and
- seasonal floodplain and wetland habitat.

Primary reach breaks were established at wetland/riverine transition boundaries along the main stem of the Bujula, Bulyanhulu, and Nyakadohomi Rivers. Secondary reach breaks were established at stream confluences and at the wetland/riverine transition boundaries of the main stem tributaries. For the purposes of the assessment, reach breaks were defined as the boundaries between homogeneous sections of stream channel, or reaches, characterised by uniform discharge, gradient, channel morphology, channel confinement, and stream bed and channel materials.

The aquatic habitat and reach breaks for the drainages in the Bulyanhulu Project area are shown in Figure 4-24. Habitat boundaries and the location of reach breaks established at wetland/riverine transition boundaries are approximate, since water levels change throughout the year. In particular, the boundaries of Igonzela swamp are difficult to define, since they are determined by seasonal and long term changes in climate. For the purposes of habitat mapping, the approximate boundaries of Igonzela swamp were defined by the extent of standing water observed during the field studies program.

The quality of spawning habitat in the Bulyanhulu and Kabhanda Rivers appears to be poor, as well-aerated gravel substrates were not observed during the study. Instead, stream substrates consisted of fine sediments and areas of sand. Besides being unstable during high flows and subject to scouring, the fine sediment material may inhibit water circulation and oxygen exchange within the substrate. This may result in poor survival rates for fish eggs deposited in the sediment.

At site S_4 in Igonzela swamp, benthic faunal sampling revealed the presence of fish eggs in the sediment. This suggests that favourable habitat for spawning may occur at this location, although the presence of mud sediments and minimal water circulation indicates that conditions remain sub-optimal.

Disturbances to Aquatic Resources

Disturbances to aquatic resources caused by past human activities are significant in the region. Many of these activities, particularly those associated with artisanal mining, have resulted in physical disturbances that are directly observable in the field. These include sedimentation as the result of gold ore washing, deposition of tailing material in and around the stream channel, interruption of stream flow patterns through temporary dam construction and water withdrawal, and displacement of riparian and aquatic vegetation. Evidence of artisanal mining activity was observed at four of the five sampling locations, the exception being site S_4, located within Igonzela swamp.

The absence of bridges at stream crossings requires traffic to use the stream bed as a road surface. This activity increases turbidity and physically disrupts the local aquatic habitat. Dam construction and water withdrawal are also known to occur for agricultural purposes, to meet the irrigation requirements of local farmers during the dry season.

The mercury amalgamation technique is widely used for gold extraction in the region. At site S_3 on the Kabhanda River, the use of this technique was observed at an active artisanal mining operation. While the unregulated use of mercury has been identified as a potential environmental concern, the artisanal mine tailing may pose additional risks to aquatic resources. For example, tailing leachates may contain metals or acid generating sulphides. Water quality investigations are intended to identify any additional environmental concerns associated with artisanal mining.

At the regional level, devegetation and water consumption are likely causing some level of disturbance to the aquatic environment. In particular, increased erosion and sediment transport are potentially degrading to aquatic ecosystems. The loss of vegetative cover also interrupts the local hydrological regime, potential causing redistribution of surface flows, decreased water retention, and increased stream temperatures. While these disturbances are difficult to quantify, they remain significant environmental concerns.

Fishing activity in the region is of a subsistence nature with no established market system. Therefore, overfishing in the area is not considered a problem. The low market demand for fish makes overfishing uneconomical and most fishermen limit their catch to what their family can consume on a daily basis.

Fisheries Sampling Program

During the survey, a total of seven fish species were collected from five families and six genera (Table 4-18). Based on the results of sampling, fish diversity was highest at site S_4 (Igonzela swamp), where six of the seven species were collected. Only two genera were present in the remainder of the study area, with *Barbus* and *Haplochromis* being the only fish captured at sites S_1 and S_2 on the Bulyanhulu River. *Barbus* was the only fish species captured at site S_3 on the Kabhanda River. Due to the complex taxonomy of these genera, they could not be identified to species. In addition, all of the *Barbus* and *Haplochromis* specimens captured were fry or juveniles, complicating their identification. Therefore, the possibility exists that more than one species of each genus were present during sampling.

There appears to be a strong correlation between the distribution of fish species in the study area and the presence of specific habitat types. During the study, five of the seven fish species were only collected at sampling site S_4 (Igonzela swamp). These included all of the medium and large sized fish collected in the study. Conversely, only two fish species were collected in riverine habitat. This marked preference of larger fish for wetland habitat suggests that they have adapted to the ephemeral nature of the local drainages by using wetlands as seasonal refuges. It is likely that these fish species expand their ranges into riverine habitat during the peak of the wet season.

Interviews with local fishermen from Kakola have confirmed that fish from Igonzela swamp migrate into the Bulyanhulu River (Tamatamah, 1997). The timing of this migration occurs following the onset of the wet season in March. Peak catches on the Bulyanhulu River are reported to occur in April and May. The fish genera reported in these movements include *Clarias*, *Protopterus*, *Mormyrus*, *Labeo*, and large specimens of *Barbus*. While the reason for the migration is likely spawning, the river floodplains also present opportunistic species with access to additional food sources.

The distribution of *Barbus* and *Haplochromis* in the Bulyanhulu Rivers indicates they are able to tolerate a wider range of environmental conditions than other species. However, the apparent absence of larger, sexually mature individuals of these genera indicate that they may only utilise the area as juveniles. By colonising marginal habitat as juveniles, these genera avoid competition with adult fish species and reduce the chance of predation. *Barbus* tends to be an opportunistic genus, colonising a wide range of habitats in eastern Africa. Haplochromine cichlids were once represented by approximately 350 species in Lake Victoria, although a large percentage of these have become extinct (Pitcher and Hart, 1995). Their presence in the local rivers is not unexpected, as they are a diverse genus.

The apparent migratory behaviour displayed by the fish fauna in Igonzela swamp during the wet season indicates that their distribution is wider than what was revealed by the field studies program. Based on this premise, the fish collected at site S_4 (Igonzela swamp) can also be used as indicators of fish presence in the Bulyanhulu and Kabhanda Rivers during the peak of the wet season. Adult fish presence at site S_4 included five species and a total of 24 specimens (Table 4-19). However, it should be recognised that the presence of these species in the local rivers may only occur for a few months of the year.

Based on sampling results from site S_4, *Protopterus aethiopicus* and *Clarias liocephalus* are the most commonly occurring species in the study area. *C. liocephalus* and *P. aethiopicus* accounted for 37.5 % and 33.4 % of the total catch, respectively (Table 4-19). Since both of these species have developed highly specialised apparatus to utilise atmospheric oxygen, it is likely that their abundance is the result of their ability to persist in oxygen-depleted aquatic environments. *Marcusenius victoriae* was the third most abundant species at this location, accounting for 12.5 % of the total catch. *Petrocephalus catostoma* and *Clarias werneri* each accounted for 8.3 % of the total catch (Table 4-19).

The average length of the adult fish collected during the study ranged from 8 cm (*P. catostoma*) to 56 cm (*C. werneri*) (Table 4-19). While specimens of *P. catostoma* were too small to be weighed, the largest specimen captured in the study was also *C. werneri*, at 1500 g. The lengths and weights of juvenile *Barbus* and *Haplochromis* species were not recorded. Based on the total catch of adult fish species at sampling site S_4, the average length and weight were 29 cm and 432 g, respectively (Table 4-19).

Gonad inspection revealed the presence of mature egg cases in three of the five adult species collected at sampling site S_4. One gravid female, apparently on the verge of spawning, was observed in each species of *C. liocephalus*, *C. werneri*, and *P. aethiopicus*. However, among these three species, the number of gravid females recorded was only three out of a total of 19 individuals (Table 4-20). Ripe gonads were not observed in *M. victoriae* or *P. catostoma*. Few conclusions can be drawn from these results. A likely scenario is that spawning occurs in rivers during the flood stages of the wet season. The occurrence of a low number of potential spawners may indicate that sampling was conducted at the tail end of the spawning season. Therefore, the gravid females collected were likely the remnants of a larger spawning population.

During the fisheries sampling program, incidental catches of the freshwater shrimp, *Caridina nilotica*, were recorded at all sampling locations. The genus *Caridina* are small species of freshwater shrimp which are commonly found in the littoral regions of lakes and in streams having beds of submerged vegetation. *Caridina nilotica* has a wide distribution in the Lake Victoria basin. Goldschmidt et al., (1993) indicate that before the 1980s, *Caridina* was an insignificant element in the sublittoral community of the Mwanza Gulf. However, since 1986, large quantities of these shrimp are often caught by trawl nets from this area. In the Bulyanhulu study area, postlarval and juvenile *Caridina nilotica* were caught in dip nets at all sampling sites.

<u>*Life Histories of the Species Collected*</u>

The following information has been adapted from: Eccles (1992); Gosse (1984, 1986); Lévêque and Daget (1984); Teugels (1986); and, van Oijen (1991).

Family Protopteridae (African lungfish)

African lungfish are lobe-finned fishes of the Order Lepidosireniformes. They are part of a group of aestivating lungfishes which includes species from South America. They are characterised by an elongate body with string-like pectoral and pelvic fins. The dentition of lungfish consists of upper and lower tooth-plates in the form of sharp cutting ridges. They typically live in slow-moving freshwater and swamps. African and South American lungfish have evolved mechanisms to survive dry periods by aestivation (a state of reduced metabolism). To prevent desiccation, they burrow into mud holes enveloped in a mucus cocoon. As obligatory air breathers, they are restricted to the shallow inshore waters associated with lakes and swamps and slow moving rivers.

One species of the Family Protopteridae, *Protopterus aethiopicus*, was collected during the fisheries investigations.

Protopterus aethiopicus (marbled lungfish)

The marbled lungfish occurs in the shallow portions of lakes, rivers, and swamps. Spawning occurs during the rainy season in sheltered bays, rivers, and ephemeral streams fringed with papyrus swamps. One or several females spawn in burrows which are dug and cleaned by the male, who later guards the eggs and the young.

The principal diet of this species includes molluscs, mainly the gastropods *Bellamya* and *Melanoides*. Small fishes and insects are also eaten. Immature marbled lungfish less than 30 cm in length feed almost entirely on insects.

During the study, *P. aethiopicus* was the most abundant adult species collected, with a total of nine specimens captured at sampling site S_4 (Table 4-19). They ranged in length and weight from 35 cm to 73 cm and from 155 g to 1360 g, respectively (Table 4-20). Of the five females collected, one was immature and four were mature. Of the four mature females, one had ripe gonads and appeared to be ready to spawn. The four males specimens collected included three in a mature and one in an immature condition. The specimens were captured by a number of methods, through the use of a beach seine, 3.8 cm and 5.1 cm gill nets, and baited hooks and lines (Table 4-20).

Family Clariidae (air breathing catfishes)

Air breathing catfishes are ray-finned fishes of the Order Siluriformes. Their distribution includes Africa, Syria, and southern and eastern Asia. They have a dorsal fin extending over much of their body which is united to the rounded caudal fin in some species. Airbreathing is accomplished with an airbreathing organ arising from the gill arches. This allows them to survive in relatively oxygen-depleted water.

The genus *Clarias* is characterised by their long bodies and flattened heads with enclosed bony plates. In other parts of Africa, there are several records of *Clarias* moving from one body of water to the next when ephemeral streams or swamps dry out. Although resident species are common in Lake Victoria, their distribution is confined the inshore waters around marginal water lily and papyrus swamps. However, reproduction occurs in the surrounding drainages, where they migrate into rivers and ephemeral streams to spawn. Local fishermen report landings of *Clarias* from the Bulyanhulu River near the peak of the wet season, suggesting that they may migrate into the area to spawn.

Clarias spp are omnivorous, although they feed predominantly on small fish such as *Haplochromis* and *Barbus*. Other food sources include insect larvae, plankton, molluscs, and plants.

Two species of the Family Clariidae, *Clarias liocephalus* and *Clarias werneri*, were collected during the fisheries investigations.

Clarias liocephalus (smoothhead catfish)

The smoothhead catfish occurs in a range of habitats, including marginal water-lily and papyrus swamps, marginal weed beds, and in high mountain streams. Generally, it is found above 915 m in elevation and in waters with temperatures below 18°C. The dorsal fin is disconnected from the caudal fin and the pectoral fin spine is serrated on both the inner and outer sides. The serrations on the outer side are directed upward.

C. liocephalus was the second most common adult fish species captured during the study, with a total of eight specimens collected at site S_4 in Igonzela swamp. Based on the inspection of gonads, five specimens were classified as immature, one male and one female were classified as mature, and one gravid female was classified as spawning. Their lengths and weights ranged from 17 cm to 30 cm and from 38 to 200 g, respectively. While a single specimen was captured in a 5.1 cm mesh gill net, the remaining seven specimens were captured using a beach seine (Table 4-20).

Clarias werneri

C. werneri is found in both lakes and rivers. Like *C. liocephalus*, it can be identified by serrations on both sides of the pectoral fin spine. However, the serrations on the outer side lie in the same plane as the fin, unlike *C. liocephalus*, where they are directed outwards. The diet of *C. werneri* consists mainly of insects, including adult and larval Coleoptera, terrestrial insects, chironomid larvae, and the larvae of Povilla (mayfly spp), culicenes, and hydroptilids. They also feed on ostracods, gastropods, plants, copepods, and Hydracarina (water mites).

Only two specimens of *C. werneri* were captured during the study, including one mature male and a gravid female. While the male captured was 62 cm long and weighed 1500 g, the female was 50 cm long and weighed 930 g. Both were caught using baited hooks (Table 4-20).

Family Mormyridae (Elephantfishes)

Elephantfishes are ray-finned fishes of the Order Osteoglossiformes (bony tongues). Their distribution includes tropical Africa and the Nile River basin. Physical characteristics include a narrow caudal peduncle and a deeply forked caudal fin. The dorsal and anal fins are usually opposite to one another on the posterior part of the body. The mouth form is highly variable, and as their common name suggests, often trunk-like. Mormyrids are noted for their large cerebellums and their use if electricity and sound. While the maximum length of some species reaches 1.5 m, most mormyrids are 9 cm to 50 cm in length.

Two species of the Family Mormyridae, *Marcusenius victoriae* and *Petrocephalus catostoma*, were collected during the fisheries investigations.

Marcusenius victoriae

The genus *Marcusenius* is a group of relatively small fishes which are characterised by a golden colour both dorsally and ventrally. Mature adults reach a length of 15 cm. *Marcusenius* spp. are distinguished from the other mormyrids by their prominent chin, which extends beyond the snout. *M. victoriae* typically occurs in inshore waters over both sandy and rocky bottoms. Seasonally, it may appear over muddy bottoms adjacent to extensive papyrus swamps. In river habitats, *M. victoriae* prefer weedy or vegetated areas. Generally, it feeds on small organisms like Ostracoda, Hydracarina, and *Diaptomus* (copepod) and insects such as chironomid larvae.

A total of three specimens were collected during the study, including two mature females and one mature male. Lengths and weights ranged from 14 cm to 15.5 cm and from 50 g to 52 g, respectively. All specimens were captured in a 3.8 cm mesh gill net (Table 4-20).

Petrocephalus catostoma (Churchill)

The genus *Petrocephalus* is another group of small mormyrid species, with adults reaching a maximum length of 10 cm. *P. catostoma* has a short and rounded snout which projects beyond the mouth. The mouth lies immediately below the eye. *P. catostoma* occurs in muddy waters, sheltered bays, lagoons, and swampy areas. Groups of this species often form shoals within the quiet reaches of rivers and floodplains. *P. catostoma* breeds during the rainy season and appears to move upstream to suitable spawning locations. It has been observed schooling with other species with identical electric organ discharge (OED) waveforms.

A total of two specimens were collected during the study, both in 3.8 cm mesh gill nets. One mature male and female were collected. Lengths ranged from 7.5 cm to 8 cm (Table 4-20). Weights for these specimens were not recorded.

Family Cyprinidae (minnows or carps)

The Cyprinidae family is among the most diverse and dynamic group of fishes in the world. Cyprinids are a group of ray-finned fishes belonging to the Order Cypriniformes. Their distribution includes northern Canada to Mexico, Africa, and Eurasia. The family includes herbivores and predators. Some cyprinid species may reach 2.5 m to 3 m in length, although many species are small, with lengths under 3 cm.

During the study, juvenile specimens of *Barbus* were collected at all sampling locations except site S_4 in Igonzela swamp. Due to the complex intraspecific variability within this genus, identification to species was not conducted.

Barbus

The members of this genus typically have one or more pairs of barbels (slender, fleshy protuberances) near the mouth. Small *Barbus* species in the Kinhansi River in Tanzania were found to feed on aquatic insects, plant seeds, and plant debris (Tamatamah and Armbruster, 1995). While only juveniles of *Barbus* were collected during the fisheries investigations, local fishermen report catches of large *Barbus* adults near the peak of the wet season. This suggests that large *Barbus* species migrate into the Bulyanhulu River seasonally, for the purposes of spawning or in search of additional food sources.

Family Cichlidae (cichlids)

Cichlids are ray-finned fishes of the Order Perciformes. They are a very diverse group of freshwater fish, with perhaps over 1500 species. Their distribution includes Central and South America, West Indies, Africa, Madagascar, the Middle East, and India. However, the majority of cichlid species live in large species flocks in the Great African Lakes. A species flock is a group of closely related species all living in the same ecosystem. Due to their diverse maximum size, coloration, behavior, and ecology, they are difficult to characterise (Oliver, 1997).

During the study, fry and juveniles of the genus *Haplochromis* were captured at sites S_1 and S_2 in the Bulyanhulu River and at site S_4 in Igonzela swamp. Due to the small morphological differences between *Haplochromis* species, their identification to species level was difficult, particularly in juveniles. Therefore, the haplochromine cichlids collected during the study were only identified to the level of genus.

Haplochromis

The haplochromine cichlids were once the dominant fish group in Lake Victoria, accounting for over 80% of the demersal fish biomass. The numbers of species that once inhabited Lake Victoria has been estimated at over 400. While they remain the most diverse group of fish in the region, over 200 species may have become extinct during the last two decades. In the 1970s, a small-scale trawl fishery established near Mwanza once harvested haplochromine cichlids of catch rates exceeding 1000 Kg/h.

Haplochromine species once exploited virtually all food sources and habitats in Lake Victoria, with each species having a unique combination of food and habitat preferences. Some of these species utilise the drainages within the Lake Victoria basin on a permanent or seasonal basis. Fisheries research in the region has focused on lake systems, so there is very little information available on the food and habitat preferences of riverine haplochromine cichlids. However, the absence of mature *Haplochromis* during the study suggests that they may only utilise the Bulyanhulu Project area seasonally, likely for spawning and juvenile rearing purposes.

4.8.1.4 Fish Tissue Mercury Analysis

Background

As discussed previously, the unregulated use of the mercury amalgamation technique by artisans in the gold extraction process is a significant environmental concern in the region. Inorganic mercury released to river systems has the potential to be transformed into highly toxic methylmercury. Through the process of biomagnification, methylmercury can be concentrated in aquatic food chains. In particular, organisms near the top of the food chain, including fish, can accumulate potentially toxic levels of mercury in their tissues. Predators who consume contaminated fish, including humans, are exposed to a number of health risks associated with mercury poisoning.

The impacts methylmercury introduction to the aquatic environment are influenced by a number of environmental factors. The most obvious is the amount of mercury that is released to the environment, both in terms of magnitude and frequency of occurrence. Although the amount of introduced mercury is difficult to quantify, the level of artisanal mining activity in the region suggests that the amount is considerable.

Once the inorganic mercury is released, a second factor is its subsequent bioavailability to aquatic organisms. Soils, sediments, and organic material can bind methylmercury so that very little is released to the surrounding water bodies. In order to predict the fate of inorganic mercury released during the gold extraction process, a detailed understanding of mercury cycling in the local environment is required. However, mercury concentrations in fish tissue can act as an index of bioavailability. The levels of mercury in fish tissue were studied:

- to obtain baseline data on fish tissue mercury levels;
- to describe the fate of mercury in the aquatic environment. In combination with sediment and water quality information, the concentrations of mercury in the tissue of fishes allows the description of the environmental fate of mercury that enter the aquatic ecosystem; and
- to describe the health of the aquatic biota.

Because mercury detected in water and sediment may not be in a bioavailable form, concentrations of mercury in the tissue of fish a potential indicator of the health of an aquatic ecosystem. As the top of the aquatic food chain, fish are most likely to accumulate any mercury that are transferred from the physical environment (water and sediment) to the biotic environment (aquatic organisms).

The results from preliminary sediment and water quality testing indicate that elevated levels of mercury and other metals are present in the local aquatic environment. Mercury concentrations in the water column appear to fluctuate seasonally, as varying amounts of precipitation influence dilution in the local drainages. The results from water quality testing in January of 1997 show levels of mercury that exceed Tanzanian drinking water criteria (0.001 mg/L) and Canadian standards for the protection of aquatic life (0.0001 mg/L; CCREM, 1996). During monthly water quality sampling in 1997, mean total mercury concentrations from three sampling locations in the Bulyanhulu River ranged from 0.00079 mg/L to 0.00263 mg/L (Table 4-21). Individual monthly values ranged from below detection (< 0.00005 mg/L) to 0.00794 mg/L.

Muscle and liver tissue samples were collected from four species during the fisheries sampling program. Among the four species were thirteen specimens, with weights ranging from 52 g in *M. victoriae* to 1500 g in *C. werneri*. Tissue samples were shipped to a laboratory for analysis and total mercury levels were determined for each sample.

Results and Discussion

The results from the fish tissue mercury analysis are presented in Table 4-22. Total mercury levels were higher in liver tissue than muscle tissue for all samples. In liver tissue, values for total mercury for individual specimens ranged from 0.06 mg/Kg in *C. liocephalus* to 1.18 mg/Kg in *P. aethiopicus*. In muscle tissue, values ranged from 0.05 mg/Kg to 0.13 mg/Kg. Average total mercury values for liver tissue by species were highest for *P. aethiopicus* (0.61 mg/Kg), followed by *C. werneri* and *M. victoriae* (0.13 mg/Kg), and *C. liocephalus* (0.10 mg/Kg).

Monitoring of environmental and human exposure to mercury has been conducted in the Nungwe Bay area of Lake Victoria (Ikingura and Akagi, 1996). Nungwe Bay is located approximately 70 km northwest of the Bulyanhulu Project area. Fish samples from the Nungwe Bay area were determined to have a mean mercury concentration of 0.007 mg/Kg. Considering the high level of artisanal mining activity in the region, the fish analysed during the study had surprisingly low mercury levels in their tissues.

The World Health Organisation (WHO) has established a guideline of 0.2 mg/Kg for mercury concentrations in freshwater fish (WHO, 1976). Mercury concentrations in fish exceeding this value indicate a polluted river. Liver tissue concentrations from *P. aethiopicus* exceeded the WHO guideline, indicating potential mercury contamination of Igonzela swamp. None of the muscle tissue mercury values exceeded the WHO guideline of 0.2 mg/Kg. Mercury contamination in the Bulyanhulu or Kabhanda Rivers may parallel that of Igonzela swamp, since artisanal gold ore processing has been conducted extensively in these drainages.

While mercury is directly toxic, it can also accumulate at sub-lethal doses because the uptake of mercury in organisms typically occurs more rapidly than excretion. This may or may not have a detrimental effect on the organism itself but does provide a source for further concentration in consumers. In humans, continued ingestion of mercury-contaminated fish can damage the sensory nervous system. Symptoms include abnormal sensations (paraesthesis), uncoordinated movements, constricted visual field, slurred speech, and hearing difficulties in more severe cases. A daily intake of 300 g of fish per day with more than 0.005 mg/Kg mercury content can result in some of these symptoms in adult humans (UNEP, 1990).

Based on the results of fish tissue mercury analysis, methylmercury appears to have bioaccumulated in the local food chain. However, current mercury concentrations appear to be within safe consumption levels. Since artisanal mining activity is apparently decreasing in the Bulyanhulu Project area, tissue mercury values should decrease over time, as the introduction of inorganic mercury to the local environment also decreases.

4.8.2 Benthic Macroinvertebrates

4.8.2.1 Background

Benthic macroinvertebrates are animals which lack backbones and inhabit bottom sediments in aquatic systems. The major taxonomic groups of invertebrates are presented in Table 4-23. Other aquatic macroinvertebrates, collected during the fisheries sampling program as incidental catches, are discussed in section 4.8.1.5.

Most benthic macroinvertebrates spend their entire life cycle in an aquatic environment, although some aquatic insect species spend their short, reproductive, adult stage out of water. Because each species has developed adaptations to survive in certain environments, communities of species act as indicators of water quality within the environment they inhabit. Benthic community composition varies throughout the year, depending on the state of the aquatic environment and the juxtaposition of the life cycles of the species.

The community structure in a given section of river reflects the type and quality of habitat. External disturbances may cause changes in habitat and water quality. These changes may, in turn, cause large shifts in population demographics and certain species to dwindle while others thrive.

Benthic samples provide a measure of secondary production in lakes and rivers. Secondary consumers at the macroinvertebrate level feed upon primary producers such as bacteria and algae, and are in turn consumed by tertiary consumers such as fish. Therefore, by measuring secondary productivity, it is possible to derive a useful estimate of the quality of habitat and the quantity of food provided from the project area.

The objectives of the baseline inventory of benthic macroinvertebrates in the Bulyanhulu Project area were to determine community structure and make a relative assessment of secondary productivity in the project watersheds.

4.8.2.2 Methodology

Benthic macroinvertebrate sampling was conducted at sites S_1 and S_2 on the Bulyanhulu River, at site S_3 on the Kabhanda River, and at site S_4 on the Nyakadohomi River (Igonzela swamp). These sites are the same locations where fish sampling and habitat characterisation studies were also conducted.

Sediment meiobenthos were collected using a hand core sampler, constructed of an end-cut plastic syringe with open ends and an internal diameter of 2.6 cm. The sampler was pressed to the river bottom sediment to a depth of 5 cm and retrieved carefully without losing any of the sediment contents. The contents of the sampler were emptied into a clean sampling jar and preserved with 5% formalin solution. The sampling jars were sealed with air-tight lids, affixed with identification labels, and transported to the University of Dar es Salaam for identification. Three replicate samples of sediment cores were collected from random positions at each sampling site. The water depth was recorded for each replicate sample. Due to the relatively deep water at sampling site S_4, three replicate samples, at average depths of 70 cm and 115 cm, were collected at this location.

Sample preparation at the laboratory was conducted to separate the macroinvertebrates from the sediment and organic matter in the samples. Meiobenthos samples were washed with tap water over a 40 μm sieve to remove fine material and water from the sample. After the sieve was wiped dry, the material on the sieve was washed into a conical flask using colloidal silica (Ludox MT), maintained at a specific gravity of 1.15. The flask was then filled with colloidal silica to the neck region, stirred thoroughly, and left to stand for 25 minutes. After the resulting supernatant was decanted over a 40 μm sieve, the organisms retained by the sieve were washed and stored in separate jars for each sampling site. Three decantations were conducted for each sample.

After the sample preparation was completed, the organisms were transferred to Petri dishes where they were observed using a dissecting microscope. Organisms with similar morphological characteristics were placed in groups and their numbers were recorded for each sampling location. Due to the lack of identification keys for Tanzanian freshwater meiobenthos, the identification of faunal groups was limited to major taxa.

4.8.2.3 Results and Discussion

A total of 58 specimens of six macroinvertebrate taxa were identified during the study (Table 4-24). Additionally, six fish eggs were discovered in each of the sediment samples collected from sampling site S_4. The greatest diversity occurred at site S_4, where six macroinvertebrate taxa were identified in the sample collected from a depth of 70 cm. Conversely, only one major taxon (Nematoda) was identified at site S_1 on the Bulyanhulu River.

The highest number of total specimens (24), which included fish egg specimens, occurred in the sample collected from a depth of 115 cm at site S_4. However, the highest number of macroinvertebrate specimens (19) was collected from site S_3 on the Kabhanda River. The lowest number of specimens collected occurred at sites S_1 and S_2 on the Bulyanhulu River, where only 2 and 7 specimens were collected, respectively (Table 4-24).

The most abundant macroinvertebrate group was the chironomid larvae, accounting for 52 % of the macroinvertebrate specimens collected during the study. The second most abundant group were nematodes, accounting for 24 % of the macroinvertebrate specimens collected. Relative abundance of other the macroinvertebrate groups included oligochaetes at 17 %, leeches (Hirudinea) 3.4 %, *Anisoptera* larvae (odonata) at 1.7 %, and cladocerans at 1.7% (Table 4-24).

The results of macroinvertebrate sampling indicate that diversity and abundance are higher in the wetland habitat of Igonzela swamp (site S_4). Riverine habitats show considerably less diversity and abundance, particularly at site S_1 on the Bulyanhulu River, where only two nematode specimens were collected. The apparent differences between the benthic communities that occur in wetland and riverine habitats can be attributed to a number of factors, some of which include substrate conditions, abundance of vegetation, water quality, hydrology, and exposure to physical disturbances.

At site S_4 in Igonzela swamp, the substrate was predominantly muddy, aquatic vegetation was abundant, and water movements were minimal. This area has been subjected to the indirect effects of artisanal mining, since it is located several kilometers downstream from the primary area of mining operations. The result was increased water clarity and considerably less direct physical disruption of the benthic habitat. Combined with the local abundance of aquatic vegetation and increased light penetration in the water column to support primary production, site S_4 appears to provide more suitable habitat conditions for benthic communities. However, fine sediments in the substrate may promote anoxic conditions, which are unsuitable for many species of macroinvertebrates.

At sites S_1 and S_2 on the Bulyanhulu River, the substrate consisted of coarser sediments, aquatic vegetation was less prevalent, and water movement was more pronounced than at site S_4. In particular, site S_1 had a coarse pebble bottom and a moderate to strong current flow. These conditions are favourable for macroinvertebrates like caddisflies, which prefer conditions of high flows and coarse substrates. However, human activities at these locations had resulted in direct physical disturbance to the river channel and decreased water clarity. Sedimentation of the river substrate was also observed, raising the concern of decreased oxygen availability to organisms that reside in the substrate. These factors appear to have resulted in less favourable habitat conditions for benthic communities.

At site S_3 on the Kabhanda River, the substrate was predominantly muddy, aquatic vegetation was sparse, and the amount of water movement was negligible. While reduced flows were mainly the result of decreased precipitation in the area, artisanal mining activity upstream had disrupted the normal flow pattern. In addition, gold ore washing had introduced significant amounts of tailing material to the river, causing sedimentation in the river channel and increased turbidity in the water column. The resulting conditions appear to be unfavourable to many macroinvertebrate species and are likely the cause of the low species diversity and abundance.

Macroinvertebrate communities are useful indicators of ecosystem health. In particular, the presence or absence of specific taxonomic groups in benthic communities can act as indicators of water quality. For example, chironomids have been used as a pollution indicator organism in water quality assessments, since some species are tolerant of poor water quality conditions. They often proliferate in the absence of other competitors which are adversely affected by pollution. During the study, chironomid larvae accounted for 52 % of the macroinvertebrate specimens collected. This may suggest that poor water quality exists in the area. The source of the potential water quality problem may be more difficult to identify, since it may have resulted from a combination of factors, including artisanal mining, sewage, and agricultural runoff.

The absence of indicator organisms can also be used for water quality assessments, provided that the limitations of the resulting conclusions are recognised. For example, since Ephemeroptera, Plecoptera, and Ephemeroptera (EPT) taxa generally indicate relatively clean water, their absence may be the result of poor water quality conditions. However, without the assistance of pre-disturbance baseline data, it is difficult to establish if indicator organisms were ever present in the local aquatic environment. Therefore, while pollution sensitive taxa were not identified during the study, it is inappropriate to conclude that they were displaced by pollution or other disturbance.

Benthic community assessments were conducted on the Kinhansi River in Tanzania by Ndaro (1995). In the Kihansi River, average faunal densities were calculated to be 13 to 16 specimens/cm^2. Average faunal densities in the Bulyanhulu study area are presented in Table 4-24. Faunal densities ranged from 0.13 specimens/cm^2 at site S_1 to 1.51 specimens/cm^2 at site S_4. The average faunal density of 0.88 specimens/cm^2 is considerably less than the average from the Kihansi River. Based on the comparison of faunal densities, the benthic communities in the Bulyanhulu Project area appear to be unusually poor. However, this comparison are only valid if the Kihansi River provides an accurate representation of typical benthic community productivity in the region.

4.8.3 Algae and Aquatic Macrophytes

4.8.3.1 Periphytic Algae

Background

Periphytic algae are nonvascular aquatic plants that colonise river and lake substrates. As photosynthesisers, algae form the base of the aquatic food web. Algal concentrations and population composition vary seasonally with changing photoperiod, temperature, nutrient levels, and flow regimes. Periphyton can provide a valuable biological monitoring tool to assess potential impacts of nutrient enrichment and metal toxicity.

Of the different groups of algae, the diatoms tend to be good indicators of environmental changes. The diatoms are ecologically diverse, and will colonise a variety of surfaces including plants, rocks, muddy soils, and animals. Periphyton communities are generally developed in areas where water movements are sufficiently strong to impede the settling and deposition of fine sediments. Increases in periphyton can sometimes be attributed to increases in UV light and increases in temperature. Decreases may be related to decreases in nutrient levels.

The rates of growth, nutrient absorption, respiration, and photosynthesis are better for periphyton in moderate currents than in slow currents or tranquil waters. High temperatures (35°C or greater) induce an increase in cyanobacteria and blue-green algae and a decrease in diatoms. Diatoms respond quickly to environmental changes such as eutrophication, metal loadings, changes in salinity, and dissolved oxygen. In many cases, such environmental changes will alter species composition and/or cell density.

Taxonomic identification and relative abundance ranking of the algae samples provide information on community complexity and composition. Species presence information allows comparison to known community associations from the literature and regional studies, and can be used to predict impacts. This qualitative sampling should be able to detect gross changes in the dominant species.

Results and Discussion

During the field studies program, suitable substrates for the growth of periphytic algae were not observed. Therefore, periphytic algae were not found. The lack of suitable material for algal growth can be attributed to a number of factors:

- the lack of hard substrate material in the local stream beds (e.g. boulders, cobble, large woody debris, and aquatic vegetation);
- the scouring of the stream substrate by high flows;
- the low stream gradients, absence of riffle-pool habitats, fine sand or muddy sediment stream bottoms; and,
- the introduction of tailing material to the river channel, causing the destruction and displacement of aquatic habitat.

The absence of periphytic algae may also be the result of other environmental factors besides the apparent lack of a suitable physical substrate. Some groups of aquatic algae, particularly diatoms, are sensitive to water quality. Elevated metals, temperature, and turbidity are known to inhibit the growth of diatoms and other algae. Since increased turbidity reduces light transmission in the water column, photosynthesis of periphytic algae may be reduced. One or more of these factors may be occurring in the Bulyanhulu Project area inhibiting algal growth.

Periphytic algae often respond to seasonal fluctuations in the availability of food, nutrients, light, and substratum. Grazing by invertebrates may also influence algal populations on a seasonal basis. Therefore, the absence of periphytic algae observed during the study may be a seasonal occurrence.

4.8.3.2 Aquatic Macrophytes

Background

The term aquatic macrophyte generally refers to the macroscopic forms of aquatic vegetation, and encompasses macroalgae, the few species of mosses and ferns adapted to the aquatic habitat, as well as true angiosperms. Four groups of aquatic macrophytes can be distinguished as follows:

- *emergent macrophytes* grow on water-saturated or submersed soils from where the water table is about 0.5m below the soil surface (supralittoral) to where the sediment is covered with approximately 1.5m of water (upper littoral);
- *floating-leaved macrophytes* are rooted in submersed sediments in the middle littoral zone (water depths of approximately 0.5m to 3m), and possess either floating or slightly aerial leaves;
- *submersed macrophytes* occur at all depths within the photic zone; and
- *freely floating macrophytes* are not rooted to the substratum; they float freely on or in the water and are usually restricted to nonturbulent, protected areas.

Aquatic macrophytes are often essential components of aquatic ecosystems. They provide substrate and cover for a number of organisms, including fish, invertebrates, and algae. Aquatic macrophytes also contribute organic material to the water as detritus, which consists of dead particulate and dissolved organic matter. Dissolved organic matter is about 10 times more abundant than particulate organic matter in most aquatic ecosystems. Much of the newly synthesised organic matter of photosynthesis is not consumed by animals, but instead enters the detrital pool and is decomposed.

Results and Discussion

General observations on the presence of dominant species of aquatic macrophytes were recorded at each sampling station. In general, species abundance and diversity were considerably higher at site S_4 in Igonzela swamp. The fringing aquatic vegetation included a mixture of echinochloa grass (*E. pyramidalis*), papyrus (*Cyperus involucratus* and *C. papyrus*), and water lily (*Nymphea capensis*). These species are characteristic of wetland habitats, since they require standing water and nutrient rich substrata.

At sampling locations on the Bulyanhulu and Kabhanda Rivers, artisanal mining had displaced much of the fringing aquatic vegetation along the river channel. Echinochloa grass was the dominant aquatic vegetation at sites S_1 and S_2 on the Bulyanhulu River, although its distribution was limited to the fringes of the wetted portion of the river channel. At sites H_1 and S_3 on the Bulyanhulu and Kabhanda Rivers, the level of disturbance caused by artisanal mining was greater, resulting in the absence of aquatic vegetation.

Since aquatic macrophytes are sensitive to desiccation, their distribution is restricted by low flow conditions during the dry season. At some locations, they may be present on a seasonal basis when sufficient water is present. Since sampling occurred at the beginning of the dry season, low water conditions may have displaced some of the aquatic vegetation that was present earlier in the year. This may be particularly true on the Kabhanda River, where a large percentage of the stream bed was dry at the time of sampling.

4.9 SOILS

4.9.1 Introduction

Soil resources of the project area were described and assessed, particularly from the perspective of soil fertility related to reclamation of lands disturbed by mining. Potential for use of soils in progressive reclamation and in the post-mining landscape is of significance in mine planning and design, and directly affects land use of the area.

4.9.2 Methods

Data on soil descriptions were provided through studies conducted by Golder Associates Ltd. (Golder) during their June 1997 geotechnical site investigation work. Golder placed 41 test pits at the proposed locations of the mill site, shaft area, tailing impoundment area Option 1, tailing impoundment area Option 2, potential borrow areas, and the mbuga area. Locations of test pits are shown on Figures 4-25 (mill site area) and 4-26 (tailing pond options).

Data on chemical constituents of local soils were obtained by analysing soils samples from 20 of the test pit locations and were summarised in a report prepared by WEGS, 1997. Samples were taken from the first 15 cm from the surface of test pits. Approximately 1 Kg of sample was placed into a double plastic bag and tagged with location, date, time, and initials of the sampler. Soil samples were analysed in Tanzania by SELIAN National Service Laboratories (SELIAN) (fertility analyses) and Mlingano National Soil Service Laboratory (Mlingano) (physical analyses). Ten of the samples were analysed for metals and soil fertility parameters in Tanzania while sub-samples of all 20 samples were sent to Acme Analytical Laboratories in Canada for 24-element ICP analysis. A sub-sample of 200 g was retained at SELIAN for further testing or verification. Disposition of the 20 samples is summarised in Table 4-25.

Physical analyses performed by Mlingano included:

- volumetric moisture content (in percent; six point water retention);
- bulk density (g/cc);
- particle density (g/cc); and,
- water storage capacity.

Fertility analyses performed by SELIAN included:

- pH;
- electrical conductivity (EC);
- nitrogen (as %);
- organic carbon (as %);
- carbon/nitrogen ratio;
- phosphorus (as mg/Kg);
- cation exchange capacity (CEC as %);
- calcium (as meq/100g);
- magnesium (as meq/100g);
- potassium (as meq/100g);
- sodium (as meq/100g);
- silicate (as %);
- carbon (as %); and,
- sulphur (as %).

4.9.3 Results

4.9.3.1 Soils and Distribution

The project area is characterised by well drained, gently undulating to rolling topography. Underlying bedrocks are mainly granite and gneiss. Soils have developed from weathered granite and gneiss and are generally reddish, sandy clay loams and clay loams.

According to Golder, the surficial geology of the project area is relatively simple, comprising an upper zone of transported soils overlying residual soils. In areas of higher ground, the upper transported soil comprises slightly clayey, silty sands and organic topsoil, and is typically less than 1 m thick. In the low lying mbuba areas, these soils are typically replaced by expansive silty clays which are in the order of 1.0 m to 1.5 m thick. Residual soils which underly the transported soil are present in a number of forms due to modification of parent material through weathering and laterization. The degree to which each of these aspects has affected the parent material, as well as the original composition of the parent material, define the present form of the soil horizons. Little laterization appears to have taken place in the vicinity of the Mbugas.

A good example of soil development in the project area is the location of the box-cut. Golder (1997) described soil structure at the exposed 30 m face of the box-cut as consisting of a thin layer of silty, clayey sand topsoil overlying a dense to very dense, well cemented orange and red, sand and gravel (ferricrete), which grades to moderately to poorly cemented sand and gravel, with some silt (laterite). The laterite becomes siltier and/or more clayey with depth, with the degree of cementation also reducing. The orange and red colour grades to white and cream with some red bloching. Residual soils (likely andesites) underlie the laterites; these comprise clayey silt and sand, with some relict joints evident. The material is very stiff/dense and grades to a very soft, heavily weathered rock with depth. At about 20 m below grade, a grey, heavily jointed weathered rock is present.

In terms of soils characterisation, soils in the project area are relatively uniform. Test pits by Golder Associates (1997) indicate a topsoil layer varying from 15 cm to 60 cm, comprised of brown or grey-brown, compact, sandy silt with a trace of clay. This is generally underlain by orange and red sand and gravel, with black mottling and a trace of silt down to approximately 2.4 m. Well cemented ferricrete and laterite are also found in the lower layer.

The mbuga area consists of a wide area in relatively level ground between Bariadi and Lwabakanga, extending north and eventually west to meet the Bulyanhulu River near Nambatatu. This area appears to be often covered with water during the rainy season. Soils in this area have been affected by seasonal wet periods, which have resulted in a subsurface layer of at least 1.3 m of firm to black silty clay with numerous slickensides, overlying grey speckled white, stiff clayey silt. The lower layer comprises residual soils.

4.9.3.2 Fertility and Reclamation Potential

The potential fertility of a soil is defined as its capacity to retain nutrients, and to supply nutrients to plant roots. Soil fertility can be assessed from its physical and chemical properties. Physical properties of relevance are depth, texture, and structure. Chemical properties are mainly constituent concentrations (see above in Section 4.9.2).

Data on chemical and physical properties of soils tested from the project site are summarised in Table 4-26, from analyses conducted by SELIAN. Soil ratings assessed from physical properties are summarised in Table 4-27, from analyses conducted by SELIAN. Hydraulic properties of soil samples are summarised in Table 4-28, from analyses performed by Mlingano.

On the basis of physical and chemical analyses, the following conclusions were made with respect to soil fertility considerations:

- organic carbon level in soils from the project area ranged from 1.57 % to 3.13 %, which is considered medium to high;
- the C/N ratio ranged from 6.9 to 8.7, implying good quality of organic matter;
- available phosphorus content ranges from low to high, averaging medium;
- cation exchange capacity is relatively high;
- soils are generally acidic; and
- soils are of low salinity.

Soils of the project area are assessed as having medium inherent soil fertility that can be used for a wide range of crops, providing that moisture limitations are managed. The major limiting factor for growth of crops or vegetation is lack of moisture, resulting in drought conditions.

In terms of reclamation potential, soils of the project area are suitable for supporting vegetation.

4.9.3.3 Background Metal Levels

Data for metals are provided in Table 4-29, from analyses performed by Acme Analytical Laboratories. The Acme analytical certificate is given in Appendix 4-7. Baseline metals levels provide some information on trace elements needed for plant growth and also as background for possible future monitoring to evaluate post-mining metals levels in soils.

Background metals levels should not impede the growth of vegetation. This is confirmed by the observation of natural vegetation growing quickly on the site.

Comparing soil samples metals levels to soil standards given in the British Columbia (Canada) Contaminated Sites Regulation, Schedule 4, exceedances of agricultural land use standards were as follows:

- slightly higher cobalt in two soil samples (TP97#13 at 50 mg/Kg (ppm) and TP97#22 at 91 mg/Kg) compared to the standard of 40 mg/Kg;
- slightly higher vanadium at TP97#22 at 261 mg/Kg compared to the standard of 200 mg/Kg;
- slightly higher mercury at TP97#8 at 863 mg/Kg compared to the standard of 800 mg/Kg; and,
- most soil samples had elevated boron values (up to 42 mg/Kg) compared to the standard of 2.0 mg/Kg (water soluble).

With respect to the boron levels in soil samples, these are considered to be either background, or possibly elevated due to disturbances related to artisanal mining. The former is considered more likely since the soil samples were collected in areas thought to be unimpacted. As boron is water leachable, concentrations would decline over time if they are elevated above background. The levels are not expected to inhibit vegetation growth.

4.10 VEGETATION

4.10.1 Introduction

The flora of Tanzania is amongst the richest in East Africa, comprising an estimated 10,000 species, of which approximately 11% are endemic (Missouri Botanical Gardens, 1993). Tanzania has a remarkable diversity of habitats, ranging from humid tropical rain forest to semi-arid thicket and savannah, as well as areas of afro-montane and afro-alpine vegetation. It is estimated that more than 50% (approximately 44.4 million hectares) of the country's total land area is covered by indigenous vegetation (Mitawa and Marandu, 1995).

The study and description of the vegetation of East Africa is a constantly evolving process. Although new species are now discovered only sporadically, the analysis and mapping of communities is less advanced. There is complete vegetation map coverage for Uganda at 1:500,000 scale, but for Tanzania mapping at this detail is confined to individual forests, parks, or development areas (Pratt and Gwynne, 1977). Several national and international institutions, including the National Herbarium of Tanzania, the Royal Botanical Gardens at Kew (England), and the Missouri Botanical Gardens (United States of America), are currently working to improve the state of botanical knowledge in Tanzania.

The vegetation of an area can have numerous values, including: timber resource; grazing potential; wildlife habitat; and, scenic attraction (aesthetic value). Vegetation is also important when considering habitat for tsetse flies or other disease vectors, and as an indicator of climatic conditions or cultivation potential. The vegetation of an area can serve several ecological functions. These functions include:

- soil stability and enrichment;
- filtration and moderation of surface water flows;
- moderation of temperature;
- influence on precipitation patterns;
- structural habitat for wildlife; and
- food sources for wildlife and people.

In most cases, the vegetation of an area is likely to hold several values concurrently, and this report assumes that such is the case in the Bulyanhulu Project area.

Amongst environmental parameters, baseline vegetation data are particularly useful because the flora of an area are integrators of environmental factors which reflect climatic, physiographic, edaphic and biotic features pertaining to the land on which it grows. In addition, long-lived species can provide an indication of environmental conditions of the recent past (Timberlake *et al.*, 1993).

4.10.2 The Bulyanhulu Vegetation Study

The Bulyanhulu Project lies within a thicket and savannah area of the Central Tanzanian Plateau which, relative to other regions of Tanzania, is relatively flat and lightly treed. A 1.5 km x 1 km fenced rectangular enclosure demarcates the current activities at the site centre. The major development features within this area are described in Section 2.

Knowledge of the vegetation prior to mine start-up at the Bulyanhulu Project is critical to ascertain baseline values which will serve as minimum reclamation objectives during closure of the mine. Mitigation measures will be designed based upon the baseline vegetation inventory.

Prior to human-induced impacts to the region, the major vegetation type was probably woodlands, varying from *Brachystegia* (Miombo woodland) to *Combretum* woodland. Thickets and bushlands were also likely prominent components of the landscape.

The Bulyanhulu Project area vegetation has been severely disturbed in the recent past by artisanal mining, human settlement, and earlier mining exploration activities. It is probable that the majority of the original vegetation was cleared in association with the artisanal mining operations, although there is no record of previous botanical studies for the area. Clearing would have been done to open sites for mining pits, as well as for the harvesting of fuel-wood and construction materials.

Other human-induced disturbances to the vegetation pre-date the activities of the artisanal miners. Agriculture and cattle grazing have probably been conducted in the region since the 1800s. In the 1930s through to the 1950s, the German and then British governments attempted to control tsetse fly populations to curtail disease epidemics. Tsetse flies carry a parasite that can infect both humans and cattle with serious illnesses. The flies require the shade of thick vegetation to carry out their lifecycle. Resettlement of human populations into concentrated localities was promoted in the belief that the localities would be devegetated and so become free of tsetse flies and disease. The change in distribution of people from a dispersed agricultural landscape to concentrated settlements had major affects on the area vegetation, causing great areas of previously-tilled soil to become fallow, punctuated with cleared, settled areas. After the government abandoned the resettlement scheme, agriculture once again became more dispersed.

4.10.2.1 Study Objectives

A comprehensive study was carried out to detail the current vegetation at the Bulyanhulu Project site and surrounding areas. The study objectives were to:

- carry out a survey of the natural vegetation at the mine site and surrounding area within the prospecting concession;
- identify natural vegetation units; and,
- provide baseline data on metal levels in plant tissues.

4.10.2.2 Study Sample Site Selection

Prior to undertaking detailed field research, aerial photographs were examined to produce preliminary typing of vegetation at the site and in surrounding areas. This was followed by a reconnaissance survey to choose suitable transect sites, based on the vegetation pre-typing. Transect sites were marked on a map and the Universal Transverse Mercator (UTM) coordinates were recorded, using a Global Positioning System (GPS), to facilitate locating the transects in future monitoring work.

Sampling was carried out during the height of plant growth in the wet season during the latter part of May 1997. This is the optimum time of year for identifying the vegetation present in the area. The vegetation is much less abundant, or dormant, in the dry season. Three transects were established within the fenced area of the mine site, 5 transects were located in the immediate area surrounding the mine site, and 2 transects were located on the north side of the Bulyanhulu River, in an area that was designated as the control (Figure 4-27). The area selected as a control was located 2.5 km northwest of the Geita Road crossing at the Bulyanhulu River. The vegetation present at this site appeared to be less affected by artisanal miners than was the case for other sites, and was representative of typical area vegetation.

4.10.2.3 Study Methods

A transect belt method was employed for vegetation sampling. This method was chosen to allow for the use of nested plots to record plant species at different spatial scales. The transect lines were designed to identify representative species of natural vegetation within the categories identified from the aerial photo pre-typing. Within each transect, a series of individual, adjacent sampling plots were established. Large plots, measuring 50 m by 20 m were used to sample for tree species. Two smaller plots were demarcated within each large plot; a 2 m by 5 m plot for sampling shrubs, and a 0.5 m by 1 m plot for sampling herbs and grasses. A total of 90 plots were sampled during the study. These plots were nested within 10 transect lines. Transects were at least 250 m long, containing five 50 m by 20 m plots. Longer transects were established where vegetation exhibited greater heterogeneity, to a maximum of 1000 m (20 plots). Transect locations are illustrated in Figure 4-27.

For the purposes of this study, descriptive terms follow Beentje (1994). A record was made of the number and species of each tree, shrub, grass, and herb observed within each plot. The crown cover, height, and diameter at breast height (dbh) of each tree encountered was also measured and recorded.

In addition to the 10 transects, a qualitative assessment of the riparian vegetation along the Bulyanhulu River was conducted at three sites which coincided with water quality sampling stations (Figure 4-7). Qualitative observations were also made at the former Bariadi settlement.

Preliminary identification of plant materials was done in the field. Plant specimens were taken to the Herbarium, Department of Botany at the University of Dar es Salaam for confirmation using relevant keys (Hubbard, *et al.* 1952; Beentje, 1994) and/or matching with herbarium specimens. Voucher specimens of each species were deposited with the herbarium.

4.10.2.4 Data Analyses

All data were tabulated and descriptive statistics were calculated including:

- sum of the total number of individuals of each species found in a transect;
- sum of the total number of plots of a transect in which each species was found;
- sum of the total number of individual specimens in each transect;
- sum of the total number of species found in a transect;
- relative frequency of occurrence of each species per transect (number of plots where species occurred in a transect divided by the total number of plots in that transect, given as a percent);
- relative abundance of each species per transect (number of individuals found of the species divided by the total number of individuals of all species in that transect, given as a percent[1]);
- relative frequency of occurrence of each species per vegetation type (number of plots where species occurred in all transects within the vegetation type divided by the total number of plots in those transects, given as a percent); and
- relative abundance of each species per vegetation type (sum of individuals of the species found in all transects within the vegetation type, divided by the total number of individuals of all species in those transects, given as a percent[1]).

Relative frequency values provide information on the probability of a given species to be observed in a given transect or area, with no consideration of how many individuals were counted. Relative abundance values consider the number of individuals of a given species found in an area. In this study, relative frequency and abundance were calculated to provide an understanding of the ratio of plant types within each area to be used later during mine closure and reclamation.

4.10.2.5 Metals in Vegetation

Sampling of plant material for use in analyses for metals content was carried out in 3 sites in the Bulyanhulu Project area. The sample sites were located at 3 vegetation plots, found on Transects 7 and 9, and at Water Quality Site (WS) 2 on the edge of the Bulyanhulu River (Figure 4-27). Each site measured 5 m by 5 m, and was subdivided into twenty-five 1 m by 1 m plots. Sixteen plots were randomly selected from the 3 sites for sampling. Three replicate tissue samples were taken from the dominant species present in each plot. Samples were stored in sealed plastic bags. Voucher specimens were identified at the Herbarium, Department of Botany at the University of Dar es Salaam.

Samples were shipped to Philips Analytical Services Corporation in Vancouver, Canada, for laboratory analyses. At the laboratory, the samples were dried at ambient temperature and then ground with an electric grinder to achieve a uniform consistency. Digestion with a nitric-

[1] The herb, grass and shrub plot counts were multiplied by the appropriate factor in order to be compared with the tree plot counts. The tree plots (20 m by 50 m) had a surface area of 1000 m^2. The herb and grass plots (0.5 m by 1 m, surface area = 0.5 m^2) were multiplied by 2000, and the shrub plots (2 m by 5 m, surface area = 10 m^2) were multiplied by 100.

hydrochloric acid mixture was done to solubilise the solid matter and to remove the organic material by oxidation and volatilisation. The samples were cold digested in the acid mix for 2 to 16 hours, then heat digested for 1 hour at 95 ^{0}C. The completed digests were submitted to metals instrumentation personnel for metals analyses by Inductively Coupled Atomic Emission Spectrophotometry (ICP-AES), and mercury analysis by Cold Vapour Atomic Absorption Spectroscopy (CVAAS).

4.10.3 Results and Discussion

4.10.3.1 Vegetation Identification Survey

In total, 336 plant species were recorded during the study. A preliminary species checklist is provided in Table 4-30. This includes 98 species of grasses, 85 species of shrubs, 66 species of trees, 59 species of herbs, and 28 species of climbers. A detailed description of the species encountered in each plot is provided by transect in Tables 4-31 to 4-40. The percent composition of plants in the total project area, by growth form, is presented in Figure 4-28.

4.10.3.2 Vegetation Classification

White (1983) published the standard vegetation classification system of African flora for the Association pour L'Etude Taxonomique de la Flore d'Afrique Tropicale (AETFAT). This vegetation classification for continental Africa was based on the concept that physiognomic data, and in particular the cover and height of the vegetation, are fundamentally different from chronological data on patterns of species distribution. White's approach was to study these two aspects independently, starting with physiognomy. He developed a system in which major vegetation types are divided into 5 categories. Based on White's system, the Bulyanhulu Project area and the Kahama District in general lie within the Zambezian Regional Centre of Endemism Phytochorion. It is bordered by the Lake Victoria Regional Mosaic, and the Guinea-Congolian Phytochorion.

However, White's AETFAT classification scheme has been shown to contain inconsistencies and loose definitions, making it difficult to apply to ecological studies (Lawesson, 1994). The classification scheme used in this report does not follow the AETFAT system. Rather, it reflects the site-specific, small-scale nature of the study. Vegetation groups have been identified within the context of the study boundaries, according to the dominant species present.

Edaphic qualities were, in general, not limiting (WEGS, 1997). Vegetation groups appear to have formed, except for the riparian areas, as a response to disturbances. The vegetation of the area is dominated by grassland, with coppicing shrubs and scattered trees. The state of the shrubs, and the presence of the trees indicates that the area vegetation was composed of closed thickets and woodlands in the past. It is known that a great portion of the disturbances in the Bulyanhulu area consisted of clearing and harvesting by artisanal miners who, until recently, occupied the area. The riparian vegetation is assembled within the influence of the Bulyanhulu River.

Although the vegetation of the Bulyanhulu area is, in general, relatively homogenous, smaller-scale divisions become evident upon examination. *Combretum* open woodland interspersed with *Hyparrhenia* grassland was found on much of the higher ground of the study area. *Acacia drepanolobium* wooded grasslands are associated with lower areas near the Bulyanhulu River, and are subject to seasonal flooding. In addition, "new" vegetation groups have been created through anthropogenic activities, including agricultural land, buildings, and roads. Within the Bulyanhulu camp, some areas have been planted with a lawn, and some shade-tree species have been introduced (e.g. *Azadirachta indica*, the Neem Tree). The bulk of this study, however, was limited to the dominant naturally-occurring vegetation. Areas surrounding the project site are dominated by agricultural plots, and these areas, although not naturally-occurring, were included within the study. The area's vegetation has been divided into the following six categories (Figure 4-27), based on the data collected in the field and the aerial photo interpretation:

- dwarf *Acacia drepanolobium* wooded grassland;
- *Combretum* coppicing open bushland with scattered thickets on termitaria;
- disturbed *Combretum* open shrub with grassland patches;
- riverine (riparian) vegetation;
- heavily disturbed area with fast colonising weeds and scattered trees; and
- cultivation and settlement areas.

A discussion of each of the above vegetation categories is provided below.

4.10.3.3 Dwarf Acacia drepanolobium Wooded Grassland

This 72 ha vegetation group was sampled by plots 4 to 8 of Transect 1 and plots 2 to 8 of Transect 4 (Figure 4-27). These transects ran from the Bulyanhulu River in a southeasterly direction, almost parallel to the Geita Road. The ends of the transects most proximal to the river covered areas which are seasonally inundated grassland on dark-coloured clay soils. A portion of Transect 1 also ran through an abandoned farm area.

The Dwarf *Acacia drepanolobium* Wooded Grassland Area was dominated visually by the shrub *Acacia drepanolobium* (Plate 4-9), which was observed in 86 % of the plots sampled (Table 4-41). *Combretum adenogonium* was also observed in 86 % of the plots, but was less abundant. Grass species had the highest relative abundance (Plate 4-10), especially *Hyparrhenea small* (27 %), *Heteropogon contortus* (23 %), and *Brachiaria sp.* (17 %). Five species of trees were found in this vegetation group (Table 4-41). The most frequently encountered herbs in the two transects were (with relative frequency within the vegetation category): *Cassia mimosoidea* (57 %); *Chlorophytum sp.* (57 %); *Craterostigma plantagineum* (29 %); *Dicoma anomala* (29 %); *Sida sp.* (29 %); and *Zornia glochidiata* (29 %).

4.10.3.4 Combretum Coppicing Open Bushland

This vegetation group occurs in a band along the north west edge of the project site in sandy to gravely soil, occupying approximately 14 ha (Figure 4.10.1). Two sample plots (Plots 9 and 10, Transect 4) were positioned within the *Combretum* Coppicing Open Bushland vegetation group. Several *Combretum* shrub species were present, including (with relative abundance): *C. molle*

(0.09 %); *C. adenogonium* (0.09 %); and *C. padioides* (0.03 %, Table 4-42). Although the area had been impacted recently by anthropogenic activities, signs of natural regeneration (coppicing) of these shrubs were evident. *Zanthoxylum chalybeum* and *Commiphora africana* (0.24 % and 0.12 %, relative abundance, respectively) were also highly abundant within the plots sampled.

The dominant grasses present were *Hyparrhenia small* (41.8 % relative abundance) and *Urochloa ochinolaenoides* (41.8 % relative abundance). Dominant herbs included *Indigofera spicata* (2.4 % relative abundance), *Justicia exigua* (1.8 %), and *Cassia mimosoidea* (1.2 %) (Table 4-42). Three tree species were observed: *Linnea discolor*; *Grewia conocarpa*; and *Tamarindus indica* (Table 4-42). Of these, *Tamarindus indica* had both the largest diameter and height, averaging 30 cm and 10 m, respectively (Table 4-43).

4.10.3.5 Disturbed Combretum Open Shrubland with Grassland Patches

This vegetation category occupies approximately 887 ha; the greatest portion of the total project area (Figure 4-27). Many components of the proposed mine development will occur within its boundaries, including the mill, waste rock storage area, and some housing facilities. Much of this area has already suffered greatly from the activities of artisanal miners. Very little vegetation remains at the former Doboro village site, located at the southwestern part of this area. Intensive sampling was carried out in this area in order to reliably characterise the vegetation.

Transects 5, 6 and 7 were located within the fenced project area. Transect 5 was laid almost parallel to the southeast edge of the fenced area, running from the southwest edge to the Skanska offices (Figure 4-27). This transect was dominated by *Combretum* coppicing woodland, especially *C. adenogonium* (0.26 % relative abundance in the transect) and *C. molle* (0.23 %) (Table 4-35). A few large standing trees, including *Combretum padioides* (largest tree with mean dbh of 42 cm, mean height of 22 m, Table 4-44), *Ziziphus reticulata, Lannea sp*., and *Annona senegalensis* were present, indicating that large trees were originally dominant here. *Dalbergia melanoxylon* was also present. This is a rare species, and cutting is prohibited by law in Tanzania. Much of the wood previously available was likely used for the production of charcoal. Abandoned charcoal kilns were observed in the area.

Transect 6 ran parallel to the northwest edge of the fence, across the Magazine area (Figure 4-27). The proposed sites of the ore stockpiles and sedimentation pond lie just to the east of this transect. The area within and surrounding the transect was punctuated with termitaria which support characteristic vegetation. A few scattered trees were also present, such as: *Commiphora africana* (largest mean dbh - 30 cm, Table 4-45); *Lannea sp*.; *Phyllanthus sp*. (mean height of 12 m); *Thilachium sp*.; and *Acacia nilotica* (mean height of 12 m). Other remnant trees noted in the area included: *Brachystegia spiciformis*; *Bobgunnia madagascariensis*; *Ozoroa insignis*; and *Combretum adenogonium*. The area toward the northeastern edge of the fence was greatly affected by artisanal miners. Colonising weeds and grasses dominated that sector (Plate 4-11). The African Blackwood Tree, *Dalbergia melanoxylon*, was observed near Transect 6, predominately in the area of the explosives magazine.

Transect 7 ran parallel to the southern edge of the fence (Figure 4-27). This transect contained an area of past human settlement where some houses were built. This portion of the transect is considered to be in the "heavily disturbed" vegetation category. Trees and shrubs were scarce (Plate 4-12). Colonising herbs and grasses dominated (Table 4-37).

The remainder of Transect 7 was dominated by the grasses *Andropogon fastigiatus* (relative abundance 42 %, Table 4-37), and *Chloris pachnothrix* (9 %). *Combretum adenogonium* was the most abundant shrub (0.21 %). Several trees were scattered along Transect 7. Of these, *Acacia etbaica* was the largest, with a mean dbh of 60 cm, and a mean height of 12 m (Table 4-46).

Transects 8, 9 and 10 were located to the south of the fenced area, near the airstrip (Figure 4-27). This region was characterised by coppicing *Combretum* shrub grassland with scattered termitaria and associated vegetation. Shrubs, including *Combretum adenogonium*, *Commiphora africana*, *Bridellia micrantha*, *Harrisonia abyssinica*, and *Senna singuena* were dominant. *Dichrostachys cinerea*, an indicator of past disturbance, was also present.

In Transect 8, *Combretum adenogonium* had the highest relative frequency (100 %, Table 4-38), as well as the highest relative abundance amongst shrubs (0.22 %). *Hyparrhenia small* dominated the grasses (relative abundance 66.5 %), followed by *Heteropogon contortus* (22 %). The most abundant herbs were *Justicia sp.* (1.8 %) and *Hypoestes forskalei* (1.5 %). *Rhus natalensis* was the most abundant of the 5 tree species present in Transect 8 (Table 4-38) and *Commiphora sp.* attained the greatest height (18 m, Table 4-47).

In Transects 9 and 10, *Combretum adenogonium* had the highest relative frequency and abundance of the shrubs present, and *Hyparrhenia spp.* dominated the grasses (Tables 4-39 and 4-40). In Transect 9, the herb layer was dominated by *Sida sp.* (3.5 % relative abundance), *Justicia exigua* (2.8 %), and *Euphorbia sp.* (2.8 %) (Table 4-39). In Transect 10 the herb layer was dominated by *Justicia spicata* (6 %), *Emilia coccines* (3 %),and *Eriosema sp.* (3%) (Table 4-4-40). Only 2 species of trees were observed in Transect 9: *Ozoroa insignis*, and *Zanthoxylum chalybeum* (Table 4-48). Four tree species were found in Transect 10, including the rare *Dalbergia melanoxylon* (Table 4-49).

Combined relative frequency and relative abundance data from all 6 transects of the disturbed *Combretum* open shrubland vegetation category were compiled and are presented in Table 4-50. Grass was by far the most abundant growth type, dominated by: *Andropogon fastigiatus* (15 % relative abundance); *Hyparrhenia sp.* (12 %); *Hyparrhenia small* (9 %); and *Hyparrhenia rufa* (8 %) (Table 4-50). Prevalent herbs included: *Cassia mimosoides* (2 %); *Phyllanthus sp.* (1.3 %); *Vernonia posckeana* (1.2 %); and *Euphorbia hirta* (1.1 %).

Combretum adenogonium and *C. molle* were the dominant shrubs of the area, followed by *Commiphora africana* (Table 4-50). Twenty-eight species of trees were identified within this vegetation group, with the majority occurring upon termitaria. The most abundant trees were *Pericopsis angolensis* and *Ozoroa insignis*.

4.10.3.6 Riverine (Riparian) Vegetation

Three sites were visited along the Bulyanhulu River for the purposes of documenting the floristic composition of riparian vegetation. The sites coincided with water quality sampling sites W1, W2, and W3 (Figure 4-7). The bulk of the riparian sampling was qualitative. One plot (Plot 1, Transect 1) was sampled in this vegetation group (Table 4-31).

At W1 near the Kakola village, the flood plain was bordered by *Acacia drepanolobium*, *Ormocarpum trichocarpum*, and *Acacia polyacantha*, growing in the fringing mbuga clay. *Mimosa pigra* and *Polygonum setulosum* occurred closer to the river bank. Emergent vegetation was typical of swampy areas (Plate 4-13). Two botanically interesting species were collected from this site: wild rice (*Oryza longistaminata*); and Wild Date Palm (*Phoenix reclinata*). Both species could benefit from conservation efforts. *Oryza longistaminata* is an important source of genetic material for experiments in breeding with cultivated rice species to produce high yielding or disease resistant varieties. *Phoenix reclinata* is widely used for basketry, where young leaflets of the unexpanded leaf are cut and dried, thus arresting growth and seed production.

Site WS2 was located at the Geita Road crossing. This area was characterised by grouped trees of *Dicrostachys cinerea*, *Ficus natalensis*, *Manilkara mochsia*, and *Syzygium guineense* (Plate 4-14). *Olea capensis* also occurred in the area, which is interesting in that it is generally considered a moist upland forest species.

Relatively little disturbance has occurred at site WS3, which is reflected by the presence of large trees (Plate 4-15). The area is composed of bushed vegetation characterised by emergents such as *Acacia robusta usambarensis*, as well as climbers such as *Combretum obovatum*, *Acalypha ornata*, and *Grewia hexantha*.

4.10.3.7 Heavily Disturbed Areas

An area of former settlement (Bariadi) lies to the southeast of the mine site (Figure 4-27). It was the major settlement for artisanal miners, probably housing in excess of 5,000 individuals. The settlement was abandoned in August of 1996. Left behind is a highly disturbed area (Plate 4-16), with an approximate surface area of 76 ha. The area was qualitatively sampled as part of the vegetation study. Only a small number of standing trees were observed, occurring near a wetland. These included: *Combretum sp.*, *Acacia tortilis*, *Lonchocarpus cappasa*, *Grewia bicolor*, *Albizia harveyi*, *Albizia petersiana*, and *Diospyros abyssinica*. Termitaria in this area provided habitat for *Tarenna graveslens*, *Ficus natalensis*, and *Senna obtusifolia*. At the edge of waterholes, *Murdania semiteres* was common.

Most of the sites formerly occupied by houses and their immediate surroundings were dominated by colonising weeds and herbs. These included: *Ricinus communis*, *Solanum nigrum*, *Datura stramonium*, *Amaranthus hybridus*, *Solanum incanum*, *Solanum arundo*, *Lantana camara*, *Acanthospermus hispidus*, *Tagetes minuta*, *Hibiscus canabinus*, *Aeolanthe repens*, *Vernonia galamensis*, and *Chenopodium opulifolium*.

Transect 7 ran parallel to the southern edge of the fenced area (Figure 4-27). Much of the area covered by Transect 7 had been used as a human settlement area in the recent past. Almost all natural vegetation had been removed. Within this heavily disturbed area, herbs such as *Vernonia sp.*, *Acanthospermum hispidum*, and *Sida alba* dominated.

4.10.3.8 Cultivation and Settlement Areas

This area is the dominant vegetation category surrounding the Bulyanhulu Project area (Figure 4-27). Bushlands and woodlands are greatly reduced in this area, with most of the original vegetation having been modified into a mosaic of farmed and fallow agricultural land. Agriculture has been practised in the area for decades. Burtt (1937) noted that the area west of the Geita Hills was made up of large "islands" of old cultivation in all stages of reversion to bush.

There is considerable pressure on the sparse remaining vegetation for use as building poles, fuelwood, and for the production of charcoal. Misana (1996) has documented many of the aspects related to the reduction of trees in Kahama District. Where trees have been planted by villagers, they are often introduced shade tree species, such as *Eucalyptus* sp. and *Cassia* sp., as opposed to native species which would be more beneficial to wildlife.

Cotton is the dominant cash crop of the area, with maize and rice grown as staples. Additional crops include: cassava (*Mannihot utilissima*); sweet potato (*Ipomoea batatas*); cowpea (*Vigna unguiculata*); millet (*Eleusine coracana*); and groundnut (*Arachis hypogaea*).

Plots 2 and 3 from Transect 1, and Plot 1 from Transect 4, occur within the cultivation and settlement vegetation category (Tables 4-31 and 4-34, respectively). Within these plots, *Corchorus fascicularis* was the dominant herb, and both *Hyparrhenia rufa* and *H. small* dominated the grasses. *Dalbergia melanoxylon*, a rare and protected species, was amongst the few woody species detected in this area.

The dominant species of this vegetation group varied. In areas close to the Bulyanhulu River, the dominant trees were *Acacia polyacantha*, *A. tortilis*, and *Tamarindus indica* (from qualitative observations). South of the airstrip, *Combretum* species dominated.

4.10.3.9 Control Area: Wooded Grassland with Termitaria

A control area was established approximately 2.5 km northwest of the Bulyanhulu River, near the Geita Road (Figure 4-27). This area appeared to have sustained less damage from anthropogenic disturbances, relative to the other sites in the study area. Two transects were laid in the area (Transects 2 and 3, Tables 4-32 and 4-33, respectively).

In general the area is characterised by scattered termitaria. These support thick bushes (Plates 4-17 and 4-18) dominated by species such as *Albizia petersiana*, *Dombeya kirkii*, *Grewia sp.*, *Haplocoelom foliolosum*, and *Acacia brevispica*.

Twenty species of trees were present (Table 4-51), including *Entandrophragma bussei* (Plate 4-19). This species is used locally for making beehives, beds, chairs and milk containers

(Hubbard, *et al.*, 1952). This species was also the largest found in the area, with mean dbh of 40 cm and a mean height of 20 m (Table 4-52).

Grassland components of this area were comprised primarily of *Hyparrhenia rufa* (4 % relative abundance), *Sporobolus sp.* (3.6 %), *Aristida adoensis* (3.3 %), and *Setaria sphacelata* (2.7 %) (Table 4.10.22). The most abundant herbs in the area were *Aspilia sp.* (16 %), *Blepharis maderaspatensis* (10 %), *Vernonia undata* (5 %), and *Hibiscus sp.* (4 %).

4.10.3.10 Baseline Metals in Vegetation

Vegetation sampling in the Bulyanhulu Project area was conducted to document metals uptake by existing flora. Metals concentrations in vegetation provide a general index to metals bio-availability. Metals can be ingested by ungulates and other herbivores as they browse contaminated vegetation. If present in sufficient quantities, these metals can then accumulate in the animals' tissues, potentially causing diseases or abnormalities.

A total of 20 plant species were sampled from 3 locations for tissue metal content. Philip Analytical Laboratories conducted the analysis. The analytical certificate is given in Appendix 4-8. Results are summarised in Tables 4-53 to 4-55. In general, metal concentrations were low in plant tissues. In many cases their concentration was below detection. Mercury was found in elevated levels only in *Syzygium guineense* samples found at the edge of the Bulyanhulu River, with a mean concentration of 0.10 µg/g (ppm; Table 4-55). This is likely an artifact of the gold-extraction methods used by the artisinal miners, where raw mercury was introduced to the river.

Molybdenum is an element that can have detrimental effects on wildlife and cattle if ingested in large quantities (Jones *et al.*, 1994). High levels of molybdenum in the diet of cattle can cause the disease molybdenosis where interference with the function of copper in the liver causes a functional copper deficiency (Amdur *et al.*, 1991). Miltimore and Mason (1971) determined that a copper:molybdenum ratio of less than 2:1 is unsafe for cattle forage.

Almost all of the plants sampled were found to have copper:molybdenum ratios of greater than 2:1. The only exception was from a single replicate of *Setaria sphacelata* on Transect 7, which had a ratio of 1.6:1 (Table 4-53). The average for the 3 replicates taken of *S. sphacelata* was 4.4:1. There does not appear to be a danger of molybdenosis to wildlife or cattle in the Bulyanhulu Project area, based on the samples taken.

High aluminum concentrations were found in grass species in the plots on Transects 7 and 9 (Tables 4-53 and 4-54, respectively). Many grass species are grazed by wild herbivorous animals or by domestic cattle. Aluminum inhibits fluoride absorption and may decrease the absorption of calcium and iron compounds (Nagyvary and Bradbury, 1977). Effects on animals of increased aluminum levels can include tremors, loss of coordination, weakness, and ataxia, and can result in death (DeBoni *et al.*, 1976). High average aluminum concentrations in grasses found in the Bulyanhulu area included:

- 739 µg/g in *Sporobolus festivus* (Table 4-54);
- 322 µg/g in *Heteropogon sp.*, (Table 4-53);

- 315 µg/g in *Tragia furialis*, (Table 4-54);
- 312 µg/g in *Panicum maximum*, (Table 4-54); and
- 211 µg/g in *Setaria sphacelata*, (Table 4-53).

No other metals were found at levels above expected ambient concentrations in the Bulyanhulu Project area.

4.10.4 Weedy Plant Species in the Project Area

Weed species of plants include those which are adapted to capitalise on disturbed areas. They are generalists, allowing them to colonise areas of low nutrients, with harsh moisture or temperature regimes. They breed quickly and spread rapidly. In some situations, weeds can threaten less hardy vegetation communities through over-taxation of resources. They have been described as plants that "threaten human welfare by competing with other plants that have food, timber or amenity value" (Begon, *et al.*, 1990). Thirty-three species of weedy plants were recorded from the Bulyanhulu Project area (Table 4-56). Of these, the majority were found at the abandoned settlement of Bariadi, an area of severe disturbance.

A record of weed species observed in the project area is provided in this study as a component of the baseline vegetation record. This record serves to demonstrate the presence of weeds prior to project commencement.

4.10.5 Rare Plant Species of the Project Area

Hedberg (1979) compiled a comprehensive list of over 700 rare or vulnerable plant genera in Tanzania. Of these, 26 have been observed in the Bulyanhulu Project area (Table 4-57).

Mitawa and Marandu (1995) have suggested four primary factors which cause plant species in Tanzania to become threatened:

- overgrazing;
- shifting cultivation;
- loss of habitats; and
- destructive harvesting.

All of these factors have potentially affected the vegetation in the Bulyanhulu Project area and its surroundings. In many cases, valuable plant species of the project area have become rare through non-sustainable use. *Dalbergia melanoxylon*, the African Blackwood tree, was recorded in and around the proposed mine site, especially near the magazine area within the fenced compound. Its over-use for carvings and for charcoal burning has caused it to become a threatened species. In other cases, habitat destruction is the cause of a species' decline. Such is the case for wild rice (*Oryza longistaminata*) which was observed in the riparian vegetation on the Bulyanhulu River.

Table 4-58 lists the 12 species observed in the project area which are considered to be vulnerable, threatened, or endangered, according to the World Conservation Monitoring

Committee's list for Uganda (Okullo, 1997). Six species are considered threatened, 4 species are considered vulnerable, and two species (*Aloe christianii* and *Aloe lateritia*) are endangered.

4.10.6 Edible Plants of the Project Area

Many wild-growing plants produce seeds, fruits, or roots, which can be eaten by humans. In the Bulyanhulu Project area, at least 6 species of plants with edible parts have been observed (Table 4-59). These plants comprise only an incidental portion of the local peoples' diet, and are not considered to be important as nutritional sources.

Edible mushrooms also occur in the area. Mushrooms are generally collected and consumed by poor families that do not own herds of cattle to supply them with milk and meat. Although the fungi of the Bulyanhulu area were not directly investigated, Harkonen *et al.* (1995) carried out studies approximately 20 km from the project site. Eight species of edible mushrooms were collected:

- *Cantharellus congolensis*;
- *Lacterius phlebophyllus*;
- *Rusulla ciliata*;
- *Rusulla compressa*;
- *Rusulla congoana*;
- *Rusulla hiemisilvae*;
- *Termitomyces letestui*; and
- *Termitomyces microcarpus.*

It should be noted that the combretaceous vegetation of the Bulyanhulu area may not support the variety of mushrooms found by Harkonen *et al.*(1995), whose study area was dominated by *Brachystegia* (miombo) woodland.

4.10.7 Medicinal Plants of the Project Area

At least 4 species of plants with medicinal qualities have been observed in the Bulyanhulu area. *Sclerocarya birrea* has become listed as a vulnerable species due in part to collection of its medicinal bark (Table 4-58). The roots of *Achyrathes aspera* are used by locals for toothaches, malaria, preventing miscarriages, and as a poison antidote (Mitawa and Marandu, 1995). *Croton dichogamus* roots are used to treat wounds and sore throats, and the bark of *Lannea schweinfurthii* is used as a remedy for chest pains (Mitawa and Marandu, 1995).

4.11 WILDLIFE

4.11.1 Introduction

The past and present flora and fauna of the Bulyanhulu area can be understood if the diverse factors which operated in wide geographical areas in the late 1800s and early 1900s are known. These factors included human settlement, agriculture, trade, plagues of locusts, the introduction of a parasitic "jigger" flea from South America, tsetse flies and sleeping sickness, famine and disease, and successive government attempts to deal with these issues. A major factor in the ecology of the area since the mid-1970s has been the presence of hundreds of artisanal gold miners and associated workers. Interpretation of this complex past is made difficult by the lack of historical data from which to make quantitative comparisons with the present.

4.11.1.1 Early Ecological History of the Area

The area surrounding Lake Victoria has been populated by humans for thousands of years. In Kagera Region, early Iron Age workings go back to at least 500 years B.C. (Schmidt, 1974). The impression is sometimes given that much of this part of eastern Africa was largely uninhabited and was a paradise for the wild fauna and flora until relatively recent times. This was probably not the case as much of the Lake Victoria area was populated and under village cultivation by the 1800s. There were also major trade routes in the area, and there was considerable population migration in the lake region.

Although not all of the area was cleared, nor under permanent cultivation, humans did exert a strong ecological influence, and in some sense control, over the vegetation and fauna, especially the larger mammals. Kjekshus (1996) has discussed the ecology and history of the area in detail and much of what follows is based on his study.

Towards the end of the 19th century what he termed the "man-controlled ecological system" collapsed in East Africa; this was also the time when major European exploration and colonization was taking place. The breakdown of the "man-controlled system" occurred through a series of inter-linked human-induced and natural calamities. These included a massive rinderpest outbreak which virtually eliminated cattle from the economy of the local people, smallpox epidemics, a sand flea plague which crippled and killed many villagers, red locust outbreaks, and famine. Kjekshus (1996) noted that colonial food procurement policies, colonial warfare, labour recruitment policies, and the First World War also had severe negative effects on the local populace. As a result the human and domestic animal populations were greatly reduced. "With fewer people to till the fields and fewer cattle and goats to graze the ground and keep the bush at bay, and with imperial laws prohibiting grass-burning and hunting, nature was quick to commence its recovery" (Kjekshus 1996: 161).

To add to the already grave problems facing the populace and governments at the end of the 19th century, an outbreak of sleeping sickness was reported along the Tanzanian shores of Lake Victoria in 1904. This was brought about by specific ecological imbalances in the relationships between humans, domestic livestock, and wild fauna, and the effects of these changes on the trypanosome parasite and tsetse fly populations (Ford, 1971).

Tsetse flies (*Glossina* spp.) are capable of biting through wild mammal skins, as well as through clothing, to obtain a blood meal. They require the shade associated with dense vegetation for part of their life cycle. Through their bite, the tsetse flies may transmit unicellular parasites, *Trypanosoma* spp., some forms of which cause the disease trypanosomiasis in cattle. Other forms cause "sleeping sickness" in humans. Both diseases are serious and can have dire economic effects.

In response to this sleeping sickness epidemic, the German and then British colonial governments attempted to resettle the people living in scattered settlements within the tsetse infested areas into "sleeping sickness concentrations". These were areas which the government felt had fertile soils, sufficient permanent water, and were suitable for settlement. These areas were then cleared of bush for permanent occupation. The theory was that by concentrating people, they would then cultivate sufficiently large areas to keep away the tsetse flies, which depended on the shade of the thicker vegetation. These same settlements would then serve as foci for education, improved health, and other improvements. It was estimated that each family in each settlement would keep 8-12 acres of land under effective control.

Over 40 % of the 76,000 people who inhabited Kahama District were moved into such sleeping sickness concentrations in 1934. The moves to concentrate people continued throughout the 1940s and 1950s.

However, this strategy did not seem to have the desired effect. Instead, large areas of bush which were formerly kept open under varying systems of cultivation were left to regenerate, precipitating an increase in tsetse populations. The settlement areas themselves were not always pleasant places in which to live, and many social systems and local customs were disrupted.

What had been a landscape largely managed by humans became overgrown with shrubs and trees with only small, concentrated points of settlement and clearing. Wild mammals which were recovering from the rinderpest outbreak moved into the abandoned areas. With their successful recolonization came the expansion of the tsetse fly into areas where formerly cultivation had largely prevented its occurrence. Despite colonial efforts to the contrary, the area occupied by tsetse flies actually increased from 1913 to 1937 (Kjekshus, 1996). Details of the varied attempts to control tsetse through habitat alteration are described by Swynnerton (1936).

4.11.1.2 More Recent Background Information

<u>*Mammals*</u>

In the 1930s and 1940s, an experiment was carried out at Shinyanga and in nearby areas, including Kahama District, in which large numbers of wild mammals were killed because they were believed to act as reservoirs for the trypanosome parasite. Details of the Shinyanga game destruction experiment are given by Potts and Jackson (1952).

The only source of records of mammals for the project area prior to the 1950s is the annotated list for the entire country by Swynnerton and Hayman (1951), in which they list records by locality and in some cases, simply by presence within a District. These records are summarised in Table 4-60, largely following the nomenclature of Wilson and Reeder (1993). Because relatively few records were available for Kahama District, those for Shinyanga and Mwanza, (where much more intensive collecting was done), and in a few cases, Geita, are included for comparison.

An East African survey of larger mammals was carried out from 1955-1965 (Rodgers, 1967) in which the presence or absence of each species was indicated according to a quarter degree latitude by quarter degree longitude grid.

Data from this study were computerised and mapped by R. Botterweg of the Biodiversity Database of the Department of Zoology and Marine Biology, University of Dar es Salaam, using MapInfo software. Because the project site falls almost exactly on the border of two grid units, as well as on region and district administrative boundaries, records from adjacent grid units were also included to provide a more meaningful picture of large mammal species presence. These large species can easily move long distances and are not limited in their distribution by small geographical features or habitat differences.

Figure 4-29 shows the location of the Project site, and the grid of four squares surrounding it, in a regional context. Figure 4-30 shows the results of the survey compiled by Rodgers (1967). As shown in Table 4-60, there were relatively few species of larger mammals recorded in the project area and environs prior to mine development.

No definite data exist for the project area since the 1965 survey. General distribution information on most species is provided in Kingdon (1971-1982b). It is assumed that the trend seen in the study by Rodgers (1967) continued. That is, in areas near human occupation and activities, the few larger species of mammals remaining continued to be reduced in numbers and, in many cases, were locally extirpated through poaching and habitat alteration. A similar fate likely befell many of the medium to smaller sized mammals.

One of the surprising findings of the review of the small mammal data from Swynnerton and Hayman (1951) was the paucity of records for the Geita, Kahama and Sengerema Districts. There are few data on small mammals available for comparison with findings at the project site and surroundings. The only other detailed studies on small mammals which might be comparable are geographically remote from the study site and in rather different habitats.

Other Wildlife

No detailed historic records of birds are available from the study area. Hall and Moreau (1970), and Snow (1978) plotted bird specimen records from the general area. Other studies of Tanzanian birds include: Moreau (1943), and Ulfstrand and Lamprey (1960), for the eastern side of Lake Tanganyika; Haldane (1951), for the Ngara District; Vesey-Fitzgerald and Beesley (1960), for the Rukwa valley; Sinclair (1978), Folse (1982), and Schmidl (1982), for the Serengeti National Park; Reynolds (1965, 1969), for woodland habitat at Tabora, some 200 km to the south; and, Mlingwa (1989) for marabou nesting in Shinyanga District.

No historic data are available for amphibians and reptiles from the project site. Available information for amphibians deals with treefrogs from Mwanza (Schiotz, 1975), and a short checklist of amphibians and reptiles for the Serengeti National Park (Kreulen, 1975).

Earlier reports of the tsetse control program indicate that crocodiles were destroyed during the tsetse control programs. These reptiles are generally killed when they are found to come into conflict with humans, and are also hunted for their skins.

4.11.1.3 Current Ecological Conditions

Since the 1950s, the regenerating bushland and woodland have become much reduced, due largely to human agricultural and settlement activities. Consequently, tsetse and sleeping sickness have become less of a problem in many areas. The human population has expanded greatly in the general area since the late 1950s, especially in the Geita and Kahama Districts.

Today, between Sengerema and the Bulyanhulu Project Site, there is only a remnant of the former dense miombo woodland vegetation. Most of the remaining woodland is within the Mienze Forest Reserve, Geita District. There is no indication of former substantial populations of large mammals. Much of the original vegetation has been highly modified into farm/bush, a mosaic of farmed and fallow agricultural land.

No precise ecological data were available for the project site in the period of time immediately before it was occupied by the artisanal miners. Given the large population increases in Geita and Kahama Districts and the subsequent ecological effects (felling of trees during land clearing, fuel-wood consumption, overgrazing), the condition of the land in the vicinity of Kakola is assumed to have been similar to its present condition. Photographs were taken during the time when the artisanal miners were present, but no data are available from the point when the miners were removed.

While historic records and surveys indicate the presence of some large mammals in Kahama District in the area of the project site, these have mostly been killed or have moved. This is confirmed by informants who reported elephants and a variety of antelope present in the area, approximately twenty to twenty-five years ago, that have since disappeared.

4.11.2 Baseline Studies At The Bulyanhulu Project Site

4.11.2.1 Study Area

The location of the study area in relation to administrative boundaries, larger towns, and National Parks and Game Reserves is shown in Figure 4-29. Brown and Britton (1980) provide eco-climatic data for the general area.

This study focused on the project site and its environs. The project site is rectangular in shape, with a northeast/southwest orientation, a length of 1.5 km, and a width of 1 km. The entire project site lies within a fenced enclosure.

4.11.2.2 Objectives and Scope

The focus of the study was on wildlife (non-domesticated fauna) that could be affected by project development through loss of habitat and/or food source. The baseline wildlife inventory included an assessment of the amphibian, reptile, bird, and mammal populations within the project area and its surroundings, including portions of the four districts that surround it.

The objective was to inventory existing wildlife in the area with emphasis on rare and endangered species, if present, and species whose habitat could be reduced by mining activities. This inventory is essential for:

- assembling information that can be used to help maintain diverse wildlife populations, and protect threatened, endangered, and legally protected species;
- understanding faunal interactions with the environment in order to identify essential habitats, and develop mitigation and compensation plans for disturbed areas;
- understanding the local food web and the importance of each species for human needs (food supply, crop management), and management of essential links in the food web; and
- identifying local populations of parasite reservoir hosts for epidemiological assessment, and control of infectious parasitic diseases.

Tasks during the baseline study included:

- a review and evaluation of existing information;
- inventory of existing wildlife in the area; and
- production of a map for the project area showing wildlife habitat and capability.

4.11.2.3 Methods

A preliminary visit to the site was made from 3-6 March 1997 in preparation for formal sampling from 13-26 May 1997. Colour print photographs were taken to indicate the condition of the study sites and a video recording was made showing some of the activities and the habitats. Data on all specimens were entered electronically using Microsoft Access in the Biodiversity Database of the Department of Zoology and Marine Biology, University of Dar es Salaam. A third visit was made to the site from Sept 30-Oct 10, for dry season sampling.

<u>*Mammals*</u>

The presence of rodents and insectivores (shrews) was assessed using several different techniques, all of which have been shown to be effective elsewhere in Tanzania (Howell, 1995, 1996; Stanley and Kihaule, 1997). These previous studies indicated that a minimal sample period of seven nights, and preferably ten, are required to obtain a reasonable estimate of the numbers of shrew and rodent species present.

Pitfall trap lines were used for live capture of specimens. Plastic buckets (20 litre Cotex Polyplex buckets, 39 cm inside diameter, 44 cm depth) were used as pitfall traps (Bucket Pitfall Traps, or BPFTs). These were arranged in seven, 55 m long lines (Bucket Pitfall Lines, or BPFLs), with a bucket placed every 5 m. A plastic drift fence made of transparent plastic sheeting, approximately 0.5 m high, and supported by wooden stakes, served to guide animals encountering it into the buckets (Plate 4-20). The base of the drift fence was buried to prevent escapement under the fence. The locations of BPFLs 1 through 7 are indicated in Figure 4-31.

- BPFLs 1 and 2 (Plate 4-21) were set in the vicinity of the Magazine area;
- BPFLs 3 (Plate 4-22) and 4 were set in the disturbed shrubland south of the camp;
- BPFL 5 was set in a temporarily flooded grassland/bushland with termitaria nearby; and
- BPFLs 6 (Plate 4-23) and 7 (Plate 4-24) were set in bushland along the northern side of the airstrip.

Snap traps were also used for capture of specimens. One hundred seventy standard rat traps (break-back or snap traps) were set in trap lines of 20 to 30 traps, with traps placed at 5m intervals. Zlip Mouse Traps, all metal design, with dimensions 175 mm by 95 mm, were used (Plate 4-25). Each trap was numbered using a piece of red flagging tape tied to nearby vegetation. This permitted data to be recorded for individual traps, as well as ensuring that traps were relatively easy to locate. Snap traplines were generally associated with BPFLs. Global Positioning System (GPS) readings were taken so that BPFLs and traplines could be mapped on the UTM grid, and to allow for repeat trapping sessions in the future. Trap locations are shown in Figure 4-31.

- trap numbers 1-60 were set near BPFLs 1 and 2;
- trap numbers 61-120 were set near BPFLs 3 and 4;
- trap numbers 121-140 were set near the airstrip and BPFLs 6 and 7; and
- trap numbers 141-170 were set in a shamba (cultivated area) of millet and pumpkin, just to the north of the perimeter fence, approximately opposite the position of the magazine.

Traps were baited each afternoon from approximately 16:30-18:00 hrs with small pieces of freshly fried coconut coated in peanut butter. Old bait was removed and discarded away from the trapline. Unfortunately a total of 24 snap traps and 11 buckets (the entire BPFL 5) were stolen during the May sampling period.

Two 12 m wide by 3 m high mist nets, each with four shelves (areas of the netting for the bats to fall into) were used to capture bats (Plates 4-26 and 4-27). The nets were set up between two wooden poles stabilised with guy lines with the base of the net at ground level. These were set on the site compound on two nights, for a total of 18 net hours. Mist net locations are shown in Figure 4-31.

For each sampling visit (May and October), capture rates were calculated for the BPFTs and snap traps. The capture rate is the number of captures divided by the total number of traps for each sampling visit.

Records were kept of all mammals seen. Tracks and scats (foeces) were noted during fieldwork. Residents and workers were also informally interviewed as to the presence of mammals.

Each specimen captured was assigned a unique field number. Specimens were measured, weighed, and their reproductive condition noted according to standard procedures (Deblase and Martin, 1981). Animals were either prepared as a standard museum study skin and skull, or fixed as fluid specimens in 10 % formalin. Voucher specimens were deposited in the collections of the Department of Zoology and Marine Biology, University of Dar es Salaam. It should be noted that all identifications presented herein are provisional and may require confirmation by examination of skulls, further specimens, or chromosomal and molecular studies.

Birds

Birds were identified visually, using binoculars (7 x 50 magnification), and by their vocalizations. Identification and verification of records in the field were made using Mackworth-Praed and Grant, (1957,1960); Brown, Urban, and Newman, (1982); Fry, Keith, and Urban, (1988); Urban, Fry, and Keith, (1986, 1992); and Van Perlo (1995). Tape recordings of bird vocalizations were made using a Marantz cassette tape recorder and a Zennheiser microphone. Names generally follow Britton (1980) except as updated in NEMC (1997).

Originally, it was planned that a transect based on the open areas along the perimeter fence would be used to assess avian species presence and abundance. However, trials in the field indicated that this would only sample a very small portion of the available habitat types, and would seriously underestimate birds found away from the short vegetation associated with the perimeter road and fence. Therefore, a Timed Species Count (TSC) method was used. In this method the observers recorded all species, detected visually and/or audibly, for each habitat. Species identified during the TSCs were individually ranked according to which ten minute sample session, over a one hour continuous sample period, the species was first noted. The significance of each ranking is such that, assuming equal detectability in species, the greater the mean ranking for the species (average rankings for a species over time), the higher its abundance (Pomeroy, 1992).

Timed Species Counts were conducted within the fenced project site with an unrestricted count area (species recorded no matter how far away from the observed). The sites were marked for sample repetition, and are shown in Figure 4-31. Transects within the disturbed *Combretum* woodland were identified which could be repeatedly sampled individually. This allowed for any future changes in the study area, such as construction or severe alteration, which might affect, or render unsuitable for sampling, one portion of the study area.

Mist netting was carried out to assist in detection and identification of species which were not readily detected due to either cryptic plumage, coloration, or behaviour (i.e., species which did not vocalise or which remained hidden in low and/or thick vegetation). Standard museum study skins were made from a sample of the birds netted. Voucher specimens were deposited in the collections of the Department of Zoology and Marine Biology, University of Dar es Salaam.

Two 12 m wide by 3 m high mist nets, each with four shelves, were used at the sites indicated in Figure 4-31. These were the same nets used for mist netting of bats. The nets were open from 08:30-12:00 hrs and 17:00-18:30 hrs on 22 and 23 May.

All species seen/heard in the study area were noted as part of preparation of an overall species list for the site. Breeding species were recorded following standard criteria (Jackson, 1997).

Data for presence of species and species breeding records were forwarded to the Tanzanian Bird Atlas Scheme for inclusion in their national database.

Amphibians and Reptiles

The same methodology used to sample mammals has also been shown to be effective in sampling amphibians and reptiles, especially cryptic and burrowing forms, which would otherwise go undetected. Therefore the BPFLs set out for mammals were also sampled for reptiles and amphibians. In addition, opportunistic collecting (including animals found dead on road, "DOR") was carried out during all fieldwork. Captured animals were processed and preserved according to standard procedures, and fixed in 10 % formalin or 70 % ethanol (Heyer *et al.*, 1994). Each specimen was labelled with a unique field number. Samples of muscle and blood were preserved in dimethylsulphoxide (DMSO) or 70 % ethyl alcohol for later analysis.

Audio tape recordings were made of some amphibian vocalizations at night using the same equipment as for birds. Larval amphibians (tadpoles) were also collected using a hand dip net.

A similar caveat to that given for the identification of mammals applies to amphibians and reptiles. While for the reptiles a standard key does exist (Broadley and Howell, 1991), there is much to be understood concerning variation of characters in little studied populations. Less information is available for amphibian distribution and identification in Tanzania.

4.11.2.4 Results

Mammals

During the baseline study of the project area and its surroundings in the wet season, the mammal species composition was initially identified as containing 5 species of rodents (45 % of the rodent species in the region), 2 species of antelope (8.4 % of the artiodactylid species in the region), 1 species of mongoose (5 % of the carnivore species in the region), 1 species of bat (33 % of the chiropteran species in the region), 1 species of hare (the only representative species of order Lagomorpha in the region), 1 species of elephant-shrew (33 % of the elephant-shrew species in the region), 1 species of monkey (25 % of the primate species in the region), and 1 species of hedgehog (an insectivore).

In the dry season, the number of species identified at the project site and in the surrounding area, was significantly lower. One further species was identified, a species of mouse (family Muridae). Only three species, previously identified during the wet season survey, were found, including: two rodents, the Natal multimammate mouse (*Mastomys natalensis*), and the fringe-tailed gerbil (*Tatera robusta*), and an insectivore, the short-snouted elephant-shrew (*Elephantulus brachyrhynchus*). This species of elephant-shrew has been shown to inhabit the region around the project site but was not identified during the previous surveys by Swynnerton and Hayman (1951), or Rodgers (1967). Samples of specimens collected are documented in Plate 4-28.

Trap effort and captures for the May 1997 survey are indicated in Table 4-61. No shrews were captured in the BPFTs, and only a single rodent, a Natal multimammate mouse, was taken in a pitfall trap. Snap traps captured two species of mammals, a gerbil (*Tatera*), and a four-toed hedgehog (*Atelerix albiventris*).

Trap effort and captures for the October 1997 survey are indicated in Table 4-62. In addition to the traplines set during the dry season, traps were placed in dwellings in Kakola, from 3-6 Oct 1997. Ten traps were set each night in Kakola. The only animals captured were a single black rat (*Rattus rattus*) and two Natal multimammate mice.

No bait was taken from the other snap traps. No small mammals which are usually associated with trees, such as bushbabies (*Galago*), dormice, (*Graphiurus*) or climbing mice such as *Grammomys* were detected. Most surprising was the apparent absence of true shrews, family Soricidae, including the widespread genus *Crocidura*. A single elephant-shrew, not positively identified to species but possibly *Elephantulus brachyrhynchus*, was seen in March, in a tangle of dense vegetation near the magazine. The worn paths on termitaria and in thick vegetation between BPFLs 3 and 4 may have been the runs of elephant-shrews. Given the close proximity of both the camp and at least three former village sites, it is somewhat surprising that not a single black rat (*Rattus rattus*) was captured. Kakola residents reported that this species was present in their dwellings, and presumably the theft of traps was related, at least in part, to local efforts to deal with this ubiquitous pest.

A checklist of the mammal species observed or reported in the project area are presented in Table 4-63. Hares (*Lepus* sp., probably *victorae*) were observed in the vicinity of the airstrip. Local residents informed us that springhares (*Pedetes capensis*) were also found nearby. A single small antelope was observed in thick vegetation near BPFL 3. This was most likely a dik-dik, as dik-dik tracks were also found near BPFLs 1 and 2 as well as at BPFL 3. Scats from apparently two species of small antelope were seen. Old, dry scats which may have been those of bushpig or warthog were also observed on one occasion. Bushbuck were reported from the property adjacent to the Bulyanhulu concession.

Four individuals of the yellow-winged bat (*Lavia frons*) were seen near the BPFLs. This is a widespread species which roosts in vegetation and is active from late in the afternoon until late at night. At least one other species of insectivorous bat was seen catching insects inside the camp area. No fruit bats were heard or seen.

A group of at least five dwarf mongooses (*Helogale parvula*) were seen near the magazine area, as they were easily able to pass through the fence. No nocturnal primates were seen or heard calling. The only diurnal primate recorded was the vervet monkey (*Cercopithecus aethiops*).

Birds

Based on the number of avian species recorded for Kenya, the number of bird species in Tanzania is estimated to exceed 1,300 (Williams, 1963). In the project area a total of 129 bird species were recorded using mist netting, timed species counts, and incidental observations. During the wet season, a total of 93 species were identified, including 39 species not present during the dry season. During the dry season, 90 species were recorded, including 17 species that were not present during the wet season.

A species list for birds which were recorded at the project site and the surrounding area is given in Table 4-64. This list of species is by no means exhaustive or complete. For at least three records, it was not possible to provide identification at the species level. The project site is likely to attract many more species during drier periods than during the wet season. Most of the species detected were typical of woodland and thicket. Only a few species, such as the hammerkop (*Scopus umbretta*) and little egret (*Egretta garzetta*), are associated with wetlands.

Intra-African migrants can be expected to visit the area as would wanderers during times of drought. Two hundred five (205) palaearctic bird species known to winter in the eastern savannah and highlands of Ethiopia, Somalia, eastern Zaire, Kenya, Uganda, and Tanzania (Curry-Lindahl, 1981). Of these, 93 species are known to occur in Tanzania. Except for those which only use the coast, the majority of these might be expected to pass over, or winter in, the general project area (Moreau, 1972). A further 27 species of intra-African migrants are known from Tanzania, many of which may also be expected to occur in the project area (NEMC, 1997).

Results from the Timed Species Counts (TSCs) during the May wet season are presented in Table 4-65. Results from the TSCs during the October dry season are presented in Table 4-66. The results of mist netting for birds are presented in Table 4-67. Plate 4-29 shows a female pennant-winged nightjar (*Macrodipteryx vexillarius*) that was observed on-site.

The bird life at Bulyanhulu is typical of the woodland which dominates much of central Tanzania. The presence of 18 species showing breeding behaviour or in breeding plumage indicates that for at least some species, in the period immediately following the rains, conditions were suitable for nest building and the rearing of young. Of these, the didric cuckoo (*Chrysococcyx caprius*), Klaas' cuckoo (*Chrysococcyx klaas*), great spotted cuckoo (*Clamator glandarius*), black-throated honeyguide (*Indicator indicator*), an indigobird (*Hypochera sp.*), the paradise whydah (*Vidua paradisaea*), and the pin-tailed whydah (*Vidua macroura*), are all brood parasites and must lay their eggs in the nests of other birds. Some species such as the grey hornbill (*Tockus nasutus*) and red-billed hornbill (*Tockus erythrorhynchus*) made only brief visits to the site during the observation period. Similarly, there were very few birds of prey and water birds observed; only little egrets were seen in numbers, and these were flying over the site. One owl (*Bubo c.f. africanus*) was recorded. No woodpeckers or spinetails were seen, both groups of which are dependent on dead trees for feeding and roosting, respectively. No quelea (*Quelea quelea*) were detected or reported during this study. However, this pest species occurs nearby and would be expected to occur at least occasionally (Bruggers and Elliott, 1990; Elliott, 1990).

Away from the focus of activities at the box cut and waste dump, and in other portions of the project site where there was less human activity, a wider variety and larger numbers of birds were seen. Some seemed unconcerned with the noise and activity associated with the project, and were engaged in elaborate courtship displays (e.g. paradise whydah). Others, such as the cordon-bleus (*Uraeginthus* spp.) and the variable sunbird (*Nectarinia venusta*), had already built nests, laid eggs and were incubating. The camp compound and guard houses at the main gate provided nesting habitat for striped swallows (*Hirundo abyssinica*), and a large group of at least 30 African pied wagtails (*Motacilla aguimp*) gathered nightly at a fig tree in the compound. During the March preliminary visit, marabou storks (*Leptoptilos crumeniferus*) were attracted to waste food thrown just outside the Skanska camp in the vicinity of the club. This source had been removed by the May visit, and fewer birds were present, although individuals could still be found inside the KMCL camp compound. The trees which have been planted within the KMCL camp should provide useful cover for roosting and nesting birds.

In the acacia thornbush and grassland to the north of the Bulyanhulu Project Site rufous-crowned rollers (*Coracias naevia*) were observed. Species typically associated with wetlands that were observed along the Bulyanhulu River near Kakola included the sacred ibis (*Threskiornithis aethiopica*), and the black-necked heron (*Ardea melanocephala*).

Amphibians

During a brief site visit, soon after the rains had begun in March, two Peters' foam-nest frogs (*Chiromantis petersi*) were found emerging from aestivation. Aestivation is the frog's method of retaining water during the dry season. During this time, they remain hidden and inactive.

Pitfall trapping results for reptiles and amphibians for May and October, 1997 are presented in Tables 4-68 and 4-69, respectively. A species list of amphibians and reptiles at the project site is provided in Table 4-70. Pitfall traps were the only method able to capture sand frogs (*Tomopterna sp.*, Plate 4-30) and dwarf toads (*Bufo cf. taitanus*). The Peters' foam nest-frog was captured by hand inside the camp. The puddle frog (*Phrynobatrachus* sp.), plain grass frog (*Ptychadena ancheitae*), and a guttural toad (*Bufo gutteralis*, species complex), were also captured by hand. The sand frog and Peters' foam-nest frog are both indicative of relatively drier habitats. Other species have wider distributions, but as far as is known (with perhaps the exception of the two species of toads) all breed quickly, taking advantage of any rainwater pools. Tree/reed frogs (*Hyperolius* sp.) were heard calling in the distance, near the river, but were not found at the project site. Only *Hemisus*, *Ptychadena*, *Phrynobatrachus*, and *Chiromantis* (unconfirmed), were calling during the May 1997 visit. Few tadpoles were seen as breeding had largely been completed by that time. None of the sampling visits coincided with a period of maximum breeding activity for amphibians. A few tadpoles were collected at the Bulyanhulu River near water quality sampling point WS 1. Amphibian activity was almost non-existent during the October survey period, with only a single toad, *Bufo* sp., taken in the pitfalls, and a sand frog collected by hand.

Informal night searches of the fenced project area for amphibians were carried out in March during the preliminary site visit. Species identified from vocalizations included: Peters' foam-nest frog and a species of puddle frog.

The shovel-nosed frog (*Hemisus marmoratum*) is apparently a new record for the area, although the species is widely distributed in East Africa.

Reptiles

Two species of large venomous snake were observed on site, the black mamba (*Dendroaspis polylepis*), and black-necked spitting-cobra (*Naja nigricola*). Envenomation by either of these is potentially life-threatening, therefore these species, as well as any other snakes, are killed on sight by villagers. No observations were made as to the presence of crocodiles, or tortoises in the area.

The reptiles found at the project site are listed in Table 4-70, with pitfall results in Tables 4-68 and 4-69. For reptiles, the effectiveness of the BPFTs in capturing species which were not otherwise detected, was especially noticeable. Only three species of lizards, the common striped skink (*Mabuya striata*), and two geckos were seen in fieldwork and/or in camp. One of these, the thick-toed gecko (*Pachydactylus* sp.), was found trapped inside a hole dug for planting a tree. Several Tana writhing skinks (*Lygosoma afrum*), as well as a short-necked skink (*Mabuya brevicollis*), and three species of small snakes were captured by the bucket pitfalls. The only snakes seen during the fieldwork were a beaked snake (*Rhamphiophis rostratus*), killed in camp, a black mamba, and a black-necked spitting-cobra. Both the mamba and the cobra were found dead on arrival (DOA). In addition, a single black mamba was seen near the airstrip, near the remains of the one killed by a vehicle (Plate 4-31). During the March visit, a black mamba was also found DOA, north of the project site.

Reptile activity was low during the October survey. Only four skinks and a single lacertid lizard were taken in the traps. No reptiles were observed otherwise. However, a single black mamba was reported by the survey team; it took refuge in a termite mound when encountered.

4.11.2.5 Discussion

Mammals

There are approximately 289 species of terrestrial mammals in Tanzania, which is, for the size of its land base, one of the highest species diversities in the world (Owen, 1976). This species diversity includes at least 89 species of small herbivores, 47 species of large herbivores, 91 species of insectivores, 41 species that are primarily carnivorous, 11 species of fruit bats, and 10 species of primarily vegetarian primates. In the districts surrounding the project area there have been a total of 74 species of mammals recorded. These include 24 species of even-toed ungulates (order Artiodactyla), 20 species of meat-eaters (order Carnivora), 11 species of rodents (order Rodentia), 4 species of primates (order Primates), 3 species of bats (order Chiroptera), 3 species of hyrax (order Hyracoidea), 3 species of elephant-shrew (order Macroscelidea), 2 species of insect-eaters (order Insectivora), 2 species of odd-toed ungulates (order Perissodactyla), 1 rabbit (order Lagomorpha), 1 pangolin (order Pholidota), and 1 elephant (order Proboscidea).

Trapping in October, during the dry season, resulted in higher capture rates (1.4 % for BPFTs, 4.2 % for snap traps) than during the wet season (0.17 % for BPFTs, 0.39 % for snap traps). All of the species present in the dry season were present during the wet season, but the dry season numbers were higher. Gerbils were by far the most common species trapped in both seasons.

The low trapping capture rates in May, 1997 may have been partially due to heavy rains for two nights. This seemed to reduce small mammal activity. The lack of shrews trapped was unexpected, as is the relatively low trap success. No elephant-shrews (*Elephantulus* sp.) were captured during the wet season.

Outside of the fenced area some evidence of rodent activity in a cassava cultivation was observed. This activity was likely that of Natal multimammate mice (*Mastomys natalensis*). This species as well as the black rat (*Rattus rattus*) were trapped in Kakola village.

Birds

Eighteen of the 93 species recorded from the site during the May sample were observed exhibiting breeding activity (the number is probably much greater, since almost all of the species resident would be expected to breed sometime during the year). In October, at the end of the dry season, only two species were detected as breeding, although one other, the flappet lark (*Mirafra rufocinnamomea*), was giving displays often associated with breeding.

The much lower numbers of species present in the dry season may be attributed at least in part to lower levels of visibility and identification (female weavers, and those in non-breeding plumage, for example, are difficult to identify). However, many species appeared to have moved elsewhere; these included many of the weavers, waxbills, and their brood parasites, such as the cuckoos and whydahs.

In each sample period, species which were not present in the other were noted; this reflects the highly seasonal nature of the environment, and the patchy nature of surrounding habitat. Birds pass through for a short period of time when resources are available, and then move on so the bird fauna is constantly changing. These factors as well the vegetation types (woodland, riverine, etc) and the position of the project site on a main migration path for palaearctic migrants, suggests that the number of species which may visit the site over a year could easily reach 200.

Low species diversity of birds during the dry season, in general, may be attributed to the lack of food resources. Low species diversity in birds of prey, and the lack of woodpeckers and springtails may be accounted for by the lack of trees for perching, roosting, or nesting. The low species diversity of waterbirds at the site during the wet season may be attributed to the turbidity and disturbance of the water in the Bulyanhulu River. With high turbidity in the water, fishing by piscivores would be difficult. Low species diversity in waterbirds during the dry season can be attributed to the general deficiency of water resources. Flood conditions, which might result in an influx of waterfowl did not occur during either sample period.

Amphibians

The low numbers of amphibians recorded in the project area, even during the wet season, may be due, in part, to the relatively small amount of habitat available to them for breeding purposes. Only two species of dry region amphibians were observed. However, the surprising discovery by Drewes (1997) of a species of *Hyperolius* treefrog in the Serengeti National Park that is new to science only indicates that there is still much to be learned about African amphibians, even in the more open habitats such as savannahs and woodlands.

Reptiles

No freshwater terrapins were detected although they are expected to be present in permanent bodies of water and in seasonally flooded areas. Although relatively common in the Serengeti ecosystem, tortoises were not detected. This was most likely due to the highly disturbed vegetation in the project area, but other factors may also be involved. A species endemic to rocky outcrops in Kenya and Tanzania, the pancake tortoise (*Malcochersus tornieri*), is reported from Busisi, 70 km north of the project area. However, the habitat to which this species is apparently restricted is not found in the immediate area of the study site.

4.11.2.6 Conservation Status of Wildlife at the Bulyanhulu Project Site

The factors used here to assess conservation status include: level of endemism, level of threat as assigned by the International Union for the Conservation for Nature (IUCN), and whether or not the species appears on a Convention on International Trade in Endangered Species (CITES) appendix list. The IUCN has long used a series of categories, including: Rare, Vulnerable, and Endangered, to assess the conservation status of a species. In 1994, the IUCN modified its criteria to make these classifications more objective (Baillie and Groombridge, 1996). The new categories are: Data Deficient (DD), Least Concern (LC), Vulnerable (VU), Endangered (EN), and Critically Endangered (CE). The international live animal trade has also raised conservation concerns. Species in which trade is prohibited are listed in CITES Appendix I. Species in which trade is permitted, but is regulated and monitored, appear in CITES Appendix II.

According to IUCN standards, a species is considered endangered when its existence throughout all, or a significant portion, of its actual range is threatened with imminent extinction. A species is considered vulnerable when the species may become endangered if the factors affecting its vulnerability are not reversed.

The following are of conservation concern in Tanzania: 57 species of amphibians; 159 species of reptiles; 168 species of birds; and, 82 species of mammals (Howell, 1997). These species are listed in Appendix 4-9. Of these species, 1 mammal, 1 reptile, and 13 birds have been identified in the project area.

Mammals

The terrestrial mammal species list for Tanzania (NEMC, 1997) consists of 263 species. This does not include bats, of which there are an estimated 26 species. Ten species were reported from the Bulyanhulu Project Site and its immediate surroundings. This is approximately 3.5 % of Tanzania's terrestrial mammalian fauna. While the species list produced as a result of the baseline study should not be thought of as complete, it does reflect the relatively poor state of the habitat and the high level of human disturbance present at the site prior to initiation of the project.

Tanzanian non-marine mammals of conservation concern are listed in Appendix 4-9. No endemic species of mammal is found on the site or surrounding area. However, a number of species which formerly were present in Kahama District and its surrounding areas (Swynnerton and Hayman, 1951, Rodgers, 1967) are included in the IUCN classification system as follows: Wild dog, endangered; cheetah, vulnerable; black rhinoceros, critically endangered; African elephant, endangered; leopard, data deficient. As far as is known, none of these occur near the project site today. Species formerly present in Kahama District and surrounding area that are included on Appendix II of CITES include: hippopotamus, caracal, serval, African wild cat, lion, yellow baboon, and several species of bushbaby. Species listed in CITES Appendix I, and formerly found in Kahama and surrounding Districts include: cheetah, leopard, African elephant, and black rhinoceros. None of these species were detected on the project site nor are they likely to be present in the immediate surrounding area.

The only mammal of conservation concern observed in the project area was the vervet monkey. These primates are considered as a species of least concern, and are currently listed on CITES Appendix II. The life histories of all mammal species observed in the project area are presented in Table 4-71. Mammalian life histories were compiled from: Maberly, 1960; Haltenorth, 1980; Estes, 1991; Whitaker, 1992; and, Alden *et al.*, 1995.

Birds

Tanzanian birds of conservation concern are also listed in Appendix 4-9. Two endemic species occur at the project site but are not restricted to it: ashy starling (*Cosmopsarus unicolor*) and Fischer's lovebird (*Agapornis fischeri*). Another possible endemic species, the Usambiro barbet (*Trachyphonus usambiro*) may be present but was not distinguished from d'Arnaud's barbet (*Trachyphonus darnaudii*), with which it was, until recently, regarded as conspecific. The Usambiro barbets' conservation status is of least concern. The populations of the grey-headed sparrow (*Passer griseus*) found in the area have been given subspecific rank as the Swahili sparrow (*Passer suahilicus*); these are endemic to interior Tanzania and Southern Kenya from Rukwa, Njombe, and Songea north to Karungu Bay, including Mwanza, Shinyanga, and Wembere. Some authors regard these birds sufficiently different to assign them full specific rank as Swahili sparrow. They appear to have wide ecological tolerances and are ranked as LC. No species restricted to miombo vegetation were found in the project area during either visit as there is a lack of well-developed miombo woodland nearby.

The records of the ashy starling from the Bulyanhulu area represent the westernmost occurrence of this species, and are at the edge of its range. Its IUCN status is of least concern. Fischer's lovebird is a Tanzanian endemic which is regarded as near threatened and is in CITES Appendix II. It has a wide distribution and was the subject of a major study by Moyer (1995) because it has, in the past, been exported in large numbers for the live animal trade. Currently its export is prohibited. The red-headed lovebird (*Agrapornis pullaria*), although not a Tanzanian endemic, is considered as a species of least concern in the project area, and is listed in CITES Appendix II.

Other bird species identified in the project area that are considered as species of conservation concern include: tawny eagle (*Aquila rapax*), LC, CITES Appendix II; brown snake-eagle

(*Circaetus cinereus*), LC, CITES Appendix II; fish eagle (*Haliaeetus vocifer*), LC, CITES, Appendix II; dark chanting-goshawk (*Melierax metabates*), LC, CITES Appendix II; African harrier-hawk (*Polyboroides radiatus*), LC, CITES Appendix II; black kite (*Milvus migrans*), LC, CITES Appendix II; bateleur (*Terathopius ecaudatus*), LC, CITES Appendix II; African hobby (*Falco cuvieri*), LC, CITES Appendix II; and spotted eagle-owl (*Bubo cf. africanus*), LC, CITES Appendix II.

The life histories of the species of conservation concern, as identified in the project area are outlined in Table 4-71. Information was compiled from Mackworth-Praed and Grant, 1957; Williams, 1963; Benson *et al.*, 1971; and Alden *et al.*, 1995.

Amphibians

Appendix 4-9 provides a list of Tanzanian amphibians of conservation concern. None of these species have been reported from the project site as all but a very few are forest dependent species, restricted or nearly restricted to closed forest.

Reptiles

Tanzanian reptiles of conservation concern are listed in Appendix 4-9. One species identified in the project area and its surroundings are listed in this appendix. The Nile monitor lizard (*Varanus niloticus*) is widespread but is listed as a species of least concern by IUCN, and is listed in CITES Appendix II due to trade in skins.

The life history of the Nile monitor lizard is outlined in Table 4-71. Information was compiled from Fourie, 1984; and Alden *et al.*, 1995.

Two species of reptiles which likely occur near the project site are also listed in Appendix 4-9. The Nile crocodile (*Crocodylus niloticus*) is regarded as vulnerable by the IUCN and is on CITES, Appendix II, and the African python (*Python sebae*), a widespread species, is considered a species of least concern by IUCN, and is in CITES, Appendix II because of trade in skins.

4.11.3 Valued Ecosystem Components

4.11.3.1 Introduction

The recent activities in the Bulyanhulu area by artisanal miners had negative effects on the already greatly reduced fauna and flora. Miners felled almost all of the large trees for the support of mine shafts, for building poles, and for fuel-wood. Furthermore, the presence of the shafts and the associated digging and sluicing of the mined rock all served to further alter the environment. There is no way to objectively measure the disturbance of humans, the noise from the break up of rock, and the removal of vegetation, but all of these must have reduced the suitability of the area for wildlife.

For species associated with wetlands and the Bulyanhulu River, as well as those which depend on seasonal temporary pools of water for breeding, the high levels of siltation associated with artisanal gold mining likely had negative effects. In addition, there is also the possibility of further ecological damage from contamination by mercury, which was used to amalgamate the recovered gold (Ikingura and Akagi, 1996). The riparian vegetation has not been as heavily impacted by the presence of the artisanal miners as other habitats within the Bulyanhulu Project area.

The original vegetation of much of the site (combretaceous woodland) was extremely degraded by the presence of the artisanal miners, making the area much less suitable for wildlife. The removal of the larger trees as well as the cutting of smaller ones means that roosting and nesting sites for birds, and cover for mammals, amphibians, and reptiles, were reduced. Cavity nesting birds (eg. woodpeckers, lovebirds, some owls) are likely the most affected by the loss of the woodland. Similarly, the fruits of some large trees are no longer available to birds such as hornbills, parrots, and pigeons. Other tree dependent wildlife such as bushbabies (*Galago senegalensis*), would be expected to be scarce or altogether absent. Tree dwelling rodents, such as dormice (*Graphiurus* sp.) would also not be expected in high numbers.

Due to human activities, those species which depended on the woodlands for cover and food either moved from the area, or were eliminated. Only the species which were able to survive in edge situations, or in close proximity to humans, were able to persist. In addition, poaching for meat took a toll on the larger antelope, and even the smaller antelope, such as dik-diks.

There are no quantitative data on the populations of plants and animals present before the arrival of the artisanal miners, or of the effects of artisanal mining activities on these populations and the environment generally. Observations made at the outset of the baseline studies program indicate that the ecological and environmental conditions at the project site, and much of the surrounding area of the concession, must be described as highly disturbed and degraded.

4.11.3.2 Wildlife Habitat

Wildlife habitat can be defined as follows: the region an animal species has chosen in which to feed (feeding habitat), breed (breeding habitat), escape from predators, or sleep. Animals can be classified into two main groups, based on the habitats they prefer. Animals that have no specific preference for any one habitat type are referred to as generalists. Animals that have very specific habitat requirements are referred to as specialists. These same terms can be used to segregate species based on the food sources they require. Species that can obtain nutritional value from a large number of food sources are considered generalists; these species tend to be the most adaptive to changes in the environment. Animals that require very specific food sources are considered specialists; it is these species that are likely to be most affected by changes in the environment. For the most part, the wildlife species found in the Bulyanhulu Project area are generalists, both on the basis of habitat type and food preference.

Each habitat is generally defined by a feature or combination of features, such as a stream, a copse of trees, or a vegetation association (a group of plants that are generally found growing together). In the Bulyanhulu Project area, the vegetation groups delineated in Section 4.10 and Figure 4-27 of this report represent the available habitat types. Six types were identified:

- dwarf *Acacia drepanolobium* wooded grassland;
- *Combretum* coppicing open bushland with scattered thickets on termitaria;
- disturbed *Combretum* open shrub with grassland patches;
- riverine (riparian) vegetation;
- heavily disturbed area with fast colonising weeds and scattered trees; and
- cultivation and settlement areas.

4.11.3.3 Habitat Capability Ratings Index For Species of Management Concern

The species observed in the Bulyanhulu Project area which are listed in Appendix 4-9, Tanzanian vertebrates of conservation concern (Howell, 1997), are considered to be of management concern. There are 13 bird species, 1 mammal species, and 1 reptile species of management concern in the area. For these 15 species, a habitat capability rating was produced for each of the 6 habitat types. The ratings system used is based on a scale of 1 to 5, where 5 represents optimal habitat, and 1 represents very poor habitat. Each rating takes into account the various characteristics that a given species requires in a habitat (eg. food, cover, nesting sites, etc.). Table 4-71 lists the 15 species of management concern and their habitat capability ratings for each habitat type. It should be noted that all habitat capability rating indices are subjective measures.

<u>Birds</u>

In most cases, birds are not limited by small-scale differences in habitat type, as they are capable of covering large distances quickly. Although the vegetation in the Bulyanhulu area likely does not currently provide habitat for the diversity of birds which it has historically, it does offer some feeding, roosting, and nesting opportunities.

The bird life in the Bulyanhulu Project area is typical of much of central Tanzania. The presence of 18 species in May showing breeding behaviour or in breeding plumage indicates that for at least some species, in the period immediately following the rains, conditions were suitable for nest building and the rearing of young. The paradise whydah (*Vidua paradisaea*) was observed engaging in elaborate courtship displays. Others species, such as cordon-bleus (*Uraeginthus* spp.) and the variable sunbird (*Nectarinia venusta*), had already built nests, laid eggs and were incubating. The camp compound and guard houses at the main gate provided nesting habitat for striped swallows (*Hirundo abyssinica*), and a large group of at least 30 African pied wagtails (*Motacilla aguimp*) gathered nightly at a fig tree in the compound.

Some species such as the grey hornbill (*Tockus nasutus*), which is primarily a herbivore, and the red-billed hornbill (*Tockus erythrorhychus*), which is primarily an insectivore were noted less frequently. This may have been due to a lack of food resources available for them.

The turbidity and seasonability of the Bulyanhulu River flows may be the cause of the paucity of records of water birds in the immediate area of the site. Only little egrets (*Egretta garzetta*) were seen in numbers flying over the site.

No woodpeckers or spinetails were seen, both groups of which are dependent on dead trees for feeding and roosting, respectively. Similarly, there were few birds of prey seen, most of which require large trees for nesting, roosting, or for hunting platforms. The trees which have been planted within the KMCL camp may provide habitat for roosting and nesting birds that tolerate the presence of humans.

With reference to the vegetation groups described in Section 4.10 of this document, riparian areas typically house the greatest abundance of large trees in the area (Habitat Capability Rating of 3.1 for birds, Table 4-71), however suitable nesting and roosting areas can also be found within the dwarf *Acacia drepanolobium* wooded grassland (Habitat Capability 2.6), *Combretum* coppicing open bushland (Habitat Capability 2.5), and disturbed *Combretum* open shrub vegetation (Habitat Capability 2.0). Fruit-bearing plants, primarily *Acacia* sp., are scattered throughout the area.

Mammals

The habitat types present in the Bulyanhulu Project area are suitable for some large mammals, but none have been observed in the area for decades. This is likely due to historical habitat reductions, hunting pressures, and competition for grazing areas by cattle. Many small mammals, such as the Natal multimammate mouse (*Mastomys natalensis*), and gerbil (*Tatera* sp.) are able to find shelter and food in the scrubby thickets and grassland areas. Other mammals, such as the bushpig (*Potamochoerus porcus*), are able to take advantage of agricultural crops grown in the Cultivation and Settlement areas. The camp buildings also provide habitat for small mammals such as Natal multimammate mouse, black rat (*Rattus rattus*), and gerbil.

Habitats for small antelope species such as Kirk's dik-dik (*Madoqua kirkii*), and bushbuck (*Tragelaphus scriptus*) are provided by the disturbed *Combretum* shrubland, but the populations of each are not expected to be large due, in part, to hunting pressures.

The only mammalian species of management concern in the project area is the vervet monkey (*Cercopithecus aethiops*), which is a widespread species in Tanzania, and is not limited to the project area. The overall rating of the habits available in the Bulyanhulu area for this species is 2.3, with the most suitable habitat types being the Riverine Vegetation (Habitat Capability of 3.5, Table 4-71), and the dwarf *Acacia drepanolobium* wooded grassland (Habitat Capability, 3.0).

Reptiles

There is little available data in the literature regarding the presence and abundance of reptiles in the project area, however some generalisations can be made. The lack of closed stands of trees will limit the distribution of arboreal species such as tree snakes and many small lizards. Due to the presence of at least two species of venomous snakes, all snakes are killed on sight by villagers. This makes the populated areas surrounding the project site unfavourable for snakes. The majority of small lizards (primarily skinks and geckos) are insectivorous, and use underground escapes for nesting and sleeping. Therefore, most small lizard species in the project area can find shelter and food in and amongst the termite mounds which are ubiquitous in the area.

There is 1 reptilian species of management concern in the Bulyanhulu Project area, the Nile monitor lizard (*Varanus niloticus).* The Riverine Vegetation habitat type and the adjacent dwarf *Acacia drepanolobium* wooded grassland provide suitable habitats for the Nile monitor Lizard (Habitat Capability Rating 3.75 and 2.4, respectively). The monitor lizard preys on a variety of foods which are likely to be found within these two habitats. Other regions of the Bulyanhulu area are less suitable for this species.

Amphibians

Very little information is available for amphibians, and their specific habitat requirements, in the project area. In general, amphibians require standing water to complete their lifecycle, and many species never leave the water's edge. Therefore, the Riverine Vegetation habitat type is important to amphibians.

Two species indicative of drier habitats were identified at the project site; Peters' foam-nest frog (*Chiromantis petersi*) and sand a frog (*Tomopterna* sp.). Both species undergo aestivation during the peak of the dry season, and are active only when moisture levels increase. During this time they bury themselves in the sand, therefore, the disturbed areas around the project site, and the dry river bed of the Bulyanhulu River during the dry season, are expected to provide habitat for both of these species.

There were no amphibians identified as species of conservation, or management concern observed in the project area.

4.12 ENDEMIC PLAGUE

In parts of Tanzania, including Singida (approximately 250 km southwest of Kahama) and Arusha (Figure 1-1), plague is endemic. Sampling for plague carriers (Rattus rattus) was carried out as part of baseline studies. One black rat was caught in Kakola. None were caught in the camp area. Two multimammate mice were caught in Kakola.

Plague may be carried by fleas residing on rodents (Msangi, 1968). No fleas, which might transmit the plague bacterium to humans, were found on the few rodents captured at the Bulyanhulu Site.

4.13 ARCHAEOLOGY/HERITAGE

4.13.1 Objectives

The main objective of the Heritage Resource Assessment (HRA) was to identify and assess any archaeological, palaeontological, or historical resources within the KCML concession. Specifically, the assessment involved the following:

- review of baseline cultural and historical information for the site;
- an archaeological survey of the immediate area of disturbance of the proposed mine and surrounding area;
- preparation of a report of field activities, and findings;
- notification of the affected public of the archaeological survey in order to gain access to the mining site; and,
- preparation of a map detailing significant archaeological features (if any).

4.13.2 Methodology

4.13.2.1 Techniques

The HRA programme entailed documentary study, ethnographic enquiry, archaeological survey and report writing.

Documentary Study

The documentary study involved collecting and analysing documentary information prior to site visits to Bulyanhulu. This facilitated planning research techniques and logistics. A large part of the documentary study was done in libraries in Dar es Salaam, while additional information was obtained through discussions and conversations with contacts in Mwanza, particularly Mr. Mbuta Mirando, the KMCL resident advisor.

Ethnographic Enquiries

The major aims of ethnographic inquiries were the following:

- study the history of the area;
- examine the archaeological and historical potential of the study area;
- locate any heritage resources in the study area;
- assess the feelings and the cultural ties the local people have with any identified heritage resources; and,
- seek opinions on measures to protect any heritage resources.

Informal conversations, rather than formal interviews, were often used as a research technique. This helped to maximise the flow of information and expression of personal feelings, bearing in mind that some interviewees do not feel comfortable with formal interviews. Some of the talks were tape-recorded. For others, data were hand recorded. Several photographs were also taken during the interviews.

A total of five days were spent at the beginning of the study interviewing local people on the archaeological potential of the study area. Interviewees ranged from District (Kahama and Geita) to village levels, and varied from government officials to local residents, particularly those reported to be conversant with the history of Bulyanhulu. Government officials included Mr. Smith Mbegu, the Kahama District Cultural Officer; Mr Silverius L. Simuli, the Kahama

District Community Development Officer; Mr. Ayubu Salum, the Kakola Village Chairman; Mr. Boniface Masagawa, the Village Executive Secretary; Mr. Munyirwa Warioba, the Village Chairman, Social Welfare; and Mama Doroti Peter, a member of the District Council, Women. Lay people who were formally interviewed included Mzee Masalisengwa Lugana (70), who immigrated to Bulyanhulu in the early 1960s; Fundi Mange (50), Masalisengwa's neighbor; Petro Lugiko (56), who immigrated to Kakola in 1959; Bundala George (23), the son of George Luhege who came to Bulyanhulu in 1988; Paulo Daudi (50), who immigrated in 1970; and Mathias Lutambi (30), who immigrated in the early 1980s. Informal discussions were also held with KMCL personnel, including J. Hylands, the Project Director, O. Lopa, Senior Geologist, Administration, and various junior staff members and workers.

The interviews and discussions centred on the following major themes:

- origin and development of Bulyanhulu and the mining industry;
- ethnic composition and history;
- heritage resources: type, distribution and significance;
- burials: how people disposed of their dead in the past, and what type of marks were used to signify burial places; and
- opinions on protection measures in case heritage resources were found within the area planned for mining activities.

Archaeological Survey

The archaeological survey was conducted in order to identify occurrences of heritage resources, document their spatial distribution and evaluate their cultural and scientific significance.

Given the small size of the study area (about 3 km^2) and relatively good ground visibility (see Plate 4-32), it was possible to conduct a thorough and complete (100%) coverage of all proposed areas (i.e., the core area, residential areas, and tailing cell area).

In order to facilitate and systematise the archaeological survey, the study area was divided into seven survey zones (see Figure 4-32). Zone I included the core (fenced) area; Zone II consisted of the No. 2 area; Zone III the first proposed staff quarters in No. 3 (reef III); Zone IV, the second proposed staff quarters in No. 9; Zone V, the third proposed staff quarters in Bariadi; Zone VI, the proposed tailing area west of the Bariadi; and Zone VII, the alternative tailing area northwest of the airstrip.

The survey team consisted of ten people: nine survey assistants recruited locally, plus the Principal Researcher. Prior to work, the assistants were trained for two hours on survey techniques and how to identify various archaeological materials in the field, such as stone artifacts, pottery, bones, etc. Samples of each were brought by the Principal Researcher from the Archaeology Unit, UDSM.

The survey was conducted using the walk-over technique. The team members aligned along one edge of a survey zone (Plate 4-33), spaced 5-10 m apart (depending on ground visibility), and walked in straight transects (Plate 4-34), observing any occurrences of archaeological materials.

The Principal Researcher, who was positioned at the mid-point of the survey line, was notified of any important finding. Based on the cultural and scientific value of the object or feature found, the Principal Researcher would plot the finding on the grid map, and make sketches and/or take photographs. The latter (photographs) were taken in order to document the types and spatial distribution of findings.

Excavation

Excavation was not conducted because both ethnographic enquiries and surface survey indicated that the area did not have heritage resources, except recent graves. In addition, the study area had numerous pits and trenches left behind by artisanal miners (Plate 4-35), as well as those dug by KMCL for various purposes. These pits were used during the survey to observe the archaeological potential of the subsurface, rendering excavation unnecessary.

4.13.3 Findings

4.13.3.1 Results from Ethnographic Enquiries

Ethnic History:

The Bulyanhulu area lies on the wide plains of southern Lake Victoria, in the Kahama District. Today, the villages in the area (see Figure 2-4), including Kakola, Nyamikonze, Number Nine (in Zone IV, Figure 4-32) and Stamico (part of Iyenze) are multi-ethnic, resulting from the gold rush which took place in the area during the past twenty years. Almost all ethnic groups of Tanzania are represented, with Sukuma being the majority. Sukuma also live on the peripheries of the villages, engaging in farming and herding.

Although the peripheral inhabitants (Sukuma) portray themselves as indigenous to the area, oral evidence given and ethnohistoric sources (de Rosemond 1943, Schmidt 1996) indicate that the preceding inhabitants of this area were Sumbwa and Rongo, who were engaged in hunting and iron smelting, respectively. It is very likely that the Sumbwa and Rongo are two of over a hundred *ng'anda* (clan groups) who, according to B. Itandala, characterised Usukuma in the second millennium AD (Itandala 1983, pp. 33-4). Itandala (*ibid*) also notes that the earliest Bantu speaking people arrived in Usukuma between 500 BC and 500 AD. Prior to this date, the area was inhabited by hunter-gatherers (Itandala 1983, p.35).

In addition to confirming what had been reported by previous researchers, this study found out that a slow but determined influx of Sukuma farmers and herders into the Bulyanhulu area became significant at about the middle of this century. Before that, the Bulyanhulu area is said to have been avoided by herders because of lions. Emphasising this point, one informant, Mzee Masalisengwa stated that the south-eastern fringes of Bulyanhulu used to be known as *Ishaka ya Shimba,* meaning "the bush of lions". As more people moved close to the area, the lions moved off and, consequently, Bulyanhulu became inhabitable by herders.

Heritage resources.

Interviewees were also asked about heritage resources, such as lithic artifacts, relics of ancient metallurgy, architectural monuments, shrines, grave yards etc. in the study area. All denied seeing any such materials, except a few graves (see details below).

4.13.3.2 Results from Archaeological Survey

The archaeological survey did not yield any archaeological remains, except burial sites. A total of thirty-one (31) graves were found. Their frequency and distribution based on survey zone, and the identity of the deceased as reported by interviewees, is presented in Table 4-72. Table 4-73 provides the estimated age of the graves, based on interviewees and the age of grave tree-markers.

The graves were found in ten different locations, henceforth referred to as burial sites.

Burial Site 1: Burial site 1 was found in survey zone I, block 22600E/14000N. It consists of only one grave. The grave is soil heaped without additional mark (Plate 4-36). It is oriented north-south, and located 5 m from the road which runs from the exploration camp, along the sides of the soccer ground to the southern fence. The grave looks recent, not more than two years old. The specific identity of the deceased could not be established. However, its location, next to what used to be previous miners' quarters, implies that the deceased was an artisanal miner. Left as is, the grave mound is likely to disappear as a result of rain washing and vegetation cover in less than two years.

Burial Site 2: Burial Site 2 was found in survey zone I, block 22400E/14400N. It consists of two graves. The graves are soil heaped with woven twigs, otherwise used as sleeping mats by the artisanal miners, spread at the top. The graves are oriented southeast-northwest, and located 8 m from the base of Stefen Hill (a soil stockpile from the box cut), and 10 m from the road running west. According to locals, the burial took place in July/August 1996. The deceased were artisanal miners who reportedly died from gas poisoning in a mining pit.

If left, the grave mounds are likely to disappear as a result of rain washing and vegetation cover in less than two years. In addition, these graves are in danger of being buried by soil from Stefen Hill.

Burial Site 3: Burial Site 3 is located in survey Zone I, block 22200-22400E/14400N. This burial site consists of four graves, all of which are soil heaped. Three graves have woven twigs placed at the top, and one seems to have shrunk and is not covered by woven twigs. All graves are oriented north-south, and located across the road from Burial Site 2. The graves look recent, not more than two years old. The identity of the deceased could not be established. However, similarity with Burial site 2 suggests that the deceased were also artisanal miners.

If left, the grave mounds are likely to disappear as a result of rain washing and vegetation cover in less than two years.

Burial Site 4: Burial Site 4 is found in survey zone II, block 23000E/15200N (Reef No. 2). It consists of one grave, oriented east-west. This is the only grave found concretised (Plate 4-37). Although the exact age of the grave is not known, locals report that the concrete is not more than a year old. The fabricator of the concrete is not known since construction of the grave was not made public. The specific identity of the deceased is not known. However, its location, next to what used to be quarters of artisanal miners, implies that the deceased was an artisanal miner.

Burial Site 5: Burial Site 5, a grave yard given the relatively large number of graves and their varied age, was found in survey zone III, block 21800E/15400-15600N. It consists of fourteen graves, four of which are marked by minyaa plants *(Euphorbia tirucalli* L). The others are unmarked. All graves are soil heaped and are oriented east-west. According to locals, this was a burial site for what used to be one of the artisanal miners' quarters. Locals also reported that some graves are more than five years old. This was verified by the age of the marker plants. If left, all graves, except those with marker trees, will lose their specific locations as a result of rain washing and vegetation cover in less than two years.

Burial Site 6: Burial Site 6 is found in survey zone III, block 22200E/15400N. It consists of two graves which belong to Paulo Daudi (age 50). In one grave, he buried his daughter and the other, one his brothers. The former, located north of the latter, is marked by a tall cactus tree, while the latter is bare and is hard to find without the assistance of Paulo himself. However, during the survey, he was advised to tree-mark it.

Burial Site 7: Burial Site 7 is found in survey zone IV, north of the artisanal miners' Number Nine sub-village. This site consists of four graves, all of which are marked by minyaa *(Euphorbia tirucalli* L). The soil heaps have disappeared, and the graves have not been tended for years. According to locals, this burial place was used by artisanal miners in the 1970s and 1980s. The size of the marker trees indicate that the graves are more than ten years old.

Burial Site 8: Burial Site 8 is found in survey zone IV, in the middle of Number Nine village. The site consists of only one grave, dug in a termite mound, 3 m east of the Kakola-Nyamikonze road. When asked why they buried their dead on a termite mound, the local people said that this was the only place which could be dug more than a meter below the surface. The rest of the area has a very thin soil layer, underlain by lateritic rock. The grave belongs to one of the residents of Number Nine.

Burial Site 9: Burial Site 9 is found in survey zone IV, south of Number Nine village. It consists of only one grave, located under a big tree. The grave is less than a year old, and belongs to one of the residents of Number Nine. It is oriented east-west.

Burial Site 10: Burial Site 10 is found in survey zone V, Bariadi. It consists of only one grave, oriented north-south. The grave is soil heaped without any additional mark. According to locals, the burial took place in July/August 1996. The deceased was a Mnyantuzu san artisanal miner. If left, the grave may disappear as a result of rain washing and vegetation cover in less than two years.

4.13.4 Conclusions

A thorough archaeological investigation involving documentary study, ethnographic enquiry and archaeological survey of the KMCL concession was conducted. The investigation has proven that the KMCL land is free from prehistoric remains. This is not unusual considering the general lithological and geographical environment of the area. As a general rule, selection of habitation or settlement locations in prehistory, as well as today, has been governed by the availability of vital natural resources, especially water and food. While such resources can be transported from long distances today, in prehistoric times, people had to live in close proximity to such resources. As a result, prehistoric human and cultural evidence are found near large water bodies, especially fresh water lakes and rivers. Apart from providing humans with water to drink, the rivers and lakes guaranteed reliable supplies of food. The KMCL study area has neither a large river nor a lake, the soil is thin, and the weather is dry, thus not attractive to farmers. However, the light bushland of the KMCL consession is conducive to game animals, and might have attracted hunters in prehistoric times. No evidence was found to support this assumption. This is probably because of the lack of water sources where animals would come to drink.

The only materials of cultural value found in the study area were graves. A total of 31 graves were found, located in ten different locations in five survey zones (I through V). Of the 31 graves, two are at risk of being buried by soil piling at Stefen Hill. The remaining 29 graves are located in open areas where there is no immediate threat of human disturbance. However, all except the concretised grave of burial site 4, and the eight tree-marked graves (three in burial site 5, one in burial site 6 and four in burial site 7) are in danger of being lost as their mounds could be washed away by rain.

According to local people, graves are culturally sensitive for ritualistic and religious purposes.

4.14 LAND USE AND WATER SUPPLY

This section describes the existing land use and status of water utilisation in the area of the project. This area includes the village of Kakola and other neighbouring villages.

4.14.1 Land Use

4.14.1.1 Objectives of the Study

The specific objectives of the study were twofold:

- to identify current land use patterns in the area, including forestry, agriculture and livestock, small scale (artisanal) mining and fishing; and,
- to identify adjacent land use and future land use trends which could affect environmental management of the facilities at the site.

4.14.1.2 Methodology

The methodology used in conducting the study involved field work in the study area from July 7 to July 20, 1997. The following aspects were covered during the field work;

- review of existing information and data on the Project Area, including use and interpretation of aerial photography and satellite imagery;
- consultations at national, regional, district, and local (ward and village) levels; and,
- field reconnaissance employing the techniques of rapid resource appraisal. This involved:
    - review and updating the findings of the documentation review on field base maps;
    - sample transects using a landscape approach to ground truth mapped data; and,
    - village consultative meetings and joint field visits.

The results of the assessment were a description of baseline land use and land use patterns, and an examination of customary land rights.

4.14.1.3 Major Soil Land Units

Knowledge of the nature of soils in an area is important for meaningful understanding of land use practices in that area. Information on the location of major soils is based on work by De Pauw (1983) and the Farming Systems Research Programme of the Ministry of Agriculture. However, their soil classification of this area is generalised. The rapid field reconnaissance information was used to improve the resolution of the land units at Bulyanhulu.

A typical soil catena above granite bedrock at Bulyanhulu is:

- a belt of coarse grained sandy to gravelly soil at the top of the ridge;
- a general slope of hill sand;
- seepage soil of coarser material;
- a cemented hardpan soil; and,
- in the valley bottom, black or grey mbuga clays.

The most extensively cultivated soils are the granitic sands which are deep brown, light and easily worked, and fairly fertile.

<u>*Vertisols - "Mbuga" soils*</u>

These are clay soils found mainly on flat plains. The main rivers in the concession area, the Bulyanhulu and the Kabhanda, and their tributaries flow along some of these plains. The village settlements of Iyenze and Nyabikonze, north of the Bulyanhulu have a large proportion of mbuga soils. These mbuga soils are developed in unconsolidated, heterogeneous, fine-textured, alluvial-colluvial deposits originating from granitic parent material. They are deep to moderately deep, black, imperfectly drained, very hard when dry and very sticky and plastic when wet. The natural fertility is moderate. Soil reaction (pH) is neutral to mildly alkaline (7.0-8.0) in the topsoil, to strongly alkaline in the subsoils (8.5-9.0). Levels of organic carbon are low to medium in the topsoil (0.8-1.4%), gradually decreasing with depth. Total nitrogen levels are very low (0.05-0.06%). Available phosphorus levels of topsoils are variable. Soil capacity to retain and release nutrients is high (CEC-range: 30-33 cmolc/kg).

Limited areas of mbuga soils are located on the lowest parts of the Bulyanhulu catena. Here, they receive excess water from upslope, and are often temporarily flooded after heavy rains. In the extensive alluvial floodplains, waterlogging may pose a problem, but flooding is not frequent. It only occurs when the river overflows its banks after prolonged heavy rainfall has occurred in a large part of the catchment area. Waterlogging and its heavy texture are serious constraints on hoe cultivation and cropping.

Acrisols - "Luseni" soils

These are found in the KMCL Project and camp area, and in the Namba Tatu and Bariadi areas. They are deep to moderately deep, brown loams with a thick sandy surface. Deeper subsoils are very gravelly. An iron and manganese crust is often present within a depth of about 50-100 cm. Outcrops of iron and manganese ironstone frequently occur. Luseni soils have a low natural fertility. Values of pH are slightly neutral in the topsoil (range: 5.5-7.0) and decrease with depth, becoming strongly acidic in the subsoil (range: 5.1-5.2). Organic matter content is low (<1%). Total nitrogen is less than 0.1 % and available P is variable and erratic in topsoils; absolute values range from 3-28 mg P/kg. Soil capacity to release nutrients is low (CEC-values range from 8 cmolc/kg in the topsoil to 4 cmolc/kg in the subsoil).

Luvisols-"Kikungu" soils

These are found in areas lying to the south of the Kakola settlement and in Lwabakanga. They have developed from gneissic or granitic rocks. They are deep or moderately deep, well drained, red to reddish brown, loamy sand to sandy clay loams. Their natural fertility is generally low, but it may vary from place to place. Although agriculturally fertile, their physical properties require care to preserve crumb-structure and avoid wet-weather poaching and dry weather pulverisation. Careful conservation is required as both wind and water erosion threaten its sustainability.

4.14.1.4 Land Use Development

Historical Land Use

Prior to 1920, the Bulyanhulu landscape was covered with miombo woodland species which consisted principally of *Brachystegia, Terminalia, Combretum, Afzelia, Acacia, Dalbergia*, and some bushes and grasses. Game such as bushbuck, wildebeest, roan and giraffe were common in the area. The area was also home to tse-tse (*Glossina*), of which typical species were *G. pallidipes, G. morsitans* and *G. brevipalpis.*

Between the year 1920 and 1956, the British colonial administration assisted the people in Kahama, Geita and other parts of Sukumaland engaged in land clearing by removing bush and trees in tse-tse infested areas as part of the tse-tse eradication efforts, and provided areas for grazing. After bush clearing campaigns to eradicate the tse-tse fly and ox-plough introduction, farmers could migrate to and settle in these areas.

Organised villages in the Bulyanhulu area were formed in 1977 during the Operation Vijiji campaign, which put together people from Bushinghwe, Ulyanhulu and other neighbouring traditional villages. Today, Kakola, the main village in Bulyanhulu, has a population of 986 comprising 477 households. People will likely migrate to this area after the mine begins operation. It is estimated that currently the proportion of land use is 21% crops, 49% grazing, 28% forest, 2% residential. Figure 4-33 indicates the general land use in the area.

Customary Land Tenure

Most of the land in Kahama District in general, and in Bulyanhulu in particular, is held under customary land tenure whereby the village elders allocate land and villagers have usufructory right to idle land. The area has not as yet experienced serious land conflicts. However, due to the development and expansion of mining operations in Bulyanhulu, the area will likely develop into a township. In order to pre-empt adverse land use developments, the Kahama District Land Office is in the process of developing a land use plan for the area with the assistance of the Dutch Government, funded by the Kahama District Rural Development Programme.

Currently, part of the village land in Bulyanhulu is within the Prospecting License (PL) area of KMCL. Villagers have usufruct right to the land, which is not being used by KMCL as long as this does not involve mining activities. These rights include use of land for farming, grazing and wood collection and other non-mining activities. If mining operations are expanded in future to include more of the village land in Bulyanhulu, KMCL will address the appropriate land ordinances and regulations in the process of transferring the land ownership from customary to title deed ownership.

Farming

Both crop farming and livestock husbandry are practised in the Bulyanhulu area. The farmers cultivate the upper sandy soils of the catena, the "Luseni", and the "Kikungu" or "Nduha" that can be worked easily by hand hoes. However, with population pressure building, farmers have begun to cultivate the more difficult mbuga soils, which are mainly used for grazing. Decreased soil fertility levels of the upper sandy soil, combined with declining availability of the lower grazing land, may in future lead to overgrazing and food shortages.

The degree of use of draught animal power is low to moderate; between 30-60% of the households possess oxen. Crops are often planted on ridges constructed by hand-hoeing. The floodplain of the Bulyanhulu River is mainly used for dry season grazing. Only limited areas are used for cultivation of sorghum, sweet potato, cotton and maize. The crops cultivated are insufficient to directly satisfy the local food demand. However, livestock and cotton sales enable food to be bought (Table 4-74). At the moment, there are no serious conflicts between crop farming and cattle rearing.

Crops

Farmers near Bulyanhulu grow maize, sorghum, cassava, sweet potatoes, and cowpeas as food crops, and cotton as a cash crop (Plate 4-38). In Nyamikonze, farmers also grow paddy rice. These are all annual crops. Apart from paddy rice, these crops are grown on the catena with Luseni or Kikungu soils. Cotton can also grow on mbuga soils on fields which are less prone to waterlogging. Rice is grown only on mbuga soils. Rice yields of 2,000-3,000 kg/ha are quite common. However, rice is of minor importance at Bulyanhulu, mainly due to the limited extent of mbuga soils.

Farmers have a high return for labour in farming where they use fertiliser. In trials on Geita granite soils, there was good response to nitrogen fertiliser. There was a mean yield increase of about 4.5 bags per acre from application of the recommended dressing of 100 kgs nitrochalk per acre, but the application of phosphate was not found to be worthwhile. The response doubled with certain hybrids.

Maize

Maize is the preferred food crop of the people in Bulyanhulu. It is mostly planted in October on ridges. High, hand-hoed ridges are constructed to prevent runoff and stabilise production. It may be grown as a sole crop or it may be mixed with cowpea or cassava. In April, the maize is cut and stocked on large heaps. This clears the field for ploughing. Once maize is harvested (February to March), cassava will continue growing until the rainy season ends (June). Maize is readily sold during the dry season when traders can reach the villages.

The degree of use of draught animal power is low to moderate. Many households do not possess oxen, and the local ridge construction method requires hand-hoeing. Labour shortages are therefore mainly concentrated during the land preparation phase. Manure is preferentially applied to horticultural crops which are mostly planted off-season.

Cotton

Cotton is the main cash crop at Bulyanhulu. Improved distribution of ox-ploughs, together with tsetse fly vegetation clearing efforts, led to a considerable increase in cotton acreage and cotton production in the area in the 1950s. In the 1960s, cotton production continued to increase due to favourable world market prices, improved organisation and marketing (very successful cooperative movement), the release of new high-yielding, pest and disease resistant varieties, and the encouraging support by traditional leaders and politicians. However, shortly after independence, the dissolution of cooperative unions, and the enforced settlement concentration campaigns, had dramatic negative effects on cotton production.

In the 1960s, cotton provided indirect food security for farmers (reliable payment and favourable prices). This function was taken over by food crops and vegetables to supply artisanal miners in the early and mid 1990s. Cotton is beginning to regain its former function after cessation of artisanal mining, although competition with food crops is heavy. There is still no reliable institutional setting for marketing cotton, and no intensification programme to increase yields.

Further increase in cotton production may be expected, especially after introduction of labour saving equipment for weed control and maintenance of soil fertility. As new ginnies are constructed in this area, there is an urgent need to address farmers' problems, especially with a view to minimising environmental degradation.

Soil and Water Conservation

High, hand-hoed ridges are constructed to prevent runoff and stabilise production. Tie-ridging was recommended since the 1940s. Tie-ridging is an invaluable soil conservation method for the easily eroded hill sands. During the period of the Sukumaland plan, when people were moved from the central zone to the less densely populated areas of Geita and Kahama, the adoption of tie-ridges was compulsory. Tie ridges are aligned along centre, and cross-ties are put in at about 2 m intervals. If carried out properly, soil and water are held in situ, whereas under the local ridging system, they are only retained after running down the slope; water often breaks through at low places with consequent gullying. There has been little acceptance of tie-ridging in Sukumaland, and local farmers obviously do not accept that adoption as being to their advantage.

Sources of Labour

The management of an adequate supply of labour at critical periods in a labour intensive farming system creates a major problem. This function of management varies greatly amongst farm families. Farm work near Bulyanhulu is largely carried out by the farm family. Additional labour, which becomes necessary because of illness, domestic problems, or the physical expansion of farm operations, may be called in through one of the many traditional sources of labour, or it may be hired.

Crop labour requirements are not demanding in the early part of the rainy season. Ronce (1948) has shown that the limiting factor to the areas which a self-supporting family could cultivate was the time taken to prepare the land and plant their main crops. He estimated that, if family labour was fully expended between the beginning of the rains and the end of January, 4 to 5 hectares of mixed crops was the most that could be cultivated by a family unit in Sukumaland in the 1940s. From the results of a farm management study carried out in Geita District in 1963, the estimated labour requirement of sesa (planting on the flat), ridging and sowing of cotton was approximately 25 mandays. An average family of 6.6 persons with 2.8 man-equivalents of family and 0.17 man equivalents of casual labour, cultivated about 5 hectares. For the greater part of the November-January period, the crop labour requirement exceeded the level of available family labour. Consequently, 62% of his farms hired labour and 71% of this labour was used for land cultivation.

Livestock

The East African Zebu is the main type of cattle reared at Bulyanhulu. (Plates 4-38 and 4-39). It is tolerant to tropical diseases, such as the East Coast Fever which is a tick-borne disease. The 1996 livestock census showed that Kakola village had 1845 head of cattle, as well as 815 goats, 160 sheep, 85 donkeys and 20 pigs, and 20-40% of the households possessed livestock (Table 4-75).

Grazing

Grazing land in Bulyanhulu is still communally held, although in practice, each village tends to graze their stock in well defined areas. Harvested fields are available for common grazing. When family labour is not available, herding problems may be overcome by running stock with those of neighbours, the owners taking it in turns to herd the animals. Conflicts between livestock and non-livestock owners are not common.

Development of Extractive Land Use at Bulyanhulu

Before KMCL commenced development activities at Bulyanhulu, very little cultivation occurred in the wooded area between Kakola and the Bulyanhulu River to the north. Before mining activities started prior to the 1970s, most of the area was covered with indigenous trees, bushes, and grasses. The Bulyanhulu River, though heavily silted, flowed almost undisturbed in its 25 km journey across the 50 km^2 of claim area in an easterly and north-easterly direction. Apparently, there were no plans by residents of the area for use of the land, except to view it as being a natural resource base for their future use. In the mid-1970s, local artisanal miners discovered the oxide zones of at least six reefs at Bulyanhulu. This discovery was followed up by drilling and trenching by government geologists between 1977 and 1982. In 1983, more drill holes were completed by the State Mining Corporation in collaboration with Finnish (Outokumpu) and Japanese (Kone) companies. Over one hundred more holes were drilled by Placer Dome Inc., from 1989 to 1992. KMCL took over in 1992.

Meanwhile, artisanal mining activities intensified, and by 1996, there were an estimated 500 miners in the area. Most miners were temporary immigrants. An estimated 400 mine pits were dug, of which 11 were owned by women. Due to the increase in number of artisanal miners, the nearby Kakola village, 3 km southwest of the camp, experienced a population explosion, as did nearby Kabale and Bushingwe settlements. This influx of people led to the mushrooming of dobboros in the camp or "Reef" area and in the vicinity, famous among which were the so-called Number Mbili, Nambatatu and Bariadi (Figure 2-4; Plate 4-40). In September 1996, the artisanal miners were peacefully moved off of the Bulyanhulu PL by government officials.

Forestry

There is no appreciable afforestation work within the villages near Bulyanhulu, although district forestry officials both in Kahama and Geita said there is a national tree planting campaign which applies to both districts. There are no village by-laws to preserve the woodlands, although there is a general awareness about the importance of doing so. Due to the rapid population growth rate, currently estimated at 5.6%, more and more of the trees in the native woodland are being depleted to give way to cultivation and grazing (Plate 4-39). The demand for the trees is also increasing to provide building material, fuelwood and charcoal (there are currently 477 households in Kakola village). These bushlands are communally owned by the villages. Bushed areas are mainly found farthest away from homesteads, separated by cultivated and fallow land.

Land Occupied by the Project

Perimeter fencing of the project area has been completed. The fence encloses the important mine reefs, the mine development area and associated infrastructure.

4.14.2 Water Utilisation

It was recognised that the proposed project could lead to increases in the populations in local villages as a result of migrants coming to directly or indirectly seek work. Such increases would create additional demands on existing resources, especially those in limited supply, such as water. Consequently, KMCL commissioned Water & Environment (Tanzania (T)) Ltd. (WEGS, based in Arusha) to prepare an inventory of water utilisation in the villages within and in proximity to the Bulyanhulu Concession.

The objectives of the inventory included the collection of the following information:

- demographics: human and livestock populations, number of households, and comments on any recent changes in growth rates;
- water demand: domestic, institutional and commercial water demand calculations;
- water supply type and status: existing water supply categorisation (springs, hand dug wells, developed wells, boreholes, pipeline schemes, artisanal activities);
- water source yields: estimated yields for water sources. General ground water levels will be given where they are observed in the water sources (wells); and,
- a village water source map: a map showing water source locations and estimated yield, catchment boundaries, water supply infrastructure (pipelines, storage tanks, domestic water points, etc.).

Significant villages within and neighboring the Bulyanhulu PL are Iyenze, Nyamikonze, Lushimba, Busulwangili and Kakola (see Figure 4-34). The first three of these villages are located in Geita District, Mwanza Region. The latter two villages are located in Kahama District, Shinyanga Region.

The villages rely on both surface water and groundwater for water supply. The Bulyanhulu River is primarily used for gold washing, cattle watering and limited, unimproved domestic supplies. Groundwater extraction points are located in the weathered overburden (regolith), although groundwater is also accessible in the fractured bedrock where the saturated regolith is thin.

In the villages surveyed, there are only a few perennial groundwater sources (hand dug wells), and only one perennial spring. The salinity (electrical conductivity) of this water is generally less than 600 μS/cm. In the five (5) villages surveyed, a total of nineteen (19) existing traditional groundwater extraction points were noted, as shown below and in Figure 4-34.

NUMBER OF WATER POINTS IDENTIFIED					
Village	**Local Well Perennial**	**Shallow Well**	**Spring Perennial**	**Borehole With Hand Pump**	**Total**
Nyamikonze	-	3	-	2	**5**
Iyenze	-	2	-	1	**3**
Kakola	5	1	-	-	**6**
Lushimba	3	-	1	-	**4**
Busulwangili	-	1	-	-	**1**
TOTAL	**8**	**7**	**1**	**3**	**19**

In the dry season, when wells become dry, villagers use water from the Bulyanhulu River. Also, it was observed that if the River is closer than the nearest well, river water is sometimes used for convenience. Dissolved iron and manganese concentrations in surface water appear to be low.

Generally, livestock are watered exclusively (100 %) from the Bulyanhulu River. When wells dry up, water supply is approximately 95 % from the river for most villagers.

Prior to KMCL's 1997-98 potable water well development program, reliable and improved water supplies in the area were represented by three (3) wells equipped with hand pumps, one (1) shallow ring well with a hand pump, and one (1) improved well where a bucket, as summarised below.

PREVIOUSLY EXISTING RELIABLE IMPROVED WATER SUPPLIES			
VILLAGE	**WATER SUPPLY**	**QUANTITY**	**STATUS**
Nyamikonze	Borehole with hand pump	2	one; working since January 1997 one; out of order with broken hand pump
Iyenze	Borehole with hand pump	1	not yet working, hand pump fitted in January 1997
Iyenze	Shallow ring well with hand pump	1	working since July 1996
Busulwangili	Shallow well no hand pump (bucket)	1	working

The village of Lushimba relies on hand dug water holes or well type springs. Shallow dug pits and shallow dug wells are generally less than 5 m deep and maybe improved by lining and placement of concrete slabs for cover. The dug wells and pits contain low conductivity water

(<100 μS/cm), but may contain potentially harmful bacteria (coliforms). Some are not perennial sources, failing during dry periods. There are no gravity pipeline schemes in the study area.

Prior to 1997, Kakola also relied on hand dug water holes or well type springs. Following KMCL's well installation program, four wells are now available in the Kakola area for potable water supply. Each well can yield approximately 2-4 m^3/hr of good quality water.

Population and livestock figures were provided by the respective villages. The last official government sponsored census was in 1988. Village boundaries were defined to establish the population distribution in each village. The villages provided maps that contained the village and sub-village boundaries. Where available, the population of sub-villages was noted.

The current total population in the area is approximately 15,000. An accepted value for water demand in the area is approximately 25 litres per day per capita. Therefore, the current demand for domestic water supply is in the region of 375 m^3/day (4.4 l/s) for the affected villages.

Details of the water extraction points, population data, physical features, population growth and water demand projections are given on Village Information Sheets in Appendix 4-10.

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TABLE 4-1
SHINYANGA MEAN MONTHLY TEMPERATURES (°C)
JANUARY 1987 THROUGH DECEMBER 1996

Period	Mean Monthly Minimum Temperature												Mean Annual
Year	January	February	March	April	May	June	July	August	September	October	November	December	Minimum
1987	17.77	17.83	17.85	17.76	16.95	16.04	12.94	m	m	20.60	19.48	19.34	17.66
1988	18.85	19.07	19.05	18.72	17.81	16.16	16.37	17.66	19.10	20.45	19.85	19.31	18.53
1989	17.92	18.17	18.27	18.08	16.91	15.14	14.66	16.14	18.51	20.09	20.22	19.04	17.76
1990	17.82	18.85	18.49	18.60	17.08	15.17	13.88	16.39	18.23	19.57	19.67	m	17.61
1991	18.59	18.42	18.10	17.96	18.15	16.30	15.52	15.73	18.11	18.75	18.79	18.58	17.75
1992	19.05	18.64	18.94	19.17	17.69	17.09	15.68	16.19	18.97	19.91	19.67	19.03	18.34
1993	18.31	18.01	18.46	20.37	m	m	11.81	15.59	17.93	20.30	20.69	20.72	18.22
1994	19.48	18.78	18.55	18.12	18.17	16.30	16.54	17.38	19.18	20.55	19.79	19.52	18.53
1995	18.93	18.24	18.27	18.75	17.75	16.36	15.89	17.01	19.21	20.25	20.53	19.76	18.41
1996	18.84	18.39	18.78	17.70	17.67	16.30	15.63	16.34	18.71	19.10	19.85	19.67	18.08
Mean	18.55	18.44	18.48	18.52	17.57	16.10	14.89	16.49	18.66	19.96	19.85	19.44	18.08

Period	Mean Monthly Maximum Temperature												Mean Annual
Year	January	February	March	April	May	June	July	August	September	October	November	December	Maximum
1987	27.96	29.84	31.04	30.10	29.51	29.65	30.89	31.20	32.39	32.87	30.07	31.71	30.60
1988	28.19	m	29.09	29.18	30.00	30.26	29.96	30.69	32.29	32.43	30.49	30.22	30.26
1989	26.14	28.44	29.72	28.24	28.15	28.86	29.30	30.52	32.04	33.02	29.73	27.96	29.34
1990	29.29	28.98	28.44	28.34	29.65	29.61	29.53	30.10	31.94	32.64	31.14	m	29.97
1991	29.57	30.49	30.65	29.21	30.26	30.64	29.55	30.91	32.38	30.13	31.65	29.21	30.39
1992	31.46	29.55	31.57	29.67	29.10	29.76	29.39	30.19	31.78	32.14	30.59	28.56	30.31
1993	28.00	28.97	29.34	31.39	30.12	29.96	29.68	30.59	32.29	33.26	32.40	33.32	30.78
1994	29.17	28.39	29.14	30.49	29.88	30.59	29.79	30.79	32.74	33.27	30.09	28.95	30.27
1995	29.51	28.82	29.19	30.30	29.34	30.64	30.26	31.57	32.27	32.87	32.57	31.63	30.75
1996	30.00	29.28	30.68	29.12	30.35	29.92	29.78	30.81	32.01	32.50	32.25	30.67	30.61
Mean	28.93	29.20	29.89	29.60	29.63	29.99	29.81	30.74	32.21	32.51	31.10	30.25	30.32

m missing

TABLE 4-2
SHINYANGA DAILY MINIMUM AND MAXIMUM TEMPERATURES FOR EACH MONTH
JANUARY 1987 THROUGH DECEMBER 1996

Period	Daily Minimum Temperature												Annual Minimum Day
Year	January	February	March	April	May	June	July	August	September	October	November	December	Temperature (°C)
1987	16.00	15.60	15.60	15.60	14.90	14.00	8.20	m	m	17.8	16.5	17.40	8.20
1988	17.00	17.40	16.70	17.60	14.60	14.10	12.40	15.70	17.50	18.00	17.80	17.50	12.40
1989	16.20	17.10	16.60	15.40	14.50	11.30	12.60	14.10	16.50	17.90	18.00	17.00	11.30
1990	15.10	16.40	16.50	17.80	14.40	12.60	11.00	14.60	15.90	17.30	17.80	m	11.00
1991	17.00	15.80	16.80	13.90	16.40	13.30	12.90	13.50	15.90	16.50	17.30	16.50	12.90
1992	17.20	17.10	17.00	17.70	15.50	15.20	13.70	13.40	16.60	17.50	17.30	17.00	13.40
1993	15.80	16.50	16.50	17.20	m	m	10.7	12.20	15.60	18.60	17.70	18.50	10.70
1994	17.50	16.80	16.80	16.00	16.00	10.30	15.40	14.80	16.00	17.50	18.00	18.40	10.30
1995	17.50	14.50	15.60	16.50	15.50	13.20	13.40	14.70	15.50	18.50	18.50	18.00	13.20
1996	16.60	17.00	17.00	15.40	14.50	13.10	13.80	12.50	17.00	16.00	17.00	17.50	12.50
Minimum	15.10	14.50	15.60	13.90	14.40	10.30	8.20	12.20	15.50	16.00	16.50	16.50	8.2 (07/31/1987)

Period	Daily Maximum Temperature												Annual Maximum Day
Year	January	February	March	April	May	June	July	August	September	October	November	December	Temperature (°C)
1987	31.70	32.20	34.00	34.70	31.30	31.70	33.10	32.8	33.8	35.4	33.7	34.70	35.40
1988	32.60	m	34.00	30.80	32.00	31.80	31.70	32.60	35.40	34.80	33.00	33.20	35.40
1989	30.30	31.90	33.20	30.20	30.00	31.60	31.80	32.80	34.20	34.60	34.70	30.20	34.70
1990	32.10	33.20	31.00	30.50	30.80	31.50	31.20	32.70	33.90	34.50	33.80	m	34.50
1991	33.00	33.50	34.90	31.30	32.00	32.80	31.70	32.50	34.20	34.60	39.80	32.50	39.80
1992	34.70	32.20	34.00	32.00	31.00	31.00	31.00	32.50	34.00	33.90	34.00	32.50	34.70
1993	31.80	32.70	31.90	32.80	32.40	31.50	31.00	32.60	34.50	35.00	34.50	34.80	35.00
1994	34.80	32.00	32.80	32.50	31.50	33.50	33.00	32.50	35.00	34.60	33.50	31.00	35.00
1995	32.30	32.50	32.50	32.00	31.00	32.50	31.80	33.50	34.60	35.30	35.00	34.40	35.30
1996	33.50	32.00	35.40	30.50	31.50	32.00	31.50	32.30	34.00	34.60	34.50	34.50	35.40
Maximum	34.80	33.50	35.40	34.70	32.40	33.50	33.10	33.50	35.40	35.40	39.80	34.80	39.8 (11/11/1991)

TABLE 4-3
SHINYANGA MONTHLY RAINFALL (mm)
JANUARY 1985 THROUGH DECEMBER 1994

Period	Monthly Rainfall (mm)												Annual
Year	January	February	March	April	May	June	July	August	September	October	November	December	Rainfall (mm)
1985	97.10	139.5	103.6	142.8	37.9	0	0	0	0.3	6.6	167.4	311.8	1007.0
1986	151.4	67.8	105.8	192.5	35.2	0	0	0	0	155.2	123.9	234.1	1065.9
1987	117	48.2	63.1	142.3	14.4	8.8	0	0	17.9	107.9	114.6	64.2	698.4
1988	190.9	102.2	149.2	81.7	2.6	0	0	2.3	0.5	32.6	104.4	202	868.4
1989	128.2	181.1	200.3	145	31.2	0.8	0	0.7	21	5.7		212.4	926.4
1990										15.7	106.6	253.7	376.0
1991	102.5	69.3	145.6	13.9	39.4	9.2	0	1.4	18.9	129.6	56.8	133.3	719.9
1992	36	102.7	84.7	213.4	53.9	1.1	0	0	0	44.2	130.4	120.8	787.2
1993	97.3	168.1	180.5	41.9	44.4	8.2	0	0	0.2	0.1	41.1	10.4	592.2
1994	136.5	94.3	142.9	95.2	38.1	0	0	0	0	19.4	182.7	138.6	847.7
Mean													788.9
Mean of monthly mean	117.4	108.1	130.6	118.7	33.0	3.1	0.0	0.5	6.5	51.7	114.2	168.1	851.1
Prorate mean													821.4
Mean (not included 1990)													834.8

TABLE 4-4
SHINYANGA MONTHLY MEAN AND MONTHLY DAILY MAXIMUM WIND SPEEDS (km/hr) @ 06:00 GMT

Period	Monthly Mean Wind Speed @ 6:00 GMT												Mean Annual
Year	January	February	March	April	May	June	July	August	September	October	November	December	Wind speed
1987										8.35	5.97	5.84	6.72
1988	4.77	5.97	5.55	5.67	8.68	9.00	8.19	7.35	7.97	7.90	5.57	6.16	6.90
1989	3.26	3.25	5.03	5.47	6.97	7.57	8.65	10.55	10.03	10.90	8.89	4.23	7.07
1990	5.87	5.71	5.16	4.50	8.29	9.27	11.48	10.94	10.60	9.68	8.83	4.19	7.88
1991	4.94	5.25	6.10	6.63	8.58	8.42	7.48	9.87	6.71	8.30	4.68		7.00
1992	4.97	3.97	5.16	5.40	5.39	7.10	8.55	8.90	11.57	5.77	5.77		6.59
1993	4.16	2.82	4.58	5.77	5.10	8.63	10.10	10.94	11.23	12.00	8.17	6.19	7.47
1994	4.13	4.54	4.97	5.67	7.87	8.43	8.84	9.42	11.97	7.71			7.35
1995	4.55	2.68	4.97	5.47	6.65	8.40	9.16	13.06	9.31	8.68	5.59	5.87	7.03
1996	4.32	3.97	5.39	9.07	9.13	8.77	9.20	9.19	5.87	6.03			7.09
Mean	4.55	4.24	5.21	5.96	7.41	8.40	9.07	10.02	9.47	8.55	6.79	5.33	7.08

Period	Monthly Daily Maximum Wind Speed @ 6:00 GMT												Annual Maximum
Year	January	February	March	April	May	June	July	August	September	October	November	December	Wind Speed
1987										16	16	10.00	16.00
1988	12.00	16.00	12.00	12.00	16.00	15.00	16.00	12.00	12.00	27.00	12.00	12.00	27.00
1989	8.00	6.00	10.00	10.00	12.00	16.00	15.00	25.00	22.00	17.00	20.00	10.00	25.00
1990	12.00	12.00	12.00	10.00	16.00	16.00	16.00	17.00	20.00	22.00	20.00	10.00	22.00
1991	10.00	16.00	12.00	16.00	16.00	17.00	16.00	22.00	17.00	20.00	10.00		22.00
1992	12.00	10.00	12.00	10.00	12.00	16.00	16.00	15.00	25.00	12.00	20.00		25.00
1993	13.00	10.00	10.00	12.00	10.00	14.00	18.00	16.00	18.00	16.00	16.00	14.00	18.00
1994	10.00	10.00	18.00	10.00	14.00	16.00	16.00	16.00	22.00	16.00			22.00
1995	12.00	16.00	16.00	14.00	12.00	15.00	18.00	22.00	20.00	18.00	14.00	20.00	22.00
1996	12.00	10.00	10.00	14.00	16.00	18.00	14.00	20.00	15.00	12.00			20.00
Maximum	13.00	16.00	18.00	16.00	16.00	18.00	18.00	25.00	25.00	27.00	20.00	20.00	27.00

TABLE 4-5

SHINYANGA MEAN MONTHLY AND MONTHLY DAILY MAXIMUM WIND SPEEDS (km/hr) @ 12:00 GMT

Period	Mean Monthly Wind Speed @ 12:00 GMT												Mean Annual
Year	January	February	March	April	May	June	July	August	September	October	November	December	Wind speed
1987										7.29	6.30	6.35	6.65
1988	6.29	7.76	6.68	7.13	6.58	9.03	7.45	6.84	7.87	7.74	5.50	6.42	7.11
1989	5.16	4.93	7.61	7.17	7.77	8.63	9.19	9.26	9.43	8.97	9.46	6.16	7.81
1990	8.03	7.04	6.03	5.97	7.58	9.87	11.65	9.61	8.07	8.13	7.10	5.03	7.84
1991	5.68	7.32	8.32	8.63	8.74	10.23	8.52	8.10	6.61	7.97	6.52		7.88
1992	5.74	5.93	7.77	6.10	8.26	7.07	7.58	6.74	5.90	4.32	6.00		6.49
1993	5.48	6.18	5.19	6.87	5.58	6.80	8.97	8.58	7.90	7.35	6.97	7.39	6.94
1994	4.77	4.54	4.45	6.13	6.84	6.93	7.03	6.58	7.10	6.94			6.13
1995	5.65	7.57	7.35	5.17	6.42	5.97	8.13	9.52	7.10	7.16	7.44	7.84	7.11
1996	5.52	5.10	7.23	8.60	8.48	8.16	8.83	8.39	7.40	5.74			7.35
Mean	5.81	6.26	6.74	6.86	7.36	8.08	8.59	8.18	7.49	7.16	6.91	6.53	7.17

Period	Monthly Daily Maximum Wind Speed @ 12:00 GMT												Annual Maximum
Year	January	February	March	April	May	June	July	August	September	October	November	December	Wind Speed
1987										16.00	12.00	12.00	16.00
1988	22.00	16.00	18.00	16.00	12.00	16.00	16.00	16.00	16.00	27.00	10.00	20.00	27.00
1989	27.00	10.00	20.00	16.00	18.00	16.00	27.00	20.00	20.00	18.00	27.00	12.00	27.00
1990	20.00	18.00	22.00	12.00	14.00	14.00	20.00	16.00	20.00	20.00	17.00	16.00	22.00
1991	12.00	27.00	24.00	16.00	16.00	20.00	16.00	16.00	18.00	19.00	30.00		30.00
1992	12.00	20.00	24.00	16.00	27.00	16.00	16.00	14.00	14.00	12.00	14.00		27.00
1993	16.00	12.00	10.00	14.00	12.00	14.00	16.00	16.00	16.00	14.00	16.00	14.00	16.00
1994	18.00	10.00	10.00	12.00	14.00	15.00	16.00	16.00	16.00	26.00			26.00
1995	10.00	20.00	18.00	12.00	13.00	14.00	18.00	30.00	15.00	18.00	14.00	25.00	30.00
1996	20.00	10.00	14.00	14.00	16.00	12.00	20.00	27.00	18.00	12.00			27.00
Maximum	27.00	27.00	24.00	16.00	27.00	20.00	27.00	30.00	20.00	27.00	30.00	25.00	30.00

TABLE 4-6
BULYANHULU WEATHER STATION
FEBRUARY 9, 1997 TO JANUARY 30, 1998

MONTH	Average Monthly Wind Direction	Average Monthly Wind Speed (km/hr)	Average Monthly Temp. (°C)	Average Monthly Solar Radiation	Average Monthly Relative Humidity (%)	Monthly Rainfall 1997 (mm)	Maximum Monthly Daily Temp. (°C)	Minimum Monthly Daily Temp. (°C)
Feb-97*	203.3	4.3	21.7	5154.4	71.0	42.4	32	15
Mar-97	146.3	4.3	22.7	5145.8	73.4	103.2	33	17
Apr-97	189.0	4.3	21.0	5169.7	83.1	158.0	30	15
May-97	184.7	4.0	20.9	5187.5	84.9	63***	28	17
Jun-97	167.1	5.7	21.3	5172.5	62.4	19.8	30	13
Jul-97	169.1	6.0	21.2	5170.4	50.3	2.6	31	13
Aug-97	151.4	5.8	22.8	5168.9	50.1	35.8	32	15
Sep-97	132.6	6.8	24.9**	5157.0	36.0	0.2	34	16
Oct-97	136.6	6.5	23.9**	5151.3	57.9	75.5	34	18
Nov-97	120.7****	6.2****	21.4	5068.4	84.0	268.6	32	17
Dec-97	m	m	20.7	5075.6	89.7	216.8	30	17
Jan-98	m	m	21.5	5270.9	87.9	163.6	31	17

* data collection began February 9, 1997
** data collected from Sept 19 to Oct 2 inaccurate, and not used
*** May 11 to May 31 data missing
**** Wind data after November 7 missing - sensor malfunction
m data missing - sensor malfunction

TABLE 4-7
SUMMARY OF WIND SPEED DATA, BULYANHULU

Wind Speed (km/hr)	*Feb -April*		*May - Oct*		*Feb 9 - Nov 3*	
	Frequency	*%*	*Frequency*	*%*	*Frequency*	*%*
< 5.0	1180	61.3	1957	44.3	3144	49.1
5.1-10.0	665	34.6	1979	44.8	2684	41.9
10.1-15.0	77	4.0	459	10.4	554	8.6
15.1-20.0	2	0.1	21	0.5	23	0.4
>20.0	0	0.0	0	0.0	1	0.0

TABLE 4-8
SUMMARY OF WIND DIRECTION DATA, BULYANHULU

	Feb -April		*May - Oct*		*Feb 9 - Nov 3*	
Wind Direction	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
0.1 to 22.5	71	3.7	131	3.0	203	3.2
22.6 to 45.0	34	1.8	106	2.4	143	2.2
45.1 to 67.5	54	2.8	115	2.6	174	2.7
67.6 to 90.0	66	3.4	175	4.0	249	3.9
90.1 to 112.5	129	6.7	382	8.7	530	8.3
112.6 to 135.0	167	8.7	1044	23.6	1238	19.3
135.1 to 157.5	203	10.5	830	18.8	1034	16.1
157.6 to 180.0	244	12.7	528	12.0	772	12.1
180.1 to 202.5	208	10.8	249	5.6	457	7.1
202.6 to 225.0	168	8.7	168	3.8	336	5.2
225.1 to 247.5	132	6.9	121	2.7	253	3.9
247.6 to 270.0	132	6.9	134	3.0	266	4.2
270.1 to 292.5	105	5.5	139	3.1	244	3.8
292.6 to 315.0	86	4.5	99	2.2	186	2.9
315.1 to 337.5	55	2.9	90	2.0	145	2.3
337.6 to 360.0	71	3.7	105	2.4	176	2.7

TABLE 4-9
DUST FALL RESULTS
BULYANHULU

Sampling Period	Station N	Station E	Station S	Station W	Monthly Median
July-Aug	1.28	1.47	1.79	6.83	1.63
Sept-Oct	1.06	3.03	1.21	0.81	1.14
Oct-Nov	3.36	4.3	1.27	2.75	3.06
Dec-Jan	0.66	1.93	n/a	1.21	1.21
Station median	1.17	2.48	1.27	1.98	

British Columbia Dust Fall Guidelines

Level A - 1.7 $mg/dm^2/day$

Level B - 2.9 $mg/dm^2/day$

TABLE 4-10

SUMMARY OF UPPER MAGOGO RIVER (1968-1986) AND BULYANHULU RIVER (1997-1998) MONTHLY STREAMFLOW

Hydrologic Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
1968/69	0.00	1.47	1.23	1.45	6.18	1.07	0.09	0.36	0.00	0.00	0.00	0.00	0.95
1969/70	0.00	1.47	0.62	1.14	0.78	4.32	7.08	0.29	0.00	0.00	0.00	0.00	1.30
1970/71	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.05
1971/72	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
1972/73	0.00	4.54	0.97	0.57	1.31	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.65
1973/74	0.00	0.00	0.00	0.00	0.00	0.88	5.17	0.95	0.00	0.00	0.00	0.00	0.58
1974/75	0.00	0.02	0.00	0.00	0.50	1.80	0.13	0.00	0.00	0.00	0.00	0.00	0.20
1975/76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976/77	0.00	0.33	0.44	0.10	0.25	0.34	4.08	0.44	0.00	0.00	0.00	0.00	0.49
1977/78	0.00	0.73	0.06	0.00	1.37	6.98	1.42	0.00	0.00	0.00	0.00	0.00	0.88
1978/79	0.00	3.54	3.54	0.07	0.12	0.19	6.48	3.85	0.00	0.00	0.00	0.00	1.48
1979/80	0.00	0.00	0.11	0.01	0.00	1.31	0.96	3.04	0.00	0.00	0.00	0.00	0.46
1980/81	0.00	1.47	1.23	0.00	0.00	1.29	8.77	4.79	0.00	0.00	0.00	0.00	1.46
1981/82	0.00	1.47	1.23	0.30	0.00	0.00	1.51	1.28	0.00	0.00	0.00	0.00	0.48
1982/83	0.00	4.81	4.55	0.44	0.00	1.98	1.79	1.78	0.00	0.00	0.00	0.00	1.29
1983/84	0.00	0.76	0.77	0.17	0.00	0.00	2.86	1.16	0.00	0.00	0.00	0.00	0.47
1984/85	0.00	0.53	0.16	0.06	1.11	1.16	7.74	1.83	0.50	0.00	0.00	0.00	1.08
1985/86	0.00	5.26	6.63	0.25	0.68	1.29	2.86	1.16	0.03	0.00	0.00	0.00	1.51
Mean	0.00	1.47	1.23	0.25	0.68	1.29	2.86	1.16	0.03	0.00	0.00	0.00	0.74
1997/98 Bulyanhulu at H2													
1996/97					3.94	0.77	1.47	6.50	1.11	0.40	0.42	0.09	
1997/98	0.04	1.51	9.44	9.29									

Note: all values in cubic meters per second (cms)

TABLE 4-11
SUMMARY OF BULYANHULU RIVER DISCHARGE MEASUREMENTS AT STATION H2

Date	Time		Staff Height (m) Manual Read		Staff Height (m) Electronic		Width	Area	Q	Avg U	Avg Z	Meter
mm/dd/yy	start	finish	start	finish	start	finish	(m)	(sq.m)	(cu.m/s)	(m/s)	(m)	Used
2/8/97	10:40		0.39		0.315		3.70	1.14	0.188	0.17	0.31	AA
2/10/97	10:00		0.38		0.300		4.20	1.30	0.215	0.17	0.31	AA
3/4/1997[a]	17:00		0.52		0.411		3.80	1.68	0.024	0.01	0.44	AA
4/26/1997[b]	14:17	15:36	0.48	0.46	0.465	0.458	7.50	1.78	0.924	0.52	0.25	pygmy
4/30/97	9:39	11:22	0.65	0.63	0.654	0.630	8.00	3.00	3.920	1.31	0.37	AA
5/10/97	11:16	12:29	0.66	0.66	0.669	0.665	8.90	3.86	5.182	1.34	0.45	AA
6/8/97	18:15		0.46[c]		NR		8.50	2.38	1.314	0.55	0.31	pygmy
7/31/97	16:35	16:49	0.20	0.20	0.154	0.153	4.40	0.42	0.606	1.46	0.11	pygmy
8/18/97	18:15		0.16[d]		0.127[d]		3.90	0.33	0.250	0.77	0.09	pygmy
11/28/97	9:50	10:40	NR	0.82	0.800	0.784	8.70	4.59	7.243	1.58	0.57	AA

NR not recorded

a readings affected by downstream dam
b gaging station moved to new location
c recorded at 15:00, not recorded during discharge measurement
d recorded at 18:30

TABLE 4-12
SUMMARY OF BULYANHULU WATER RESOURCES BOREHOLE DATA

Borehole	Date Drilled	Total Depth (m)	Depth Cased (8")	Screened Section (8")	Main Water Strike (mbgl)	RWL (mbgl)	Aquifer	Airlift Yield (m^3/hr)	Pump Test Yield (m^3/hr)	Transmissivity (m^2/d)
101	1997	98 (87)	28.5	34 - 82 (6")	47	47/35.9	Saprolite	7.1	3.0	1.65 - 3.55
102	1997	71	-	-		Dry	Saprolite	-	-	-
103	1997	59	-	-		Dry	Saprolite	-	-	-
104	1997	53	28.7	-	40 - 41	40/30.4	Saprolite	1.2	1.5	0.141 - 1.46
105	1997	80 (49.5)	49.5 (6")	24 - 44	36-42, 67-70	22/7	Saprolite	9	tbd	
106	1997	88	25.37	-	40, 66	36/8.08	Saprolite	14	6.5	1.45 - 1.69
107	1997	81	43	-	45, 57, 66, 76	61/19.43	Saprolite	4.8	2.5	1.56 - 3.16
108	1997	75		-		-	Saprolite	-	-	-
109S	1997	28	28	8 - 22	5, 10, 22	18/3.74	Laterite	22	55	154 - 500
109D	1997	98		-			Saprolite		-	
110	1997	20.5	20.5	5 - 14	6.5, 13	6/-	Laterite	5	-	336
111	1997	77	11.5	-	51, 63	51	Saprolite	6	3.0	1.5 - 2
112	1998	84 (67)	67 (4.5")	35 - 64 (4.5")	70		Saprolite	2		
113	1998	94		-			Saprolite	2.4		
114	1998			-			Laterite			
115	1998	83		-	44, 60, 72-79		Saprolite	4.8		
116	1998	47 (30.7)	30.7 (6")		5-16		Saprolite	1.0		
117	1998	90	-		39-41		Saprolite	0.2		
201	1998	24	3 (2")	3 - 24 (2")	5, 18		Saprolite	na	na	na
202	1998	24	3 (2")	3 - 24 (2")			Saprolite	na	na	na
203	1998	17	3 (2")	3 - 17 (2")			Saprolite	na	na	na
204	1998							na	na	na
205	1998							na	na	na
206	1998							na	na	na
207	1998							na	na	na

Note :

109S - Shallow screened aquifer within laterite
109D - Deep Saprolite aquifer below shallow water strike
tbd - To be carried out
RWL - Rest Water Level range observed during seasonal monitoring
Transmissivity figures determined by D&M.

TABLE 4-13
SUMMARY OF DATA FOR PRE-EXISTING CONCESSION BOREHOLES

Borehole	Date Drilled	Total Depth (m)	Depth Cased (mbgl)	Screened Section	Water Strikes/RWL (mbgl)	Aquifer	Discharge (m^3/hr)	Location
Placer Dome Kahama : Boreholes Reported by Golder Associates								
WW-1	Mar 91	30	-	-	>26	-	-	NW of Camp Well
WW-2	Mar 91	15	-	-	2	Laterite	2.1	Bariadi Village
WW-3	Mar 91	13	-	-	5.54	Laterite	2.58	Bariadi Village
Kahama Mining Corporation Boreholes								
#1	Jan 92	85	60	-	-	Saprolite	1	-
#2	Aug 95	72	-	-	-	Saprolite	-	-
#3	Aug 95	70	52	52-58	55-65	Saprolite	4	Camp Well
#4	Aug 95	88	76	76-88	-	Saprolite	-	Reef Well
#5	Mar 97	100	44	44-51	60	Saprolite	1.3	Camp Well
#6	97(?)	88	66	66-78	-	Saprolite	'high'	Reef Well
Skanska Boreholes								
S-1	1995	88	45	-	60	Saprolite	1.2(?)	Skanska Camp
S-2	1995	100	34	-	41	Saprolite	-	Construction Yard

TABLE 4-14
WATER QUALITY REGULATORY CRITERIA

		Drinking Water		Irrigation Criteria	
Sample Number		**WHO**	**Tanzanian**	**NASNAE 1972**	**Tanzanian**
Cyanide(SAD) + Thiocyanate	mg/L	0.07			
Cl	mg/L			100	
F	mg/L	1.5		1.5	
N-NO3	mg/L	50		100	
N-NO2	mg/L	3		0.01	
SO4	mg/L			1000	
Total Metals					
As	mg/L	0.01	0.05		0.1
B	mg/L	0.3		5	
Ba	mg/L	0.7			
Be	mg/L			0.1	
Cd	mg/L	0.003		0.02	
Cr	mg/L	0.05	0.05	0.1	0.1
Cu	mg/L	2	3	0.2	3
Fe	mg/L	1	1		1.2
Hg	mg/L	0.001	0.001	0.001	0.001
K	mg/L			20	
Mn	mg/L		0.5	0.2	0.8
Mo	mg/L	0.07		0.01	
Ni	mg/L	0.02		0.2	
Pb	mg/L	0.05	0.1	0.1	0.1
Sb	mg/L	0.005			
Se	mg/L	0.01	0.05	0.02	0.01
V	mg/L			0.1	
Zn	mg/L	0.2	0.2	1	0.2

TABLE 4-15
CONCENTRATION OT TOTAL AND DISSOLVED METALS IN WATER QUALITY SAMPLES

		General Parameters											
		pH pH units	EC uS/cm	TSS mg/L	TDS mg/L	Hardness Total -D mg/L	Acidity pH 8.3 mg/L	Acidity pH 4.5 mg/L	Alkalinity Phen. 8.3 mg/L	Alkalinity Total 4.5 mg/L	Carbonate mg/L	Bicarbonate mg/L	Cl mg/L
WHO Drinking Water		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Tanzanian Drinking Water		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
NASNAE 1972 Irrigation Criteria		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	100
Tanzanian Irrigation Criteria		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Sample No.	**Date**												
W4	10-Feb-97	7.4	186.	<4.	106.	41.1	8.9	<0.5	<0.5	91.	<0.5	111.	3.
Sotta	15-Oct-97	6.9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

< - less than the detection limit indicated
NC - no criteria established
☐ - Greater than WHO or Tanzanian Drinking Water Criteria
░ - Greater than NASNAE 1972 or Tanzanian Irrigation Criteria
▒ - Greater than both Drinking Water and Irrigation Criteria

TABLE 4-15

CONCENTRATION OT TOTAL AND DISSOLVED METALS IN WATER QUALITY SAMPLES

		General Parameters											
		F mg/L	TOC mg/L	TON mg/L	TKN mg/L	TN mg/L	N-NH3 mg/L	NO3+NO2 mg/L	N-NO3 mg/L	N-NO2 mg/L	OrthoPO4 mg/L	P mg/L	SO4 mg/L
WHO Drinking Water		1.5	NC	NC	NC	NC	NC	NC	50	3	NC	NC	NC
Tanzanian Drinking Water		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
NASNAE 1972 Irrigation Criteria		1.5	NC	NC	NC	NC	NC	NC	100	0.01	NC	NC	1000
Tanzanian Irrigation Criteria		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Sample No.	Date												
W4	10-Feb-97	0.88	10.7	0.8	0.92	0.92	0.162	<0.02	<0.02	<0.005	0.03	0.042	<1.
Sotta	15-Oct-97	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

< - less than the detection limit indicated

NC - no criteria established

[ ] - Greater than WHO or Tanzanian Drinking Water Criteria

[light shading] - Greater than NASNAE 1972 or Tanzanian Irrigation Criteria

[dark shading] - Greater than both Drinking Water and Irrigation Criteria

TABLE 4-15

CONCENTRATION OT TOTAL AND DISSOLVED METALS IN WATER QUALITY SAMPLES

			Total Metals																
			Ag mg/L	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Bi mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Hg mg/L	K mg/L	Mg mg/L	Mn mg/L
WHO Drinking Water			NC	NC	0.01	0.3	0.7	NC	NC	NC	0.003	NC	0.05	2	1	0.001	NC	NC	NC
Tanzanian Drinking Water			NC	NC	0.05	NC	NC	NC	NC	NC	NC	NC	0.05	3	1	0.001	NC	NC	0.5
NASNAE 1972 Irrigation Criteria			NC	NC	NC	5	NC	0.1	NC	NC	0.02	NC	0.1	0.2	NC	0.001	20	NC	0.2
Tanzanian Irrigation Criteria			NC	NC	0.1	NC	NC	NC	NC	NC	NC	NC	0.1	3	1.2	0.001	NC	NC	0.8
Sample No.	Date																		
W4.	10-Feb-97		<0.0001	<0.06	0.0028	<0.04	0.087	<0.001	<0.02	9.72	<0.0001	<0.004	0.002	0.003	0.72	<0.00005	3.9	4.27	0.036
Sotta	15-Oct-97	##	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

< - less than the detection limit indicated

NC - no criteria established

- Greater than WHO or Tanzanian Drinking Water Criteria

- Greater than NASNAE 1972 or Tanzanian Irrigation Criteria

- Greater than both Drinking Water and Irrigation Criteria

TABLE 4-15
CONCENTRATION OT TOTAL AND DISSOLVED METALS IN WATER QUALITY SAMPLES

		Total Metals																
		Mo mg/L	Na mg/L	Ni mg/L	P mg/L	Pb mg/L	S mg/L	Sb mg/L	Se mg/L	Si mg/L	Sn mg/L	Sr mg/L	Te mg/L	Ti mg/L	Tl mg/L	V mg/L	Zn mg/L	Zr mg/L
WHO Drinking Water		0.07	NC	0.02	NC	0.05	NC	0.005	0.01	NC	NC	NC	NC	NC	NC	NC	0.2	NC
Tanzanian Drinking Water		NC	NC	NC	NC	0.1	NC	NC	0.05	NC	NC	NC	NC	NC	NC	NC	0.2	NC
NASNAE 1972 Irrigation Criteria		0.01	NC	0.2	NC	0.1	NC	NC	0.02	NC	NC	NC	NC	NC	NC	0.1	1	NC
Tanzanian Irrigation Criteria		NC	NC	NC	NC	0.1	NC	NC	0.01	NC	NC	NC	NC	NC	NC	NC	0.2	NC
Sample No.	Date																	
W4	10-Feb-97	<0.004	27.9	<0.01	0.08	<0.003	0.1	<0.02	0.0016	9.4	<0.02	0.217	<0.02	<0.003	<0.03	<0.003	0.01	<0.003
Sotta	15-Oct-97	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

< - less than the detection limit indicated

NC - no criteria established

- Greater than WHO or Tanzanian Drinking Water Criteria

- Greater than NASNAE 1972 or Tanzanian Irrigation Criteria

- Greater than both Drinking Water and Irrigation Criteria

TABLE 4-15
CONCENTRATION OT TOTAL AND DISSOLVED METALS IN WATER QUALITY SAMPLES

			Dissolved Metals																
			Ag mg/L	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Bi mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Hg mg/L	K mg/L	Mg mg/L	Mn mg/L
WHO Drinking Water			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Tanzanian Drinking Water			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
NASNAE 1972 Irrigation Criteria			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Tanzanian Irrigation Criteria			NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Sample No.	**Date**																		
W4	10-Feb-97		<0.0001	<0.02	0.0022	0.023	0.075	<0.001	<0.02	9.49	<0.0001	<0.003	<0.002	<0.001	0.18	<0.00005	3.4	4.22	0.028
Sotta	15-Oct-97	##	#N/A	#N/A	0.0028	#N/A	#N/A	#N/A	#N/A	#N/A	0.000007	0.0001	#N/A	0.0008	#N/A	0.000005	#N/A	#N/A	#N/A

< - less than the detection limit indicated
NC - no criteria established
[ ] - Greater than WHO or Tanzanian Drinking Water Criteria
[light shading] - Greater than NASNAE 1972 or Tanzanian Irrigation Criteria
[shaded box] - Greater than both Drinking Water and Irrigation Criteria

TABLE 4-15
CONCENTRATION OT TOTAL AND DISSOLVED METALS IN WATER QUALITY SAMPLES

		Dissolved Metals																
		Mo mg/L	Na mg/L	Ni mg/L	P mg/L	Pb mg/L	S mg/L	Sb mg/L	Se mg/L	Si mg/L	Sn mg/L	Sr mg/L	Te mg/L	Ti mg/L	Tl mg/L	V mg/L	Zn mg/L	Zr mg/L
WHO Drinking Water		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Tanzanian Drinking Water		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
NASNAE 1972 Irrigation Criteria		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Tanzanian Irrigation Criteria		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Sample No.	**Date**																	
W4	10-Feb-97	<0.004	27.6	<0.008	0.06	<0.001	0.12	<0.015	0.0013	9.33	<0.02	0.213	<0.02	<0.003	<0.02	<0.003	<0.002	<0.003
Sotta	15-Oct-97	0.0002	#N/A	0.0073	#N/A	0.00016	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

< - less than the detection limit indicated
NC - no criteria established
- Greater than WHO or Tanzanian Drinking Water Criteria
- Greater than NASNAE 1972 or Tanzanian Irrigation Criteria
- Greater than both Drinking Water and Irrigation Criteria

TABLE 4-16
BULYANHULU SEDIMENT QUALITY CHARACTERIZATION

Initial Sampling	Sample Number [1]			Crustal Average [2]	
	S1	S2	S3	Min	Max
Total Metals (mg/dry kg)					
Silver (Ag)	9	4	5	0	0.1
Arsenic (As)	532	388	211	1	13
Barium (Ba)	23	70	241	0.4	1600
Beryllium (Be)	<0.5	0.7	1.6	1	3
Bismuth (Bi)	87	86	44	0.01	0.01
Cadmium (Cd)	<2	<2	<2	0.1	0.3
Cobalt (Co)	42	30	43	1	150
Chromium (Cr)	66	61	64	2	1600
Copper (Cu)	2790	1820	3690	4	250
Mercury (Hg)	1.87	1.63	5.19	0	4
Molybdenum (Mo)	<4	<4	<4	0.3	3
Nickel (Ni)	23	29	46	2	2000
Lead (Pb)	122	114	52	1	20
Antimony (Sb)	<20	<20	<20	0	0.2
Selenium (Se)	<50	<50	<50	0.05	0.6
Zinc (Zn)	36	37	67	16	130

(1) Samples collected at water quality sites in December 1996

(2) Price 1997 - Crustal averages for various rock types.

TABLE 4-17
DIVERSITY, ENDEMISM, AND CONSERVATION STATUS OF FRESHWATER FISH IN THE TANZANIAN WATERS OF LAKE VICTORIA

Family	Number of Genera	Number of Species	Endemic Species	Threatened Species*
Protopteridae	1	1	1	1
Mormyridae	6	7	2	7
Clariidae	3	6	2	6
Cyprinidae	3	13	4	13
Cichlidae	3	139	117	139
Characidae	1	2	1	2
Bagridae	1	1	0	1
Schilbeidae	1	1	0	1
Mochokidae	1	2	1	2
Mastacembelidae	1	1	0	1
Centropomidae	1	1	0	1
Anabantidae	1	1	0	1

* Causes of threat include: predation by Nile perch, heavy fishing across river mouths, fishing using undersized nets and water hyacinth infestation.

Source: Nhwani *et. al.* 1996

TABLE 4-18
TAXONOMIC CLASSIFICATION OF THE FISH COLLECTED FROM THE BULYANHULU, KABHANDA, AND NYAKADOHOMI RIVERS IN NORTHERN TANZANIA

SCIENTIFIC NAME	COMMON NAME	LOCAL NAME
CLASS ACTINOPTERYGII (RAY-FINNED FISHES)		
ORDER SILURIFORMES (CATFISH) FAMILY CLARIIDAE (AIRBREATHING CATFISHES)		
Clarias llocephalus	Smoothhead catfish	Kambale, Mumi
Clarias werneri	Mudcatfish, barbel	Kambale, Mumi
ORDER OSTEOGLOSSIFORMES (BONY TONGUES) FAMILY MORMYRIDAE (ELEPHANTFISHES)		
Marcusenius victoriae	Elephant-snout fish	Domodomo, Sulusulu
Petrocephalus catostoma	Elephant-snout fish	Domodomo, Sulusulu
ORDER PERCIFORMES (PERCH-LIKES) FAMILY CICHLIDAE (CICHLIDS)		
Haplochromis sp	Haplochromis	Furu
ORDER CYPRINIFORMES (CARPS) FAMILY CYPRINIDAE (MINNOWS OR CARPS)		
Barbus sp	Barbel, Barbs	Kuyu
CLASS SARCOPTERYGII (LOBE-FINNED FISHES)		
ORDER LEPIDOSIRENIFORMES CLASS PROTOPTERIDAE (AFRICAN LUNGFISH)		
Protopterus aethiopicus	African lungfish	Kambale mamba, Kamango

TABLE 4-19
SUMMARY OF THE FISHERIES DATA COLLECTED FROM THE BULYANHULU, KABHANDA, AND NYAKADOHOMI RIVERS IN NORTHERN TANZANIA

Fish Species	Number of Specimens Collected				Percent Abundance	Average Weight (g)	Average Length (cm)
	Site S_1 Bulyanhulu River	Site S_2 Bulyanhulu River	Site S_3 Kabhanda River	Site S_4 Igonzela swamp			
Clarias liocephalus	-	-	-	8	33.4%	93	22
Clarias werneri	-	-	-	2	8.3%	1215	56
Protopterus aethiopicus	-	-	-	9	37.5%	368	46
Marcusenius victoriae	-	-	-	3	12.5%	51	15
Petrocephalus catostoma	-	-	-	2	8.3%	-	8
Barbus	present	present	present	-	-	-	-
Haplochromis	present	present	-	present	-	-	-
Totals	-	-	-	**24**	**100.0%**	**1727**	**147**
Average	-	-	-	**4.8**	**20.0%**	**432**	**29**

TABLE 4-20
RESULTS OF FISHERIES SAMPLING
FROM THE BULYANHULU, KABHANDA, AND NYAKADOHOMI RIVERS IN NORTHERN TANZANIA

Fish Species	Fishing Method	Water Depth (cm)	Total Length (cm)	Weight (g)	Sex	Stage of Maturity
Clarias liocephalus	Gill net (5.1 cm mesh)	115	30	200	Female	Spawning
Clarias liocephalus	Beach seine	-	27	155	Male	Mature
Clarias liocephalus	Beach seine	-	25	124	Female	Mature
Clarias liocephalus	Beach seine	-	19	60	-	Immature
Clarias liocephalus	Beach seine	-	22	90	-	Immature
Clarias liocephalus	Beach seine	-	18.5	40	-	Immature
Clarias liocephalus	Beach seine		17	38	-	Immature
Clarias liocephalus	Beach seine		17.5	38	-	Immature
Average			**22**	**93**		
Clarias werneri	Hook and line	-	50	930	Female	Spawning
Clarias werneri	Hook and line	-	62	1500	Male	Mature
Average			**56**	**1215**		
Protopterus aethiopicus	Gill net (3.8 cm mesh)	70	41	210	Female	Mature
Protopterus aethiopicus	Beach seine	-	46	285	Female	Spawning
Protopterus aethiopicus	Beach seine	-	40	200	Male	Mature
Protopterus aethiopicus	Gill net (5.1 cm mesh)	115	49	360	Male	Mature
Protopterus aethiopicus	Hook and line	-	73	1360	Female	Mature
Protopterus aethiopicus	Beach seine	-	49	330	Female	Mature
Protopterus aethiopicus	Beach seine	-	44	250	Male	Mature
Protopterus aethiopicus	Gill net (3.8 cm mesh)	70	35	155	Female	Immature
Protopterus aethiopicus	Gill net (3.8 cm mesh)	70	36	160	Male	Immature
Average			**46**	**368**		
Marcusenius victoriae	Gill net (3.8 cm mesh)	70	15.5	52	Female	Mature
Marcusenius victoriae	Gill net (3.8 cm mesh)	70	15	52	Female	Mature
Marcusenius victoriae	Gill net (3.8 cm mesh)	70	14	50	Male	Mature
Average			**15**	**51**		
Petrocephalus catostoma	Gill net (3.8 cm mesh)	70	7.5	-	Female	Mature
Petrocephalus catostoma	Gill net (3.8 cm mesh)	70	8	-	Male	Mature
Average			**8**	-		

TABLE 4-21
PRELIMINARY RESULTS FROM WATER QUALITY SAMPLING FOR TOTAL MERCURY AT FIVE LOCATIONS IN THE BULYANHULU REGION

Date of Water Sample Collection	Water Quality Sampling Stations Total Mecury Concentrations in mg/L				
	W1 Bulyanhulu River	W2 Bulyanhulu River	W3 Bulyanhulu River	W4 Smith Sound	W5
1-Jan-97	0.00512	0.00794	0.00458		
10-Feb-97	0.00042	**0.00030**	0.00029	(-0.00005)	
1-Apr-97	0.00045	**0.00011**	0.00007		
27-Apr-97	0.00041	0.00692	**0.00068**		
13-May-97	**0.00036**	0.00164	0.00143		0.00007
8-Jun-97	0.00055	0.00057	0.00018		
12-Jul-97	**0.00228**	0.0037	0.00226		
19-Aug-97	**0.00111**	0.00077	0.00012		
4-Nov-97	-	0.00176	-	0.00053	
8-Dec-97	-	(-0.00005)	0.00046	0.00046	
Average Value	0.00134	0.00263	0.00079	0.00050	0.00007

[shaded] exceeds WHO, Tanzanian, and Canadian drinking water guidelines (0.001 mg/L total mercury)

bold value = average of two duplicate samples
(number) = below the instrument detection limit of 0.00005 mg/L
Note: the Canadian water quality guidelines for the protection of aquatic life are 0.0001 mg/L total mercury

TABLE 4-22
LEVELS OF TOTAL MERCURY IN FISH SAMPLES COLLECTED
FROM THE BULYANHULU, KABHANDA, AND NYAKADOHOMI RIVERS IN NORTHERN TANZANIA

Sample Number	Fish Species	Fish weight (g)	Fish length (cm)	Total Mercury in Muscle Tissue (mg/kg)	Total Mercury in Liver Tissue (mg/kg)
C1	*Clarias liocephalus*	200	30	0.05	0.07
C2	*Clarias liocephalus*	155	27	0.05	0.06
C3	*Clarias liocephalus*	124	25	0.07	0.18
Average		**160**	**27**	**0.06**	**0.10**
C4	*Clarias werneri*	930	50	0.06	0.07
C5	*Clarias werneri*	1500	62	0.05	0.19
Average		**1215**	**56**	**0.06**	**0.13**
M1	*Marcusenius victoriae*	52	15.5	0.07	0.05
M2	*Marcusenius victoriae*	52	15	0.08	0.2
Average		**52**	**15.3**	**0.08**	**0.13**
P1	*Protopterus aethiopicus*	285	46	0.09	0.2
P2	*Protopterus aethiopicus*	210	41	0.13	0.29
P3	*Protopterus aethiopicus*	200	40	0.11	0.6
P4	*Protopterus aethiopicus*	360	49	0.09	1.18
P5	*Protopterus aethiopicus*	1360	73	0.06	0.75
P6	*Protopterus aethiopicus*	330	49	0.09	0.63
Average		**458**	**50**	**0.10**	**0.61**

TABLE 4-23
MACROINVERTEBRATE CLASSIFICATIONS

Phylum Nematoda - roundworms

Phylum Platyhelminthes - flatworms
- Class Turbellaria - free-living flatworms

Phylum Mollusca
- Class Gastropoda - snails
- Class Bivalvia - clams

Phylum Annelida
- Class Oligochaeta - freshwater annelids
- Class Hirudinea - leeches

Phylum Arthropoda - Organisms with joined appendages and an exoskeleton
- Subphylum Uniramia
- Class Insecta - six-legged arthropods
    - Subclass Apterygota - silverfish and springtails
    - Subclass Pterygota
        - Order Ephemeroptera - mayflies
        - Order Plecoptera - stoneflies
        - Order Trichoptera - caddisflies
        - Order Diptera - true flies
        - Order Hemiptera - true bugs
        - Order Homoptera - aphids
        - Order Odonata - dragonflies and damselflies
        - Order Coleoptera - beetles and weevils
        - Order Thysanoptera - thrips
        - Order Hymenoptera - bees, wasps and ants
        - Order Megaloptera - alderflies, dobsonflies, fishflies, hellgrammites
        - Order Neuroptera - spongillaflies
        - Order Lepidoptera - butterflies and moths
- Subphylum Crustacea
- Class Branchiopoda - fairy shrimp, tadpole shrimp, clam shrimp and water fleas
- Class Ostracoda - mussel or seed shrimp
- Class Copepoda - small crustaceans with cylindrical body and long first antennae
- Class Malacostraca
        - Order Amphipoda - small crustaceans with body laterally compressed
        - Order Isopoda - crustaceans with body dorsoventrally flattened
        - Order Decapoda - shrimp, crayfish, lobsters and crabs
- Subphylum Chelicerata
- Class Arachnida - scorpions, spiders, harvestmen, mites and ticks
        - Order Araneae - spiders
        - Order Acarina - mites and ticks
            - Suborder Hydracarina - water mites

Note: This list is not all inclusive, but represents the groups potentially present in the benthic aquatic environment.

TABLE 4-24
RESULTS OF SEDIMENT MEIOBENTHOS SAMPLING
FROM THE BULYANHULU, KABHANDA, AND NYAKADOHOMI RIVERS IN NORTHERN TANZANIA

Taxonomic Group	Number of Specimens by Sampling Location (water depth)					Totals	% of Total by Taxonomic Group
	Site S_1	Site S_2	Site S_3	Site S_4			
	(120 cm)	(50 cm)	(45 cm)	(70 cm)	(115 cm)		
Benthic Invertebrates							
Chironomid larvae	-	1	14	4	11	30	52%
Nematodes	2	2	2	3	5	14	24%
Oligochaetes	-	4	3	1	2	10	17%
Cladocerans	-	-	-	1	-	1	1.7%
Anisoptera larvae (Odonata)	-	-	-	1	-	1	1.7%
Hirudinea	-	-	-	2	-	2	3.4%
Total	**2**	**7**	**19**	**12**	**18**	**58**	**100%**
% of Total (by Sampling Site)	**3%**	**12%**	**33%**	**21%**	**31%**	**100%**	
Vertebrates							
Fish eggs	-	-	-	6	6	12	100%
Total				**6**	**6**	**12**	**100%**
% of Total (by Sampling Site)				**50%**	**50%**	**100%**	
Combined Sediment Fauna							
Overall Total (by Sampling Site)	**2**	**7**	**19**	**18**	**24**	**70**	**100%**
% of Overall Total	**3%**	**10%**	**27%**	**26%**	**34%**	**100%**	
Faunal Densities	**Faunal Density by Sampling Location** (specimens/cm^2)					**Average**	
	Site S_1	**Site S_2**	**Site S_3**	**Site S_4**			
Combined Sediment Fauna	0.13	0.44	1.19	1.13	1.51	**0.88**	

Note 1: faunal densities are calculated using the total cross-sectional area from three duplicate samples (15.9 cm^2)
Note 2: depth of each sample is 5 cm and is not used in the calculation of faunal density

TABLE 4-25
LIST OF BULYANHULU SAMPLES AND SCHEDULE OF ANALYSIS

Location [1]	Type of Analysis	Date Samples
TP97-1	Full Analysis	September 29, 1997
TP97-3	Full Analysis	September 29, 1997
TP97-4	Metals Only	September 29, 1997
TP97-5	Full Analysis	September 29, 1997
TP97-8	Full Analysis	September 29, 1997
TP97-9	Full Analysis	September 29, 1997
TP97-13	Full Analysis	September 30, 1997
TP97-15	Full Analysis	September 30, 1997
TP97-17	Full Analysis	September 30, 1997
TP97-20	Metals Only	September 30, 1997
TP97-22	Metals Only	September 30, 1997
TP97-33	Metals Only	October 1, 1997
TP97-34	Metals Only	October 1, 1997
TP97-35	Metals Only	October 1, 1997
TP97-38	Metals Only	September 30, 1997
TP97-40	Metals Only	September 30, 1997
TP97-45	Metals Only	October 1, 1997
TP97-50	Full Analysis	September 30, 1997
TP97-51	Full Analysis	September 30, 1997
TP97-61	Metals Only	October 1, 1997

(1) - TP97 refers to test pit locations by Golder Associates Ltd. (1997); see Figures 4.9-1 and 4.9-2.

TABLE 4-26
CHEMICAL AND PHYSICAL PROPERTIES OF BULYANHULU SOIL SAMPLES [1]

Parameters	pH	EC (MS/cm)	N (%)	OC (%)	C/N ratio	P (Mg/kg)	CEC (Meq/100g)	Ca (Meq/100g)	Mg (Meq/100g)	K (Meq/100g)	Na (Meq/100g)	Si (%)	C (%)	S (%)
TP97-1 [2]	5.0	0.08	0.33	2.54	7.7	14.0	19.00	3.10	1.06	0.52	0.18	21.40	8.10	70.50
TP97-3	6.1	0.05	0.35	3.06	8.7	27.3	31.68	3.49	2.26	0.78	0.27	27.00	14.20	58.80
TP97-5	5.5	0.02	0.40	3.03	7.6	7.0	21.68	2.19	1.20	0.26	0.27	29.20	7.70	63.10
TP97-8	6.3	0.04	0.33	2.75	8.3	94.2	26.68	3.84	1.81	0.52	0.53	44.10	9.20	46.70
TP97-9	5.1	0.02	0.33	2.44	7.4	7.0	25.68	2.74	1.96	0.26	0.39	35.60	22.80	41.60
TP97-13	6.8	0.02	0.26	1.95	7.5	7.0	25.01	3.29	1.34	0.26	0.35	29.40	14.90	55.70
TP97-15	6.2	0.03	0.30	2.08	6.9	28.0	25.35	2.19	1.06	0.52	0.49	32.60	10.90	56.50
TP97-17	6.7	0.02	0.37	3.13	8.5	267.4	33.02	6.04	1.66	1.83	1.86	36.80	13.10	50.10
TP97-50	5.4	0.03	0.30	2.08	6.9	5.3	34.68	3.84	2.26	0.52	1.24	38.20	30.30	31.50
TP97-51	5.0	0.30	0.22	1.57	7.1	2.1	41.69	4.39	2.71	0.00	1.77	31.70	35.70	32.60

(1) - Analyses performed by SELINAN National Soil Service Laboratories
(2) - TP97 refers to test pit locations by Golder Associates Ltd. (1997);
see Figures 4.9-1 and 4.9-2.

TABLE 4-27
RATINGS FOR BULYANHULU SOIL SAMPLES [1]

Location	pH	EC	CEC	OC %	Available P (mg/kg)	Land Use
TP97-1 [2]	Strong acidic	Low salinity	High medium	High	Medium	Residential
TP97-3	Slightly acidic	Low salinity	High	High	High	Shrubland
TP97-5	Strong acidic	Low salinity	Medium	High	Low	Woodland
TP97-8	Slightly acidic	Low salinity	High	High	High	Residential
TP97-9	Strong acidic	Low salinity	High	Medium	Low	Woodland
TP97-13	Neutral	Low salinity	High	Medium	Low	Traffic
TP97-15	Slightly acidic	Low salinity	High	Medium	High	Construction
TP97-17	Neutral	Low salinity	High	High	High	Construction
TP97-50	Strong acidic	Low salinity	High	Medium	Low	Construction
TP97-51	Strong acidic	Low salinity	Very High	Medium	Low	Construction

(1) - Analyses performed by SELINAN National Soil Service Laboratories
(2) - TP97 refers to test pit locations by Golder Associates Ltd. (1997);
see Figures 4.9-1 and 4.9-2.

TABLE 4-28
HYDRAULIC PROPERTIES OF BULYANHULU SOIL SAMPLES [1]

Location	Volumetric Moisture Content (%) at different bar pressures					Particle Density	Bulk Density	Storage 0.1 to 16 bar
	0.001 bar	0.1 bar	0.25 bar	1 bar	15.8 bar	(g/cc)	(g/cc)	(At 20 cm)
TP97-1 [2]	43.43	29.05	24.79	15.02	8.65	2.39	1.36	4.1
TP97-3	40.31	28.35	24.41	13.53	8.62	2.45	1.47	3.9
TP97-5	35.95	22.41	19.32	6.03	4.63	2.56	1.67	3.6
TP97-8	42.05	27.22	24.6	12.52	7.13	2.45	1.42	4.0
TP97-9	35.1	27.75	21.67	9.3	5.9	2.5	1.55	4.4
TP97-13	35.73	23.69	18.9	7.58	5.27	2.16	1.32	3.7
TP97-15	44.11	28.07	23.29	11.26	9.07	2.59	1.45	3.8
TP97-17	39.23	28.15	23.72	9.04	6.04	2.54	1.55	4.4
TP97-50	44.65	32.47	29.25	12.93	12.03	2.5	1.4	4.1
TP97-51	47.08	39.39	24.17	17.92	11.3	2.42	1.28	5.6

(1) - Analyses performed by Mlingano National Soil Service Laboratory
(2) - TP97 refers to test pit locations by Golder Associates Ltd. (1997); see Figures 4.9-1 and 4.9-2.

TABLE 4-29
METAL ANALYSES (ICP) FOR BULYANHULU SOIL SAMPLES [1]

ELEMENT SAMPLES	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppb	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Au ppm	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm
TP97 #1	0.8	25.7	7.5	20.3	<30.	18.	13.	680.	2.11	1.3	<5.	<0.1	5.	33.	0.03	<0.2	<0.2
TP97 #3	0.7	74.6	7.5	37.2	71.	23.	16.	800.	3.48	5.1	<5.	<0.1	4.	50.	0.05	<0.2	0.3
TP97 #4	1.2	103.3	16.8	158.4	766.	30.	28.	1485.	5.07	10.3	<5.	4.5	4.	77.	0.09	<0.2	1.5
TP97 #5	0.6	21.4	6.7	22.	45.	18.	11.	623.	2.06	1.3	<5.	0.1	4.	43.	0.02	<0.2	<0.2
TP97 #8	0.9	396.7	13.3	37.1	906.	24.	20.	846.	3.18	30.8	<5.	0.6	5.	55.	0.06	<0.2	7.
TP97 #9	0.6	32.5	7.	23.5	<30.	23.	13.	558.	2.41	3.	<5.	<0.1.	5.	41.	0.03	<0.2	0.2
TP97 #13	1.5	90.4	18.5	35.3	505.	38.	50.	1883.	6.27	7.6	<5.	1.8	5.	39.	0.06	0.2	0.6
TP97 #15	1.	91.4	11.5	72.4	374.	30.	19.	888.	3.74	10.6	<5.	0.9	4.	37.	0.05	<0.2	1.
TP97 #17	1.3	102.1	72.9	140.9	146.	31.	34.	1787.	5.56	11.2	<5.	0.2	2.	86.	0.12	0.4	1.
TP97 #20	0.9	73.1	12.4	30.1	46.	38.	23.	810.	4.46	3.3	<5.	<0.1	7.	27.	0.03	<0.2	0.4
TP97 #22	2.3	138.4	31.5	25.	546.	38.	91.	3718.	11.08	19.2	<5.	1.4	5.	25.	0.07	0.4	2.4
TP97 #33	1.2	34.5	9.1	20.5	44.	28.	19.	691.	3.62	2.1	<5.	<0.1	6.	21.	0.02	<0.2	0.2
TP97 #34	0.8	35.7	7.6	23.7	<30.	28.	21.	561.	3.42	0.8	<5.	<0.1	6.	14.	0.01	<0.2	<0.2
RE TP97 #34	1.1	30.8	7.5	21.2	61.	25.	18.	481.	2.91	1.6	<5.	<0.1	6.	12.	0.02	<0.2	<0.2
TP97 #35	1.5	34.8	7.7	24.9	<30.	32.	17.	642.	4.08	3.4	<5.	<0.1	6.	17.	0.03	<0.2	0.2
TP97 #38	1.4	49.6	11.5	27.7	41.	25.	21.	1216.	5.22	2.1	<5.	<0.1	7.	18.	0.02	<0.2	0.2
TP97 #40	0.9	30.2	7.6	22.8	<30.	30.	17.	841.	2.92	1.3	<5.	<0.1	7.	29.	0.02	<0.2	0.2
TP97 #45	0.9	31.2	7.2	23.9	36.	101.	16.	639.	2.89	<0.5	<5.	<0.1	7.	34.	0.01	<0.2	<0.2
TP97 #50	0.6	55.7	11.6	18.1	45.	28.	12.	534.	3.62	2.3	<5.	<0.1	10.	36.	0.04	<0.2	0.4
TP97 #51	0.7	57.2	8.7	19.9	72.	24.	15.	450.	3.28	1.	<5.	<0.1	7.	54.	0.01	<0.2	<0.2
TP97 #61	0.2	38.7	11.3	28.4	<30.	27.	13.	307.	3.68	1.5	7.	<0.1	8.	98.	<0.01	<0.2	<0.2
STANDARD D2/C3	22.2	120.4	100.3	263.7	1808.	31.	17.	1005.	4.26	65.6	20.	4.7	19.	59.	1.87	9.7	18.4

(1) Analyses performed by Acme Analytical Laboratories

(2) - TP97 refers to test pit locations by Golder Associates Ltd. (1997); see Figures 4.9-1 and 4.9-2.

TABLE 4-29
METAL ANALYSES (ICP) FOR BULYANHULU SOIL SAMPLES [1]

ELEMENT SAMPLES	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Al %	Na %	K %	W ppm	Tl ppm	Hg ppb	Se ppm	Te ppm	Ga ppm
TP97 #1	62.	0.18	0.029	26.	35.	0.12	158.	0.02	9.	1.83	<0.01	0.11	<2.	0.2	71.	<0.3	<0.2	6.5
TP97 #3	92.	0.32	0.034	32.	48.	0.19	177.	0.03	42.	2.41	0.01	0.17	<2.	<0.2	112.	<0.3	<0.2	7.8
TP97 #4	138.	0.48	0.061	37.	64.	0.19	289.	0.03	5.	2.62	0.01	0.24	2.	<0.2	396.	0.3	<0.2	8.6
TP97 #5	58.	0.25	0.031	26.	35.	0.13	153.	0.03	3.	1.88	<0.01	0.13	<2.	<0.2	55.	<0.3	<0.2	6.1
TP97 #8	75.	0.35	0.036	35.	33.	0.14	153.	0.03	6.	1.98	<0.01	0.14	2.	<0.2	863.	0.4	<0.2	6.9
TP97 #9	60.	0.24	0.028	38.	47.	0.13	150.	0.02	27.	2.24	0.01	0.11	<2.	<0.2	81.	<0.3	<0.2	6.7
TP97 #13	146.	0.56	0.027	32.	93.	0.23	328.	0.04	6.	2.79	0.01	0.16	<2.	0.2	159.	0.3	<0.2	9.3
TP97 #15	96.	0.21	0.032	27.	68.	0.13	197.	0.04	4.	2.05	<0.01	0.16	3.	<0.2	363.	<0.3	<0.2	7.5
TP97 #17	150.	0.63	0.079	32.	103.	0.2	335.	0.03	5.	2.31	0.01	0.24	<2.	<0.2	261.	0.3	<0.2	7.2
TP97 #20	116.	0.15	0.024	56.	62.	0.16	114.	0.03	7.	3.69	0.01	0.1	<2.	<0.2	109.	<0.3	<0.2	11.9
TP97 #22	261.	0.12	0.026	39.	84.	0.1	592.	0.05	<3.	3.3	<0.01	0.11	2.	0.3	186.	0.4	<0.2	12.1
TP97 #33	102.	0.11	0.037	37.	56.	0.08	94.	0.04	<3.	2.85	<0.01	0.08	<2.	0.2	67.	<0.3	<0.2	10.8
TP97 #34	97.	0.06	0.037	42.	62.	0.07	67.	0.04	<3.	2.66	<0.01	0.08	<2.	<0.2	65.	<0.3	<0.2	8.8
RE TP97 #34	84.	0.05	0.033	35.	55.	0.06	58.	0.04	<3.	2.42	<0.01	0.07	<2.	<0.2	49.	<0.3	<0.2	9.1
TP97 #35	121.	0.1	0.042	25.	67.	0.08	75.	0.05	3.	2.62	<0.01	0.11	<2.	0.2	63.	<0.3	<0.2	10.8
TP97 #38	144.	0.08	0.045	54.	60.	0.06	109.	0.07	<3.	3.04	<0.01	0.1	<2.	<0.2	78.	<0.3	<0.2	11.3
TP97 #40	84.	0.16	0.034	32.	56.	0.11	118.	0.04	4.	2.6	<0.01	0.14	<2.	<0.2	51.	<0.3	<0.2	8.7
TP97 #45	59.	0.26	0.031	51.	234.	0.18	138.	0.03	3.	3.51	<0.01	0.14	<2.	<0.2	45.	<0.3	<0.2	9.8
TP97 #50	113.	0.28	0.028	61.	57.	0.16	114.	0.01	4.	3.03	0.01	0.11	<2.	<0.2	58.	<0.3	<0.2	12.
TP97 #51	91.	0.47	0.018	42.	53.	0.22	164.	0.02	4.	2.73	0.02	0.07	<2.	<0.2	39.	<0.3	<0.2	9.6
TP97 #61	98.	0.79	0.015	36.	74.	0.58	169.	0.01	3.	3.88	0.01	0.06	<2.	<0.2	21.	<0.3	<0.2	11.1
STANDARD D2/C3	69.	0.7	0.105	18.	56.	1.1	240.	0.14	26.	2.29	0.05	0.65	15.	2.4	1086.	0.6	1.9	6.5

(1) Analyses performed by Acme Analytical Laboratories
(2) - TP97 refers to test pit locations by Golder Associates Ltd. (1997); see Figures 4.9-1 and 4.9-2.

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FAMILY	SPECIES NAME	HABIT	AUTHORITY	SUBSPECIES/ VARIETY	AUTHORITY
ACANTHACEAE	*Barleria boehmii*	H	Lindau		
	Blepharis longifolia	H	Lindau		
	Blepharis maderaspatensis	H	(L.) Roth	*rubiifolium*	(Schumach) Wapper
	Crabbea velutina	H	S.Moore		
	Dyschoriste sp.	H			
	Hypoestes forskalii	H	(Vahl.) R.Br.		
	Justicia betonica	H	L.	*blepharosepala*	(A.Rich.) Meense
	Justicia calyculata	H	(Deflers) T.Anders		
	Justicia kirkii	H	T. Anders		
	Monechma debile	H	(Forsk.) Nees.		
	Monechma subsessile	H	(Oliv.) C.B.Cl.		
	Rhinacanthus gracilis	S	Kl.		
ALOEACEAE	*Aloe christianii*	S	Reynolds		
	Aloe lateritia	S	Engl.		
AMARANTHACEAE	*Achyranthes aspera*	H	L.		
	Amaranthus hybridus	H	L.		
	Gomphrena celosioides	H	Mart.		
	Gomphriena sp.	H			
	Pandiaka rubro-lutea	H	(Lopr.) C.C.Townsend.	*reticulata*	
	Psilotrichum scleranthum	H	Thw		
ANACARDIACEAE	*Ozoroa insignis*	T	Del.		
	Sclerocarya birrea	T	(A.Rich.) Hochst.	*birrea*	
	Lannea humilis	T	(Oliv.) Engl.		
	Lannea schimperii	T	(Hochst. ex A.Rich.) Engl.		
	Lannea schweinfurthii	T	(Engl.) Engl.		
	Rhus natalensis	S	Krauss.		
ANNONACEAE	*Annona senegalensis*	T	Pers.		
ANTHERICACEAE	*Chlorophytum macrophyllum*	H	(A.Rich.) Aschers.		
	Chlorophytum sp.	H			
APOCYNACEAE	*Diplorrhynchus condilocarpon*	T	(Muell. Arg.) Pichon		
	Landolphia eminiana	C	Hallier f.		
	Strophanthus eminii	S	Asch. & Pax		
ASCLEPIADACEAE	*Cynachium sp.*	C			
	Secamone sp.	C			
BALANITACEAE	*Balanites aegyptiaca*	T	(L.) Delile		
BIGNONIACEAE	*Markhamia obtusifolia*	S	(Baker) Sprague		
BORAGINACEAE	*Heliotropium strigosum*	H	Willd.		
	Cordia sp.	S			
BURSERACEAE	*Commiphora acuminata*	T	Mattik		
	Commiphora africana	T	(A.Rich.) Engl.		
	Commiphora campestris	T	Engl.		
	Commiphora edulis	T	(Kl.) Engl.		
	Commiphora eminii	T	Engl.		
	Commiphora habessinia	T	(Berg.) Engl.		
	Commiphora schimperi	T	(O.Berg.) Engl.		
	Commiphora spathulata	T	Mattik		
CAESALPINIACEAE	*Piliostigma thoningii*	T	(Schumach.) Milne-Redh.		
	Senna obtusifolia	S	(L.) Irwin & Barneby		
	Senna singuena	S	(Del.) Lock		
	Tamarindus indica	T	L.		
CAPPARIDACEAE	*Capparis sepiaris*	C	L.		
	Maerua kirkii	T	(Oliv.) F.White		
	Thilachium africanum	S/T	Laur.		
	Thilachium sp.	S			
CARYOPHYLLACEAE	*Polycarpaea corymbosa*	H	(L.) Lam.		
	Polycarpaea eriantha	H	A.Rich		
CELASTRACEAE	*Loeseneriella africana*	C	(Cambess.) N. Halle	var. *richardiana*	(Willd.)N.Halle
	Maytenus senegalensis	S	(Lam.) Exell		

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FAMILY	SPECIES NAME	HABIT	AUTHORITY	SUBSPECIES/ VARIETY	AUTHORITY
CHENOPODIACEAE	*Chenopodium opulifolium*	S	Koch. & Ziz		
CHRYSOBALLANACEAE	*Parinari curatellifolia*	T	Benth.		
COMBRETACEAE	*Combretum collinum*	T	Fresen	*elgonense*	(Engl.) Okafor.
	Combretum constricum	S	(Benth.) Laws		
	Combretum molle	S	G.Don.		
	Combretum adenogonium	S	A.Rich.		
	Combretum celastroides	S	Laws		
	Combretum cf. purpureiflorum	C	Engl.		
	Combretum obovatum	S/C	F.Hoffm.		
	Combretum padioides	T	Engl. & Diels		
	Combretum psioides	T	Welw.		
	Combretum zeyheri	S	Sond.		
	Terminalia sericea	T	Burch.		
COMMELINACEAE	*Commelina africana*	H	L.		
	Commelina bengalensis	H	L.		
	Commelina foliacea	H	cf. C.sp.D of KUWF (1994)		
	Commelina sp.	H			
	Cyanotis sp. nov.	H			
	Cyanotis sp.cf. barbata	H	D.Don		
	Murdania semiteres	H	(Dalz.) Brenan		
COMPOSITAE	*Acanthospermum hispidum*	H	DC.		
	Ageratum conyzoides	H	L.		
	Aspilia pluriseta	S	Schweinf.		
	Aspilia sp.	S			
	Bidens pilosa	H	L.		
	Chrysanthellum americanum	H	(L.) Vatke		
	Dicoma anomala	H	Sond.		
	Emilia coccines	H	(Sims.) G.Don.		
	Gutenbergia petersii	H	Steetz.		
	Gutenbergia polytrichotoma	H	Wechuysen		
	Gutenbergia rueppelii	H	Sch. Bip.		
	Hirpicium diffusum	H	(O.Hoffm.) Roess.		
	Kleinia abyssinica	H	A.Berger	var. *abyssinica*	
	Launaea comuta	H	(Oliv. & Hiern.) C.Jeffrey		
	Sphaeranthus gomphrenoides	H	O.Hoffm.		
	Tridax procumbens	H	L.		
	Vernonia bellinghanii	H	S.Moore		
	Vernonia galamensis	H	(Cass.) Less.		
	Vernonia karagwensis	S	Oliv. & Hiern.		
	Vernonia posckeana	H	Vatke & Hildeb.		
	Vernonia undulata	H	Oliv. & Hiern.		
	Tagetes minuta	H	L.		
CONVOLVULACEAE	*Astripomoea malvacea*	S	(Klotsch.) Meense		
	Evolvulus alsinioides	H	L.		
	Ipomoea albinervia	C	(Lindl.) Sweet.		
	Ipomoea blepharophylla	C	Hall.f.		
	Ipomoea crepidiformis	H	Hall.f.		
	Ipomoea eriocarpa	C	R.Br.		
	Ipomoea involucrata	C	Beauv.	var. *burttii*	Verdc.
	Ipomoea malvacea	H	(Klotsch) Meeuse		
	Ipomoea plebeia	C	R.Br.	*africana*	Meense
	Ipomoea sinensis	C	(Desr.) Choisy		
	Merremia medium	C	(L.) Hall.f.		
CRASSULACEAE	*Kalanchoe lanceolata*	H	(Forsk.) Pers.		
CYPERACEAE	*Bulbostylis schimperiana*	H	(A.Rich.) C.B.Cl.		
	Cyperus articulatus	H	L.		
	Cyperus comosipes	H	Matt f. & Kuk.		
	Cyperus cyperoides	H	(L.) Kuntze	*cyperoides*	
	Cyperus grandis	H	C.B. Cp.		
	Isolepis costata	H	A. Rich.		
DISCOREACEAE	*Dioscorea sansibarensis*	C	L.		
DRACEANACEAE	*Sansevieria cf.suffroticosa*	H	N.E.Br.		
EBENACEAE	*Euclea divinorum*	S	Hiern.		
	Diospyros abyssinica	T	(Hiern.) F.White		

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EUPHORBIACEAE	*Acalypha fruticosa*	S	Forsk.		
	Acalypha ornata	C	A.Rich.		
	Bridelia cathartica	S	Bertol.	ssp. *melanthesoides*	(Kl.) Leornad
	Croton dichogamus	S	Pax		
	Croton scheffleri	S	Pax		
	Erythrococca kirkii	S	Murll. Arg.		
	Euphorbia benthamii	S	Hiern.		
	Euphorbia bongensis	H	Kotschy & Pers.		
	Euphorbia hirta	H	L.		
	Euphorbia hyssopifolia	H	L.		
	Margaritaria discoidea	T	(Baill.) Webster		
	Phyllanthus maderaspatensis	H	L.		
	Phyllanthus reticulatus	S	Poir.		
	Phyllanthus welwitschianus	S	Muell.Arg.		
	Pseudolachnostylis maprouneifolia	T	Pax		
	Tragia furialis	C	L.		
FLACOURTIACEAE	*Lindackeria bukobensis*	S	Gilg.		
	Scolopia zeyheri	S	(Nees) Harv.		
GERANIACEAE	*Perlagonium quinquelobatium*	H	A. Rich.		
GRAMINAE	*Alloteropsis cimicina*	G	(L.) Stapf.		
	Andropogon ascinodes	G	C.B.Cl.		
	Andropogon fastigiatus	G	Sw.		
	Andropogon fastigiatus	G	Sw.		
	Andropogon africanus	G	Franch.		
	Aristida adoensis	G	Hochst.		
	Aristida adscensionis	G	L.		
	Aristida hordeaceae	G	Kuth.		
	Bathriochloa insculpta	G	(A.Rich.) A. Camus		
	Boerrhaaria diffusa	G	L.		
	Brachiaria brizantha	G	(A. Rich.) Stapf.		
	Brachiaria eruciforms	G	(J.E.Saup.) Grijab.		
	Brachiaria scalaris	G	(Mez.) Pilg.		
	Brachiaria xantholeuca	G	(Schinz) Stapf.		
	Chloris pychnothrix	G	Trin.		
	Chloris mossambicensis	G	K.Schum.		
	Cynodon dactylon	G	Pers.		
	Dactyloctenium aegyptium	G	(L.) Beaur.		
	Dactyloctenium ctenioides	G	(Stedl.) Bosser.		
	Dactyroctenium aegyptium	G	(L.) Willd.		
	Dichanthium sp.	G			
	Digitaria milanjiana	G	(Rendle) Stapf		
	Echinochloa crus-pavonis	G	(Kunth.) Schult.		
	Eleusine indica	G	(L.) Gaertn.	*africana*	(Kennedy-O'Byrne) S.M.Philips
	Eragrostis cilianensis	G	(All.) Lwt.		
	Eragrostis exasperata	G	Peter		
	Eragrostis patens	G	Oliv.		
	Eragrostis sp.cf. ciliamensis	G	(All.) Lutoti		
	Eriochloa fatmensis	G	(Hochst. & Steud.) W.D.Clayton		
	Eulalia aurea	G	(Bory) Kunth.		
	Harpachne schimperi	G	A.Rich.		
	Heteropogon contortus	G	(L.) Roem. & Schult.		
	Hyparrhenia anamesa	G	W.D.Clayton		
	Hyparrhenia collina	G	(Pilg.)Stapf.		
	Hyparrhenia madaropoda	G	W.D.Clayton		
	Hyparrhenia rufa	G	(Nees)Stapf.		
	Hyparrhenia schimperi	G	(A.Rich.) Stapf.		
	Loudetia arundinacea	G	(A.Rich.) Steud.		
	Loudetia kagerensis	G	(K.Schum.) Hutch.		
	Microchloa kunthii	G	Desv.		
	Panicum atrosanguineum	G	A.Rich.		
	Panicum atrosanguineum	G	A.Rich.		
	Panicum brevifolium	G	L.		
	Panicum infestum	G	Peters		
	Panicum maximum	G	Jaq.		
	Paspalum auriculatum	G	Prest.		
	Paspalum glumaceum	G	W.D.Clayton		
	Pennisetum mezianum	G	Leeke		
	Pennisetum polystachyon	G	(L.) Schultz.		
	Rhynchelytrum repens	G	Wild		
	Rottboellia cochinchinensis	G	(Lour.) W.D.Clayton		

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	Setaria homonyma	G	(Steud.) Chiov.		
	Setaria orthosticha	G	Herm.		
	Setaria pumila	G	(Poir.) Roem. & Schult.		
	Setaria sphacelata	G	(Schum.) DC.	var. *aurea*	(A.Br.) WD.
	Sporobolus pyramidalis	G	P. Beauv.		
	Urochloa brachyura	G	(Hock.) Stapf.		
	Urochloa cf. echinolaenoides	G	Stapf.		
	Urochloa echinolaenoides	G	Stapf.		
GUTTIFERAE	*Vismia orientalis*	S	Engl.		
LABIATAE	*Aeollanthus repens*	H	Oliv.		
	Ajuga remota	H	Benth.		
	Leonotis sp.	S			
	Leucas martinicensis	H	R.Br.		
	Ocimum americana	H	L.		
	Plectranthus flaccidus	H	(Vatke) Gurke		
	Tinnea aethiopica	S	(Robyns & Lebrun) Vollesen	*stoltzii*	Hoof.f.
LILIACEAE	*Asparagus africanus*	C	L.		
LOGANIACEAE	*Strychnos henningii*	S	Gilg.		
	Strychnos madagascanensis	T	Poir.		
	Strychnos angolensis	C	Gilg.		
	Strychnos lucens	C	Bak.		
	Strychnos mitis	T	S.Moore		
	Strychnos sp.	S			
MALVACEAE	*Abutilon angulatum*	S	(Guill. & Perr.) Mast	var. *angulatum*	
	Hibiscus aethiopicus	S	L.		
	Hibiscus canabis	S	L.		
	Hibiscus rostellatus	S	Guill. & Perr.		
	Sida acuta	H	(Burm.f.		
	Sida alba	H	L.		
	Sida cordifolia	S	L.		
MELIACEAE	*Entandrophragma bussei*	T	Engl.		
MIMOSACEAE	*Acacia brevispica*	C	Harms		
	Acacia drepanolobium	S	Sjostedt		
	Acacia etbaica	T	Schweinf.		
	Acacia nilotica	T	(L.) Del.		
	Acacia polyacantha	T	Willd.	*campycantha*	(A.Rich.)Brenan
	Acacia robusta	T	Burch.	*usambarensis*	(Taub.)Brenan
	Acacia seyal	T	Del.		
	Acacia tortilis	T	(Forrsk.) Hayne		
	Afzelia quanzensis	T	Welw.		
	Albizia harveyi	T	Fourn.		
	Albizia petersiana	T	(Bolle) Oliv.		
	Albizia versicolor	T	Welw. & Oliv.		
	Brachystegia spiciformis	T	Benth.		
	Cassia abbreviata	S	Oliv.		
	Cassia mimosoidea	H	L.		
	Dichrostachys cinerea	S/T	(L.) Wight & Arn.		
	Mimosa pigra	S	L.		
MORACEAE	*Ficus natalensis*	T	Hochst.		
MYRTACEAE	*Syzygium guineense*	T	(Willd.) DC.		
NYCTAGINACEAE	*Boerhavia diffusa*	H	L.		
OCHNACEAE	*Ochna mossambicensis*	S	Klotzsch		
OLACACEAE	*Olax sp.*	S			
	Olea capensis	T	L.		
	Olea europaea	T	L.	*africana*	(Mill.)P.Green
OPILIACEAE	*Opilia celtidifolia*	C	(Guill. & Perra) Walp.		
OXALIDACEAE	*Biophytum petersianum*	H	Klotzsch.		
PALMAE	*Phoenix reclinata*	T	Jacq.		

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PAPILIONACEAE	*Abrus schimperii*	S	Bak.	*africana*	(Vatke)Verdc.
	Alysicarpus rugosus	H	(Willd.) DC.		
	Bobgunnia madagascariensis	T	(Desv.) J.H.Kirkbr. & Wiersema		
	Canavaria virosa	C	(Robx.) Wight & Arn.		
	Dalbergia melanoxylon	T	Guill. & Perr.		
	Dalbergia nitidula	T	Baker		
	Desmodium salicifolium	S	(Poir.) DC.		
	Eriosema macrostipulum	H	Bak.		
	Indigofera cissalis	H	Gillett		
	Indigofera rhynchocarpa	S	Bak.	var. *rhynchocarpa*	
	Indigofera spicata	H	Forsk.		
	Ormocarpum trichocarpum	S	(Taub.) Engl.		
	Rhynchosia minima	C	(L.) DC.		
	Stylosanthes fruticosa	H	(Retz.) Alston		
	Tephrosia nana	H	Schweinf.		
	Tephrosia pumila	C	(Lam.) Pers.		
	Xeroderris stuhlmanii	T	(Taub.) Mendonca & Souza		
	Zornia glochidiata	H	DC.		
POLYGALACEAE	*Polygala amboniensis*	H	Gurke		
	Polygala erioptera	H	DC.		
POLYGONACEAE	*Oxygonum sinuatum*	H	(Meisn) Dammer		
	Polygonum setulosum	S	A.Rich.		
PORTULACACEAE	*Portulaca oleracea*	H	L.		
RHAMNACEAE	*Scutia myrtina*	S	(Burm.f.) Kurz.		
	Ziziphus mucronata	T	Willd.		
RHIZOPHORACEAE	*Cassipourea mollis*	S	(R.E.Fries) Alston		
RUBIACEAE	*Canthium burttii*	S	Bullock		
	Canthium oligocarpum	S	Hiern.	*friesiovum*	(Robyns) Bridson
	Canthium setiflorum	S	Hiern.		
	Catunaregan spinosa	S	(Thunb.) Tirvengadum	*spinosa*	
	Crossopteryx febrifuga	T	(G.Don) Benth.		
	Gardenia subcaulis	T	Stapf. & Hutch.		
	Gardenia ternifolia	T	Schum. & Thonn.	*jovis-tonantis*	(Welw.)Verdc.
	Hymenodictyon parvifolium	S	Oliv.	*scabrum*	(Stapf.) Verdc.
	Multidentia crassa	S/T	(Hiern.) Bridson & Verdicot.		
	Odenlandia herbacea	H	(L.) Roxb.		
	Pavetta schumanniana	S	K.Schum.		
	Psydrax livida	S	(Hiern.) Bridson		
	Spermacoce chaetocephala	H	DC.		
	Spermacoce congensis	H	(Bremek.) Verdc.		
	Spermacoce dibracteata	H	Oliv.		
	Spermacoce natalensis	H	Hochst.		
	Spermacoce sphaerostigma	H	A.Rich.		
	Spermacoce subvulgata	H	(K.Schum.) Gardc.		
	Tapiphyllum burnettii	S	Tennant		
	Tapiphyllum discolor	S	(De Willd.) Robyns.		
	Tarenna graveolens	S	(S.Moore) Bremek.		
	Tricalysia sp.	S			
RUTACEAE	*Vepris glomerata*	T	(F.Hoffm.) Engl.	var. *glomerata*	
	Vepris glomerata	T	(F.Hoffm.) Engl.	var. *glabra*	Kokwaro
	Zanthoxylum chalybeum	T	Engl.		
SAPINDACEAE	*Allophylus sp.cf. africanus*	S	P.Beauv.		
	Haplocoelom foliolosum	S	(Hiern.) Bullock.		
SAPOTACEAE	*Manilkara mochsia*	T	(Bak.)Dubard		
	Mimusops kummel	T	A.D.C.		
SCROPHULIACEAE	*Craterostigma plantagineum*	H	Hoschl		
	Cycnium tubulosum	H	(L.f.) Engl.		
SIMAROUBACEAE	*Harrisonia abyssinica*	C	Oliv.		
SOLANACEAE	*Datura stromonium*	H	L.		
	Solanum aculeatissimum	S	Jacq.		
	Solanum arundo	S	Mattei		
	Solanum goetzii	S	Dammer		
	Solanum incanum	S	L.		
	Solanum nigram	H	L.		

TABLE 4-30
PRELIMINARY PLANT CHECKLIST FOR THE BULYANHULU PROJECT SITE

HABIT OR GROWTH FORM: C=Climber, G=Grass, H=Herb, S=Shrub, T=Tree

FAMILY	SPECIES NAME	HABIT	AUTHORITY	SUBSPECIES/ VARIETY	AUTHORITY
STERCULIACEAE	*Dombeya kirkii*	T	Mast.		
	Sterculia africana	T	(Lour.)Fiori		
	Waltheria indica	S	L.		
TILIACEAE	*Corchorus fascicularis*	H	Lam.		
	Grewia bicolor	S	Juss.		
	Grewia conocarpa	S	K.Schum.		
	Grewia fallax	S	K.Schum.		
	Grewia flavescens	S	Juss		
	Grewia flavescens	S	Juss.	var. *flavescens*	
	Grewia hexamita	S	Barret		
	Grewia microcarpa	S	K.Schum.		
	Grewia stuhlmannii	C	K.Schum.		
	Triumfetta macrophylla	S	K.Schum.		
	Triumfetta rhomboidea	H	Jacq.		
VERBENACEAE	*Vitex doniana*	T	Sweet		
	Vitex fischeri	T	Gurke		
	Lippia sp.	S			
VITACEAE	*Cissus rotundifolia*	C	(Forssk.)Vahl.		
	Rhoicissus sp.	C			

TABLE 4-31
RAW VEGETATION SAMPLING DATA FROM TRANSECT 1
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS								Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5	6	7	8					
HERBS													
Acalypha ornata	4								4	1	12.5	8000	1.0
Achyranthes aspera	2								2	1	12.5	4000	0.5
Ageratum conyzoides	2								2	1	12.5	4000	0.5
Blepharis maderaspatensis						1			1	1	12.5	2000	0.2
Boerrharia sp.			1						1	1	12.5	2000	0.2
Capparis sepiaris			1						1	1	12.5	2000	0.2
Commelina bengalensis	2								2	1	12.5	4000	0.5
Corchorus fascicularis		54					1		55	2	25.0	110000	13.5
Craterostigma plantagineum						1			1	1	12.5	2000	0.2
Cyanotis sp.cf. barbnata						1			1	1	12.5	2000	0.2
Emillia coccinia		1							1	1	12.5	2000	0.2
Gomphreana celasioides							1		1	1	12.5	2000	0.2
Ipomoea albinervia						1			1	1	12.5	2000	0.2
Ipomoea plebeia ssp.africana							1		1	1	12.5	2000	0.2
Justicia betonica	2		1					4	7	3	37.5	14000	1.7
Leucas martinicensis		1							1	1	12.5	2000	0.2
Oxygonum sinuatum							1		1	1	12.5	2000	0.2
Rhynchosia minima			1						1	1	12.5	2000	0.2
Sida sp.		1	1					1	3	3	37.5	6000	0.7
Spermacoce congensis							1		1	1	12.5	2000	0.2
Tridax procumbens			1						1	1	12.5	2000	0.2
Vernonia undata	2								2	1	12.5	4000	0.5
GRASSES													
Aristida sp.				2					2	1	12.5	4000	0.5
Brachiaria sp. (hairy)				A	10	A	1		151	4	50.0	302000	37.1
Chloris sp.					1				1	1	12.5	2000	0.2
Dichanthium sp.					5				5	1	12.5	10000	1.2
Eragrostis ?grey				3					3	1	12.5	6000	0.7
Heteropogon contortus				A		A	A		A	3	37.5	140000	17.2
Hyparrhenia rufa			A	5		6			81	3	37.5	162000	19.9
Sporobolus sp.					1				1	1	12.5	2000	0.2
SHRUBS													
Acacia brevispica	2								2	1	12.5	200	0.02
Acacia drepanolobium			1	1	3	1		1	7	5	62.5	700	0.09
Bridellia cathartica ssp.melanthesioides				1					1	1	12.5	100	0.01
Cassia abbreviata			1						1	1	12.5	100	0.01
Cissus rotundifolia	1								1	1	12.5	100	0.01
Combretum adenogonium				1					1	1	12.5	100	0.01
Combretum molle			1		1	1	1	1	5	5	62.5	500	0.06
Commiphora africana							1		1	1	12.5	100	0.01
Commiphora sp. (Scented)							1		1	1	12.5	100	0.01
Cynachium greniuman	1								1	1	12.5	100	0.01
Dalbergia melanoxylon			4						4	1	12.5	400	0.05
Grewia discolor							1		1	1	12.5	100	0.01
Grewia sp.	1								1	1	12.5	100	0.01
Harrisonia abyssinica			3						3	1	12.5	300	0.04
Hippocratea sp.	1								1	1	12.5	100	0.01
Lannea sp.						1			1	1	12.5	100	0.01
Ormocarpum trichocarpum			1						1	1	12.5	100	0.01
Rhus natalensis	1								1	1	12.5	100	0.01
Solanum goetzii							1		1	1	12.5	100	0.01
Ziziphus mucronata							1		1	1	12.5	100	0.01
TREES													
Acacia tortilis						1			1	1	12.5	1	0.0001
Commiphora sp.								1	1	1	12.5	1	0.0001
Dichrostachys cinerea	1								1	1	12.5	1	0.0001
Manilkara mochsia	1								1	1	12.5	1	0.0001

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-32
RAW VEGETATION SAMPLING DATA FROM TRANSECT 2
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS 1	2	3	4	5	6	Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
HERBS											
Albizia petersiana (seedings)				2	4	5	11	3	50.00	22000	5.3
Asparagus africana	5			2			7	2	33.33	14000	3.4
Aspilia sp. purple flowers		3	44				47	2	33.33	94000	22.8
Blepharis maderaspatensis ssp. rubiifolium		15		6			21	2	33.33	42000	10.2
Cassia mimosoides					1		1	1	16.67	2000	0.5
Chlorophytum sp.nov	2	8	1				11	3	50.00	22000	5.3
Commelina bengalensis						2	2	1	16.67	4000	1.0
Crabbea velutina				1			1	1	16.67	2000	0.5
Cyanotis sp.	2						2	1	16.67	4000	1.0
Emilia coccines			7				7	1	16.67	14000	3.4
Hibiscus sp.				2	10		12	2	33.33	24000	5.8
Hibiscus sp. Lobed leaves				2			2	1	16.67	4000	1.0
Ipomoea involucrata var. burttii						2	2	1	16.67	4000	1.0
Justicia exigua	4						4	1	16.67	8000	1.9
Justicia forskerii	1			1			2	2	33.33	4000	1.0
Leucas martinicensis						1	1	1	16.67	2000	0.5
Plectranthus sp.						1	1	1	16.67	2000	0.5
Secamone sp.	1						1	1	16.67	2000	0.5
Spermacoce subvulgata			1				1	1	16.67	2000	0.5
Vernonia sp.		1				1	2	2	33.33	4000	1.0
Vernonia undata	6			7			13	2	33.33	26000	6.3
GRASSES											
Andropogon sp.		3	2				5	2	33.33	10000	2.4
Aristida adoensis					2		2	1	16.67	4000	1.0
Brachiaria sp. hairy			1				1	1	16.67	2000	0.5
Hyparrhenia rufla		3			4		7	2	33.33	14000	3.4
Hyparrhenia sp.		1	9			2	12	3	50.00	24000	5.8
Panicum brevifolium	1				10		11	2	33.33	22000	5.3
Panicum maximum						4	4	1	16.67	8000	1.9
Setaria pumila					2		2	1	16.67	4000	1.0
Setaria sp.	2				2		4	2	33.33	8000	1.9
Setaria spharcelata var. aurea			2				2	1	16.67	4000	1.0
SHRUBS											
[illegible]izia petersiana					1	5	6	2	33.33	600	0.15
[illegible]retum molle			1			2	3	2	33.33	300	0.07
[illegible]retum zeyheri		1	3		1	2	7	4	66.67	700	0.17
[illegible]miphora africana	1		2				3	2	33.33	300	0.07
Cordia sp.		1					1	1	16.67	100	0.02
Croton dichogamus						1	1	1	16.67	100	0.02
Grewia bicolor				2	1	1	4	3	50.00	400	0.10
Grewia conocarpa	1						1	1	16.67	100	0.02
Grewia stuhlmannii	1						1	1	16.67	100	0.02
Haplocoelom foliolosum				1		1	2	2	33.33	200	0.05
Hymenodictyon parvifolium ssp. scabrum var. scabrum	1						1	1	16.67	100	0.02
Markhamia obtusifolia	5	12	4		4	3	28	5	83.33	2800	0.68
Rhinacanthus gracilis				6	8	6	20	3	50.00	2000	0.49
Sterculia africana			1				1	1	16.67	100	0.02
Strophanthus eminii					2		2	1	16.67	200	0.05
Strychnos mitis Sp.	3					1	4	2	33.33	400	0.10
Tricalysia sp.				3	3	1	7	3	50.00	700	0.17
Vangueria sp.					2		2	1	16.67	200	0.05
Vepris glomerata		1					1	1	16.67	100	0.02
TREES											
Acacia polyacantha	1						1	1	16.67	1	0.0002
Albizia petersiana			1	3			4	2	33.33	4	0.0010
Combretum molle		1					1	1	16.67	1	0.0002
Combretum zeyheri				1	1		2	2	33.33	2	0.0005
Grewia bicolor			1				1	1	16.67	1	0.0002
Haplocoelom foliolosum						1	1	1	16.67	1	0.0002
Manilkara mochsia	1	1					2	2	33.33	2	0.0005
Markhamia obtusifolia				1			1	1	16.67	1	0.0002
Strychnos sp.						1	1	1	16.67	1	0.0002
Vangueria sp.				1			1	1	16.67	1	0.0002

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-33
RAW VEGETATION SAMPLING DATA FROM TRANSECT 3
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	Sample Plot					Total No.of	No. of Plots	Relative	Corrected	Relative
	1	2	3	4	5	Individuals	where found	Frequency (%)	Counts	Abundance (%)
HERBS										
Albizia petersiana (seedlings)		1				1	1	20	2000	1.0
Aspilia sp. purple flowers		1				1	1	20	2000	1.0
Barleria boehmii			1			1	1	20	2000	1.0
Blepharis maderaspatensis ssp. rubiifolium		3		4	3	10	3	60	20000	10.4
Cassia mimosoides	1			1		2	2	40	4000	2.1
Chlorophytum sp.nov.		1				1	1	20	2000	1.0
Cissampelos sp.		1		1		2	2	40	4000	2.1
Combretum zeyheri	2					2	1	20	4000	2.1
Crabbea velutina		1				1	1	20	2000	1.0
Dalbergia melanoxylon		1				1	1	20	2000	1.0
Dioscorea zanzibarensis				1		1	1	20	2000	1.0
Dychoriste sp. nov.	1					1	1	20	2000	1.0
Emilia coccines	3	2				5	2	40	10000	5.2
Euphorbia tricauli		2				2	1	20	4000	2.1
Haplocoelom foliolosum					1	1	1	20	2000	1.0
Hibiscus sp.					1	1	1	20	2000	1.0
Indigofera spicata		1				1	1	20	2000	1.0
Ipomoea involucrata var. burttii	1				3	4	2	40	8000	4.2
Justicia exigua		1		1		2	2	40	4000	2.1
Justicia sp. (bracteata)	2					2	1	20	4000	2.1
Kohautia herbacea		2				2	1	20	4000	2.1
Lannea humilis	1		1			2	2	40	4000	2.1
Leucas martinicensis	1					1	1	20	2000	1.0
Polycarpea eriantha					1	1	1	20	2000	1.0
Spermacoce subvulgata		1				1	1	20	2000	1.0
Vernonia undata		3				3	1	20	6000	3.1
GRASSES										
Aristida adoensis				7	1	8	2	40	16000	8.3
Hyparrhenia ruffa	2	2	1			5	3	60	10000	5.2
Melinichloa sp.					1	1	1	20	2000	1.0
Panicum festum			1			1	1	20	2000	1.0
Panicum maximum				3		3	1	20	6000	3.1
Setaria pumila			4			4	1	20	8000	4.2
Setaria spharcelata var. aurea	4	2				6	2	40	12000	6.2
Sporobolus sp.					11	11	1	20	22000	11.5
SHRUBS										
brus schimperii			4			4	1	20	400	0.21
cacia brevispica					1	1	1	20	100	0.05
Bridelia cathartica ssp. melanthesoides					1	1	1	20	100	0.05
Canthium sp.			1			1	1	20	100	0.05
Combretum molle	2	4	1			7	3	60	700	0.36
Combretum zeyheri	3	3	3	3		12	4	80	1200	0.62
Commiphora africana	1					1	1	20	100	0.05
Commiphora edulis					1	1	1	20	100	0.05
Croton dichogamus					2	2	1	20	200	0.10
Croton scheffleri			1		1	2	2	40	200	0.10
Dalbergia melanoxylon		1				1	1	20	100	0.05
Dichrostachys cinerea				8		8	1	20	800	0.42
Grewia bicolor			1			1	1	20	100	0.05
Grewia conocarpa	1					1	1	20	100	0.05
Haplocdelom foliolosum					1	1	1	20	100	0.05
Hymenodictyon parvifolium ssp. scabrum var. scabrum	4	2	1			7	3	60	700	0.36
Markhamia obtusifolia	10	3	3	5		21	4	80	2100	1.09
Omorcarpum trichocarpum	1					1	1	20	100	0.05
Rhinacanthus gracilis			6		12	18	2	40	1600	0.94
Sterculia africana	1			1		2	2	40	200	0.10
Strychnos mitis Sp.			1			1	1	20	100	0.05
Strychnos sp. (unmatched)				1	1	2	2	40	200	0.10
Terminalia sericea		1				1	1	20	100	0.05
Tricalysia sp.			1			1	1	20	100	0.05
Vepris glomerata		1	1			2	2	40	200	0.10
Zanthoxylum chalybeum		1				1	1	20	100	0.05
TREES										
Albizia petersiana			2	2	2	6	3	60	6	0.0031
Commiphora eminii			1			1	1	20	1	0.0005
Dalbergia melanoxylon		1				1	1	20	1	0.0005
Dichrostachys cinerea		1				1	1	20	1	0.0005
Entandrophragma bussei			1			1	1	20	1	0.0005
Grewia bicolor			1			1	1	20	1	0.0005
Grewia conocarpa					1	1	1	20	1	0.0005
Haplocoelom foliolosum				1	3	4	2	40	4	0.0021
Hymenodictyon parvifolium	1	1				2	2	40	2	0.0010
Margaritaria discoides				1	1	2	2	40	2	0.0010
Olax sp.		1				1	1	20	1	0.0005
Ozoroa insignis		1				1	1	20	1	0.0005
Thilachium africanum					1	1	1	20	1	0.0005

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Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-34
RAW VEGETATION SAMPLING DATA FROM TRANSECT 4
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS										Total No.of	No. of Plots	Relative	Corrected	Relative
	1	2	3	4	5	6	7	8	9	10	Individuals	where found	Frequency (%)	Counts	Abundance (%)
HERBS															
Acacia drepanolobium			1								1	1	10	2000	0.1
Beckeropsis sp.	1										1	1	10	2000	0.1
Blepharis longifolia		2									2	1	10	4000	0.3
Cassia mimosoidea		1	1				4	2	2		10	5	50	20000	1.3
Chlorophytum sp.			1	1		5	2				9	4	40	18000	1.1
Commelina bengalensis							1				1	1	10	2000	0.1
Craterostigma plantagineum				2							2	1	10	4000	0.3
Dichrostachys cinerea			1								1	1	10	2000	0.1
Dicoma anomala					1	2					3	2	20	6000	0.4
Dyschoriste sp.	5										5	1	10	10000	0.6
Euphorbia sp.								1			1	1	10	2000	0.1
Evolvulus alsinoides									1	1	2	2	20	4000	0.3
Heliotropium strigosum									1		1	1	10	2000	0.1
Hibiscus sp.	2		1								3	2	20	6000	0.4
Indigofera cissalis									1		1	1	10	2000	0.1
Indigofera sp.	1										1	1	10	2000	0.1
Indigofera spicata									1	3	4	2	20	8000	0.5
Justicia exigua										3	3	1	10	6000	0.4
Justicia sp.							3				3	1	10	6000	0.4
Justicia spicata										1	1	1	10	2000	0.1
Lannea humilis						1					1	1	10	2000	0.1
Leucas martinicensis							3				3	1	10	6000	0.4
Meremia medium			1								1	1	10	2000	0.1
Ormocarpum trichocarpum						1					1	1	10	2000	0.1
Oxygonum sinuatum										2	2	1	10	4000	0.3
Phyllanthus maderaspatensis	1										1	1	10	2000	0.1
Rothmannia sp.	20										20	1	10	40000	2.5
Sida cordifolia		1									1	1	10	2000	0.1
Sida sp.							1	2			3	2	20	6000	0.4
Tephrosia pumila									1		1	1	10	2000	0.1
Tragia furialis	1										1	1	10	2000	0.1
Vernonia karagwensis	2										2	1	10	4000	0.3
Waltheria indica					1						1	1	10	2000	0.1
Zornia glochidiata				2				1			3	2	20	6000	0.4
GRASSES															
Andropogon sp.							1				1	1	10	2000	0.1
Aristida adoensis			5								5	1	10	10000	0.6
Dactyloctenium aegyptium				2							2	1	10	4000	0.3
Dichathium sp.						3					3	1	10	6000	0.4
Digitaria milanjiana					4						4	1	10	8000	0.5
Eragrostis sp.					1						1	1	10	2000	0.1
Hyparrhenia rufa	5									2	7	2	20	14000	0.9
Hyparrhenia small	A	8	A	4	12	13	A	A	A		387	9	90	774000	49.1
Loudetia arundinacea	1									6	7	2	20	14000	0.9
Microlepis sp.		1		8	A						79	3	30	158000	10.0
Urochloa ochinolaenoides		6	A	6	7	8	15	7	A		189	8	80	378000	24.0
SHRUBS															
Acacia drepanolobium		1	2	4	4	3	2				16	6	60	1600	0.10
Bridellia cathartica										1	1	1	10	100	0.01
Catunaregan spinosa			1								1	1	10	100	0.01
Combretum adenogonium	3	3	2	3	2		5	3		3	24	8	80	2400	0.15
Combretum molle						1	1			3	5	3	30	500	0.03
Combretum padioides										1	1	1	10	100	0.01
Combretum sp. liana						1					1	1	10	100	0.01
Commiphora africana										4	4	1	10	400	0.03
Commiphora sp. Scented 3-leaved									1		1	1	10	100	0.01
Crossopteryx febrifuga	1				1			1		1	4	4	40	400	0.03
Dalbergia melanoxylon			1		1	5					7	3	30	700	0.04
Dichrostachys cinerea		1	1								2	2	20	200	0.01
Dombeya kirkii										1	1	1	10	100	0.01
Harrisonia abyssinica			1								1	1	10	100	0.01
Hymenodictyon parvifolium										1	1	1	10	100	0.01
Indigofera sp.										1	1	1	10	100	0.01
Lannea mossambicensis						2	1	3	10		16	4	40	1600	0.10
Lannea schimperii					1						1	1	10	100	0.01
Olax sp.				1							1	1	10	100	0.01
Ormorcarpum trichocarpum		3	1		2	2					8	4	40	800	0.05
Piliostigma thoningii							1	2			3	2	20	300	0.02
Rhoicissus sp.							1				1	1	10	100	0.01
Senna singuena			2			3	2		1		8	4	40	800	0.05
Sida sp.		1	2								3	2	20	300	0.02
Solanum incanum									10		10	1	10	1000	0.06
Sterculia africana										1	1	1	10	100	0.01
Zanthoxylum chalybeum									8		8	1	10	800	0.05
TREES															
Albizia petersiana								1			1	1	10	1	0.0001
Balanites aegypticum	1										1	1	10	1	0.0001
Grewia conocarpa										1	1	1	10	1	0.0001
Lannea discolor										1	1	1	10	1	0.0001
Lannea schweinfurthii							1				1	1	10	1	0.0001
Tamarindus indica										1	1	1	10	1	0.0001
Ziziphus mucronata								1			1	1	10	1	0.0001

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-35
RAW VEGETATION SAMPLING DATA FROM TRANSECT 5
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS								Total No.of	No. of Plots	Relative	Corrected	Relative
	1	2	3	4	5	6	7	8	Individuals	where found	Frequency (%)	Counts	Abundance (%)
Aspilia sp.			1	1					2	2	25.0	4000	0.6
Astripomoea malvacea						3			3	1	12.5	6000	0.9
Cassia mimosoides		1		1	6	3	3	3	17	6	75.0	34000	5.1
Chlorophytum sp.								1	1	1	12.5	2000	0.3
Composite sp. big lvs	1	4							5	2	25.0	10000	1.5
Crabbea velutina.			1	2					3	2	25.0	6000	0.9
Dyschoriste sp.	4								4	1	12.5	8000	1.2
Emilia coccinia	1	3					1	2	7	4	50.0	14000	2.1
Euphorbia hirta	3	1	8			2			14	4	50.0	28000	4.2
Hibiscus sp.	1								1	1	12.5	2000	0.3
Indigofera cissalis					3				3	1	12.5	6000	0.9
Indigofera sp.			3	3					6	2	25.0	12000	1.8
Indigofera spicata					1				1	1	12.5	2000	0.3
Justicia sp.						1			1	1	12.5	2000	0.3
Leucas martinicensis	1					1		1	3	3	37.5	6000	0.9
Odenlandia sp.							10		10	1	12.5	20000	3.0
Oxygonum sinuatum								1	1	1	12.5	2000	0.3
Phyllanthus sp.	3			2					5	2	25.0	10000	1.5
Polygala amboniensis					2				2	1	12.5	4000	0.6
Sida sp.			1						1	1	12.5	2000	0.3
Sida sp.(a)	1		1		5				7	3	37.5	14000	2.1
Spermacoce dibracteate				2					2	1	12.5	4000	0.6
Spermacoce natalensis				3					3	1	12.5	6000	0.9
Spermacoce sp.	1								1	1	12.5	2000	0.3
Spermacoce sphaerostigma					2				2	1	12.5	4000	0.6
Stylosanthes sp.				2					2	1	12.5	4000	0.6
Tephrosia sp.					4				4	1	12.5	8000	1.2
Tragia furialis	1	1							2	2	25.0	4000	0.6
Triumfetta sp.							1		1	1	12.5	2000	0.3
Vernonia cinerascensis							1		1	1	12.5	2000	0.3
Vernonia posckeana							30		30	1	12.5	60000	9.0
Vernonia undata			3				10		13	2	25.0	26000	3.9
Zornia glochidiata					4			1	5	2	25.0	10000	1.5
GRASSES									0				
Andropogon ascinodis				1					1	1	12.5	2000	0.3
Chloris pachnothrix			1		6	2	2	3	14	5	62.5	28000	4.2
Eragrostis cilianensis					3				3	1	12.5	6000	0.9
Eragrostis axasperata		1			3			2	6	3	37.5	12000	1.8
Eragrostis patens							1		1	1	12.5	2000	0.3
Eriochloa fatmensis				1					1	1	12.5	2000	0.3
Hyparrhenia rufa	4		1	6		1	A		12	5	62.5	24000	3.6
Hyparrhenia sp.	A	A	A	7	7	A	8	18	40	8	100.0	80000	12.1
Microlepis sp.							A		A	1	12.5	140000	21.1
Setaria pumila		16							16	1	12.5	32000	4.8
SHRUBS									0				
Abrus schimperii								1	1	1	12.5	100	0.02
Bridellia cathartica		1	1	2					4	3	37.5	400	0.06
Canthium burttii		1							1	1	12.5	100	0.02
Cassia singuena	1	1						1	3	3	37.5	300	0.05
Catunaregan spinosapilosa	1			1					2	2	25.0	200	0.03
Combretum adenogonium	3			1		8	3	2	17	5	62.5	1700	0.26
Combretum constrictum								1	1	1	12.5	100	0.02
Combretum molle	2	2	2	4	1	1		3	15	7	87.5	1500	0.23
Combretum psiodioides	1		1			1	1		4	4	50.0	400	0.06
Combretum sp.softly hairy lvs pressed	1		1	1					3	3	37.5	300	0.05
Commiphora africana		1	1					1	3	3	37.5	300	0.05
Commiphora schimperi					2				2	1	12.5	200	0.03
Crossopteryx febrifuga	3		1	3		1			8	4	50.0	800	0.12
Dalbergia melanoxylon		1				1			2	2	25.0	200	0.03
Dichrostachys cinerea						1			1	1	12.5	100	0.02
Gardenia jovis-tonantis		1							1	1	12.5	100	0.02
Harrisonia abyssinica		2							2	1	12.5	200	0.03
Lannea sp. pinnate lvs	1							1	2	2	25.0	200	0.03
Leonotis sp.								1	1	1	12.5	100	0.02
Markhamia obtusifolia								2	2	1	12.5	200	0.03
Maytenus holstii		1	1						2	2	25.0	200	0.03
Ochna sp.		1							1	1	12.5	100	0.02
Pericopsis angolensis	2			1					3	2	25.0	300	0.05
Phyllanthus reticulata		1							1	1	12.5	100	0.02
Phyllanthus welwitschianus						1			1	1	12.5	100	0.02
Pseudolachynostylis maproneufolia			2						2	1	12.5	200	0.03
Solanum incanum					10				10	1	12.5	1000	0.15
Vitex doniana		1							1	1	12.5	100	0.02
TREES									0				
Annona senegalensis	1								1	1	12.5	1	0.0002
Combretum padioides	1							2	3	2	25.0	3	0.0005
Dalbergia melanoxylon			1						1	1	12.5	1	0.0002
Lannea sp. (pinnate leaves)	1								1	1	12.5	1	0.0002
Pericopsis angolensis		1			1				2	2	25.0	2	0.0003
Strychnos sp.						1			1	1	12.5	1	0.0002
Ziziphus mucronata						1			1	1	12.5	1	0.0002

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-36
RAW VEGETATION SAMPLING DATA FROM TRANSECT 6
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS																			Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5	6	7	8	9	8	9	10	11	12	13	14	15	16	17					
HERBS																								
Achyranthes sp.																	1			1	1	5.88	2000	0.1
Asparagus africana											1									1	1	5.88	2000	0.1
Aspilia sp.		1																		1	1	5.88	2000	0.1
Berkhea sp. composite																		1		1	1	5.88	2000	0.1
Cassia mimosoides	2		7	1	1	5							2				1	1		20	8	47.06	40000	2.9
Commelina sp.			4																	4	1	5.88	8000	0.6
Commelina sp. Yellow flowers															1					1	1	5.88	2000	0.1
Composite (yellow bracts)												3								3	1	5.88	6000	0.4
Cyamopsis sp.		3																		3	1	5.88	6000	0.4
Cyanotis sp.			4		1												2			7	3	17.65	14000	1.0
Dicoma anomala		1																		1	1	5.88	2000	0.1
Emilia coccines						1														1	1	5.88	2000	0.1
Gomphreana celasioides					9															9	1	5.88	18000	1.3
Heliotropium strigosum										1										1	1	5.88	2000	0.1
Hibiscus ethiopicus												1								1	1	5.88	2000	0.1
Hypoestes forskalii	1																			1	1	5.88	2000	0.1
Indigofera sp.	1																			1	1	5.88	2000	0.1
Ipomoea sp yellow flowers																		1		1	1	5.88	2000	0.1
Leucas martinicensis														1						1	1	5.88	2000	0.1
Meremia medium													2							2	1	5.88	4000	0.3
Monechma subsessile	3	2	1																	6	3	17.65	12000	0.9
Monechma subsessile						1														1	1	5.88	2000	0.1
Ocimum americana											1									1	1	5.88	2000	0.1
Odenlandia sp.							1													1	1	5.88	2000	0.1
Oxygonum sp.					1															1	1	5.88	2000	0.1
Pavonia sp.															1					1	1	5.88	2000	0.1
Phyllanthus sp.	2	5		1	1	3						4								16	6	35.29	32000	2.3
Piliostigma thoningii										1										1	1	5.88	2000	0.1
Polycarpon sp.																	1			1	1	5.88	2000	0.1
Polygala amboniensis							2													2	1	5.88	4000	0.3
Polygala erioptera										1										1	1	5.88	2000	0.1
Portulaca oleracea																		1		1	1	5.88	2000	0.1
Rhinacanthus gracilis				7																7	1	5.88	14000	1.0
Secamone sp.											1									1	1	5.88	2000	0.1
Sida sp.					1		2			1				1						5	4	23.53	10000	0.7
Solanum incanum																		1		1	1	5.88	2000	0.1
Solanum nigram															1					1	1	5.88	2000	0.1
Spermacoce sp.		1				2	1													4	3	17.65	8000	0.6
Tephrosia nana			1	2	3	2														8	4	23.53	16000	1.1
Tephrosia pumila							1													1	1	5.88	2000	0.1
Triumfetta sp.		3																		3	1	5.88	6000	0.4
Vernonia sp.		1												2						3	2	11.76	6000	0.4
Zornia glochidiata					1															1	1	5.88	2000	0.1
GRASSES																								
Alloteropsis cimicina																	2			2	1	5.88	4000	0.3
Andropogon ascinodes													1							1	1	5.88	2000	0.1
Aristida sp.		1																		1	1	5.88	2000	0.1
Bathriochloa insculpta												A								A	1	5.88	140000	10.0
Chloris pachnothrix					5															5	1	5.88	10000	0.7
Chloris mossambicensis			3																	3	1	5.88	6000	0.4
Eleusine sp.															3					3	1	5.88	6000	0.4
Eulalia aurea												1								1	1	5.88	2000	0.1
Heteropogon contortus				5	3						1							12		21	4	23.53	42000	3.0

TABLE 4-36
RAW VEGETATION SAMPLING DATA FROM TRANSECT 6
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS																			Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5	6	7	8	9	8	9	10	11	12	13	14	15	16	17					
Hyparrhania anainesa										1										1	1	5.88	2000	0.1
Hyparrhenia schimperi	1																			1	1	5.88	2000	0.1
Hyparrhenia sp.	10	3		17	1	A				A			20				1			192	8	47.06	384000	27.5
Hyparrhenia collina										1										1	1	5.88	2000	0.1
Hyparrhenia madaropa	2									2					1					5	3	17.65	10000	0.7
Hyparrhenia rufa			1			1	A					A	1							143	5	29.41	286000	20.5
Loudetia kagerensis		2																		2	1	5.88	4000	0.3
Microchloa kunthi	8					1												16		25	3	17.65	50000	3.6
Panicum atrosanguineum				5										11				4		20	3	17.65	40000	2.9
Panicum brevifolium															1					1	1	5.88	2000	0.1
Panicum maximum			1								3									4	2	11.76	8000	0.6
Panicum maximum																		1		1	1	5.88	2000	0.1
Rotboellia pser.													1							1	1	5.88	2000	0.1
Setaria orthosticha															2					2	1	5.88	4000	0.3
Urochloa cf. echinolaenoides				9		12	10													31	3	17.65	62000	4.4
Urochloa echinolaenoides			6		20															26	2	11.76	52000	3.7
SHRUBS																								
Acacia nilotica													1							1	1	5.88	100	0.01
Annona senegalensis	1																			1	1	5.88	100	0.01
Brachystegia spiciformis																	2			2	1	5.88	200	0.01
Bridelia cathartica	2																			2	1	5.88	200	0.01
Catunaregan spinosa		1				1							1							3	3	17.65	300	0.02
Combretum adenogonium	6	2			3	3												1	1	16	6	35.29	1600	0.11
Combretum constrictum				1																1	1	5.88	100	0.01
Combretum molle	1	2				1	2			3										9	5	29.41	900	0.06
Combretum padioides		1																		1	1	5.88	100	0.01
Combretum sp. scandent shrub											1									1	1	5.88	100	0.01
Combretum sp. with purple fruits						2							3							5	2	11.76	500	0.04
Commiphora africana			1	1									1							3	3	17.65	300	0.02
Commiphora sp.			4																	4	1	5.88	400	0.03
Crossopteryx febrifuga										2			1							3	2	11.76	300	0.02
Dalbergia nitidula																	1			1	1	5.88	100	0.01
Dichrostachys cinerea						2								2						4	2	11.76	400	0.03
Euclea natalensis											1									1	1	5.88	100	0.01
Harrisonia abyssinica	1				1	1					1		1							5	5	29.41	500	0.04
Hymenodictyon parvifolium																	2			2	1	5.88	200	0.01
Lannea sp.	1																			1	1	5.88	100	0.01
Lannea sp.			4																	4	1	5.88	400	0.03
Margaritaria discoides	2												2							4	2	11.76	400	0.03
Markhamia obtusifolia	1																		3	4	2	11.76	400	0.03
Olax sp.													1							1	1	5.88	100	0.01
Olea europaea ssp. africana		1																		1	1	5.88	100	0.01
Olea sp.													1							1	1	5.88	100	0.01
Parinari curatellifolia				1																1	1	5.88	100	0.01
Rhus natalensis						1														1	1	5.88	100	0.01
Senna singuena			1										1							2	2	11.76	200	0.01
Solanum incanum										3								10		13	2	11.76	1300	0.09
Sterculia africana													1							1	1	5.88	100	0.01
Tamarindus indica	1																			1	1	5.88	100	0.01
Terminalia sericea		1																		1	1	5.88	100	0.01
Thilachium sp.											1									1	1	5.88	100	0.01
Vernonia bellinghanii			1																	1	1	5.88	100	0.01
Xeroderris stuhlmanii																	2	1		3	2	11.76	300	0.02

TABLE 4-36
RAW VEGETATION SAMPLING DATA FROM TRANSECT 6
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS																			Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5	6	7	8	9	8	9	10	11	12	13	14	15	16	17					
TREES																								
Acacia nilotica												2								2	1	5.88	2	0.0001
Brachystegia spiciformis													1							1	1	5.88	1	0.0001
Combretum adenogonium	1																			1	1	5.88	1	0.0001
Commiphora africana										1										1	1	5.88	1	0.0001
Lannea sp.		1								1										2	2	11.76	2	0.0001
Ozoroa insignis	1																			1	1	5.88	1	0.0001
Pericopsis angolensis			1				1													2	2	11.76	2	0.0001
Phyllanthus sp.		1																		1	1	5.88	1	0.0001
Senna singuena												1								1	1	5.88	1	0.0001
Thilachium sp.		2																		2	1	5.88	2	0.0001
Ziziphus mucronata		1																		1	1	5.88	1	0.0001

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-37
RAW VEGETATION SAMPLING DATA FROM TRANSECT 7
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS																				Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
HERBS																									
Abutilon sp.							1														1	1	5.0	2000	0.11
Acanthospermum hispidum							1	5			1										7	3	15.0	14000	0.76
Achyranthes aspera										1											1	1	5.0	2000	0.11
Ageratum conyzoides											4		4								8	2	10.0	16000	0.87
Amaranthus hybridus								1	1	1											3	3	15.0	6000	0.33
Aspilia sp. (yellow flowers)				3	2																5	2	10.0	10000	0.54
Bidens pilosa								2													2	1	5.0	4000	0.22
Cassia mimosoides	1				3						7	1								2	14	5	25.0	28000	1.52
Commelina bengalensis							1														1	1	5.0	2000	0.11
Crabbea velutina			1		1												1			2	5	4	20.0	10000	0.54
Dychoriste sp.			6	1																	7	2	10.0	14000	0.76
Emilia coccines					4	1					2		4			1	1				13	6	30.0	26000	1.41
Euphorbia hirta							2				5		6			1					14	4	20.0	28000	1.52
Euphorbia hyssopifolia												1								1	2	2	10.0	4000	0.22
Euphorbia sp. (red)											1										1	1	5.0	2000	0.11
Evolvulus alsinoides									1									1			2	2	10.0	4000	0.22
Gardenia sp.			10																		10	1	5.0	20000	1.08
Harrisonia abyssinica														3							3	1	5.0	6000	0.33
Indigofera sp.																1					1	1	5.0	2000	0.11
Indigofera spicata																1					1	1	5.0	2000	0.11
Ipomoea sp.				1			1									1					3	3	15.0	6000	0.33
Ipomoea sp. (pinkish flower)												1									1	1	5.0	2000	0.11
Justicia spicata																3					3	1	5.0	6000	0.33
Justicia bracteata					1																1	1	5.0	2000	0.11
Justicia exigua				1					1												2	2	10.0	4000	0.22
Launaea cornuta														4							4	1	5.0	8000	0.43
Leucas martinicensis											1	1					1				3	3	15.0	6000	0.33
Monechma subsessile		7										1	1								9	3	15.0	18000	0.98
Odenlandia sp.		1		1								1	1								4	4	20.0	8000	0.43
Oxygonum sinuatum				1	1																2	2	10.0	4000	0.22
Pandiaka sp.				1	2	1						1									5	4	20.0	10000	0.54
Phyllanthus sp.		3	1	3		5	1														13	5	25.0	26000	1.41
Polycarpaea eriantha		8																			8	1	5.0	16000	0.87
Polygala erioptera															4			2		2	8	3	15.0	16000	0.87
Secamone sp.																1					1	1	5.0	2000	0.11
Senna senguena	1																				1	1	5.0	2000	0.11
Sida sp.						1	2	4		2				3							12	5	25.0	24000	1.30
Sida sp. (grey)															5						5	1	5.0	10000	0.54
Sida sp. (purple)															6						6	1	5.0	12000	0.65
Spermacoce dibracteata			1																		1	1	5.0	2000	0.11
Spermacoce natalensis		2		2								1	1				1				7	5	25.0	14000	0.76
Spermacoce subvulgata		3			1												4				8	3	15.0	16000	0.87
Tephrosia nana															1			2	1		4	3	15.0	8000	0.43
Tragia furialis																			1		1	1	5.0	2000	0.11
Tridax procumbens									1												1	1	5.0	2000	0.11
Triumfetta rhomboidea				1													4				5	2	10.0	10000	0.54
Triumfetta sp.	2					2															4	2	10.0	8000	0.43
Vemonia undata						1	1		1		1										4	4	20.0	8000	0.43
Waltheria sp.				5			1														6	2	10.0	12000	0.65
Zomia glochidiata				1																	1	1	5.0	2000	0.11
GRASSES																									
Allopteropsis cimicina	1																				1	1	5.0	2000	0.11
Andropogon africanus				2																	2	1	5.0	4000	0.22
Andropogon fastigiatus	A	2	A		12	10					5		A	A				8		A	387	10	50.0	774000	41.95
Aristida adoensis															6						6	1	5.0	12000	0.65
Beckeropsis sp.	3	1	2		2								2			3	2				15	7	35.0	30000	1.63
Brachiaria sp. (hairy)							2	1	1								5			4	13	5	25.0	26000	1.41
Brachiaria sp. (glabrous)																			4		4	1	5.0	8000	0.43

TABLE 4-37
RAW VEGETATION SAMPLING DATA FROM TRANSECT 7
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS																				Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
Chloris pachnothrix								7		A	2										79	3	15.0	158000	8.56
Chloris sp.													1					4			5	2	10.0	10000	0.54
Cyanodon dactyroptenium									1												1	1	5.0	2000	0.11
Dactyroctenium sp.								1													1	1	5.0	2000	0.11
Dicanthium sp.														3	3						6	2	10.0	12000	0.65
Eleusine indica ssp. africana								1													1	1	5.0	2000	0.11
Eleusine sp.									3												3	1	5.0	6000	0.33
Eragrostis impatiens										5									3		8	2	10.0	16000	0.87
Eragrostis sp.								2			1										3	2	10.0	6000	0.33
Heteropogon contortus		10		8		8									8	2	10		1	3	50	8	40.0	100000	5.42
Hyparrhenia rufa		11					6		1			8	1			7					34	6	30.0	68000	3.69
Microchloa kunthi				2							15						1				18	3	15.0	36000	1.95
Pennisetum sp.													2								2	1	5.0	4000	0.22
Setaria pumila					7							1		6					1		15	4	20.0	30000	1.63
Setaria sp.				4					1												5	2	10.0	10000	0.54
Setaria sp. (big leaves)					1		1			1											3	3	15.0	6000	0.33
Sporobolus sp.			1					2	3		8								4		18	5	25.0	36000	1.95
SHRUBS																									
Acacia drepanolobium														2							2	1	5.0	200	0.01
Acacia nilotica															1						1	1	5.0	100	0.01
Albizia harveyi				1																	1	1	5.0	100	0.01
Albizia petersiana																	1				1	1	5.0	100	0.01
Annona senegalensis											1					1					2	2	10.0	200	0.01
Asparagus africana			1			1															2	2	10.0	200	0.01
Bridellia cathartica	3					1							2							1	7	4	20.0	700	0.04
Catunaregan spinosa		1	1																2		4	3	15.0	400	0.02
Combretum adenogonium	3	7	5		3	3						5	3		1	4			3	1	38	11	55.0	3800	0.21
Combretum constrictum			1															1			2	2	10.0	200	0.01
Combretum molle	4	3		1		1															9	4	20.0	900	0.05
Combretum padioides		1	1																		2	2	10.0	200	0.01
Combretum sp. climbing liana				3			1														4	2	10.0	400	0.02
Combretum sp. reddish brown fruit													2								2	1	5.0	200	0.01
Commiphora africana		1		2	1						2								1	1	8	6	30.0	800	0.04
Commiphora sp. scented							12														12	1	5.0	1200	0.07
Crossopteryx febrifuga		2	1		1																4	3	15.0	400	0.02
Dalbergia melanoxylon		1																			1	1	5.0	100	0.01
Dichrostachys cinerea			4									3									7	2	10.0	700	0.04
Diplorrhynchus condilocarpon		1																			1	1	5.0	100	0.01
Erythrococca kirkii											1										1	1	5.0	100	0.01
Grewia flavescens											2										2	1	5.0	200	0.01
Harrisonia abyssinica	2				1																3	2	10.0	300	0.02
Lannea sp. 9-leaflets																1			1		2	2	10.0	200	0.01
Margaritaria discoidea	2		2			1															5	3	15.0	500	0.03
Maytenus holstii						1							1			4	2	1		2	11	6	30.0	1100	0.06
Olax sp.												1									1	1	5.0	100	0.01
Ormorcarpum trichocarpum							1														1	1	5.0	100	0.01
Pericopsis angolensis	1			1																	2	2	10.0	200	0.01
Phyllanthus welwitschianum													1								1	1	5.0	100	0.01
Pseudolachnostylis mapronelfolia						1														1	2	2	10.0	200	0.01
Senna obtusifolia											1										1	1	5.0	100	0.01
Senna singuena											1					1					2	2	10.0	200	0.01
Sida cordifolia											3										3	1	5.0	300	0.02
Tapiphylum burnettii		1																			1	1	5.0	100	0.01
Triumfetta rhomboidea											1										1	1	5.0	100	0.01
Triumfetta sp.												8									8	1	5.0	800	0.04
Vismia orientalis						1															1	1	5.0	100	0.01
Waltheria indica											11		2								13	2	10.0	1300	0.07
TREES																									
Acacia etbaica					1		1														2	2	10.0	2	0.0001
Albizia harveyi																					1	1	5.0	1	0.0001

TABLE 4-37
RAW VEGETATION SAMPLING DATA FROM TRANSECT 7
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS																				Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
Combretum zeyheri							1	1													2	2	10.0	2	0.0001
Lannea sp.																				1	1	1	5.0	1	0.0001
Ozoroa insignis								1													1	1	5.0	1	0.0001
Parinari curatellifolia		1																			1	1	5.0	1	0.0001
Pericopsis angolensis							1													1	2	2	10.0	2	0.0001
Pseudolachynostylis maproneufolia																	1				1	1	5.0	1	0.0001
Sclerocarya birrea	1																	1			2	2	10.0	2	0.0001
Senna singuena																				1	1	1	5.0	1	0.0001

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-38
RAW VEGETATION SAMPLING DATA FROM TRANSECT 8
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS					Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5					
Cissampelos pumila		1				1	1	20.00	2000	0.3
Commiphora africana		1				1	1	20.00	2000	0.3
Crebbia sp.				2		2	1	20.00	4000	0.6
Harrisonia abyssinica			1			1	1	20.00	2000	0.3
Hypoestes forskalei			5			5	1	20.00	10000	1.5
Indigofera fisalis	1					1	1	20.00	2000	0.3
Justicia sp.	3	3				6	2	40.00	12000	1.8
Justicia spicata			1			1	1	20.00	2000	0.3
Oxygonum sinuatum	1					1	1	20.00	2000	0.3
Secamone sp.			2			2	1	20.00	4000	0.6
Sida sp.	1			1		2	2	40.00	4000	0.6
Vernonia unduta			1			1	1	20.00	2000	0.3
Zornia glochidiata	1					1	1	20.00	2000	0.3
GRASSES										
Aristida adscensionis	1					1	1	20.00	2000	0.3
Brachyaria sp.		1				1	1	20.00	2000	0.3
Eragrostis sp.				1		1	1	20.00	2000	0.3
Heteropogon contortus	1			3	A	74	3	60.00	148000	22.1
Hyparrhenia rufa		3	3			6	2	40.00	12000	1.8
Hyparrhenia small	10	A	A	A		220	4	80.00	440000	65.8
Setaria pumila			4			4	1	20.00	8000	1.2
SHRUBS						0				
Bridellia cathartica		1	2	3		6	3	60.00	600	0.09
Combretum adenogonium	2	2	5	5	1	15	5	100.00	1500	0.22
Combretum constrictum					1	1	1	20.00	100	0.01
Combretum molle	1	1				2	2	40.00	200	0.03
Combretum zeyheri	1					1	1	20.00	100	0.01
Commiphora africana	1		1	1	1	4	4	80.00	400	0.06
Dalbergia melanoxylon					1	1	1	20.00	100	0.01
Dalbergia nitidula		1				1	1	20.00	100	0.01
Dichrostachys cinerea		1				1	1	20.00	100	0.01
Harrisonia abyssinica		1	2	2		5	3	60.00	500	0.07
Margaritaria discoidea		2				2	1	20.00	200	0.03
Maytenus holstii				1		1	1	20.00	100	0.01
Onchoba spinosa		1				1	1	20.00	100	0.01
Pavetta schumanniana					1	1	1	20.00	100	0.01
Pericopsis angolensis					1	1	1	20.00	100	0.01
Phyllanthus welwitschia				1		1	1	20.00	100	0.01
Pseudolachynostylis maproneufolia		1				1	1	20.00	100	0.01
Senna singuena	1	1				2	2	40.00	200	0.03
Terminalia sericea	1					1	1	20.00	100	0.01
Vismia sp.					2	2	1	20.00	200	0.03
TREES										
Commiphora sp. 3-leaved				1		1	1	20.00	1	0.00015
Dalbergia melanoxylon	1					1	1	20.00	1	0.00015
Rhus natalensis				2		2	1	20.00	2	0.00030
Xerroderis stuhlmanii	1					1	1	20.00	1	0.00015
Zanthoxylum chalybeum				1		1	1	20.00	1	0.00015

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-39
RAW VEGETATION SAMPLING DATA FROM TRANSECT 9
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS					Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5					
HERBS										
Crebbia sp.			1		1	2	2	40	4000	1.4
Dychoriste sp.	1					1	1	20	2000	0.7
Emilia coccines		1	2			3	2	40	6000	2.1
Euphorbia sp. red				1	3	4	2	40	8000	2.8
Evolvulvus alsinoides	1					1	1	20	2000	0.7
Indigofera spicata					1	1	1	20	2000	0.7
Ipomoea sp.			1			1	1	20	2000	0.7
Justicia bracteata					1	1	1	20	2000	0.7
Justicia exigua	2		2			4	2	40	8000	2.8
Justicia sp.				1		1	1	20	2000	0.7
Odenlandia sp.					1	1	1	20	2000	0.7
Oxalis sp.		2				2	1	20	4000	1.4
Oxygonum sp.					1	1	1	20	2000	0.7
Sida sp.	2	2	1			5	3	60	10000	3.5
Solanum incanum			1			1	1	20	2000	0.7
Tragia furialis		2				2	1	20	4000	1.4
GRASSES										
Andropogon sp.		1				1	1	20	2000	0.7
Beckeropsis sp.		2	2			4	2	40	8000	2.8
Hyparrhenia sp.	A			2	10	82	3	60	164000	56.7
Hyparrhenia rufa		4	3	3		10	3	60	20000	6.9
Microchloa sp.			3			3	1	20	6000	2.1
Panicum maximum	1					1	1	20	2000	0.7
Setaria sp. big leaves		4				4	1	20	8000	2.8
Sporobolus sp.				3	2	5	2	40	10000	3.5
SHRUBS										
Acacia tortilis	1					1	1	20	100	0.03
Asparagus africana					1	1	1	20	100	0.03
Bridelia cathartica		3				3	1	20	300	0.10
Combretum molle			3		4	7	2	40	700	0.24
Combretum adenogonium	3	3	1		3	10	4	80	1000	0.35
Combretum padioides		2				2	1	20	200	0.07
Commiphora africana	1			2		3	2	40	300	0.10
Crossopteryx febrifuga		2	1			3	2	40	300	0.10
Dalbergia melanoxylon	1	1	1			3	3	60	300	0.10
Dichrostachys cinerea	5					5	1	20	500	0.17
Fadogia sp.		1				1	1	20	100	0.03
Harrisonia abyssinica		3		3		6	2	40	600	0.21
Lannea humilia	4					4	1	20	400	0.14
Lannea sp. large leaves		1				1	1	20	100	0.03
Markhamia obtusifolia			2		5	7	2	40	700	0.24
Maytenus holstii		3				3	1	20	300	0.10
Pericopsis angolensis		1				1	1	20	100	0.03
Rhus natalensis		3				3	1	20	300	0.10
Senna singuena		1		1		2	2	40	200	0.07
Solanum incanum				5		5	1	20	500	0.17
Zanthoxylum chalybeum		1				1	1	20	100	0.03
TREES						0				
Ozoroa insignis	1					1	1	20	1	0.0003
Zanthoxylum chalybeum					1	1	1	20	1	0.0003

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.

Corrected counts multiply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-40
RAW VEGETATION SAMPLING DATA FROM TRANSECT 10
WITH RELATIVE FREQUENCY AND RELATIVE ABUNDANCE

SPECIES NAME	SAMPLE PLOTS					Total No.of Individuals	No. of Plots where found	Relative Frequency (%)	Corrected Counts	Relative Abundance (%)
	1	2	3	4	5					
HERBS										
Cassia mimosoides		1				1	1	20	2000	1.0
Crebbia sp.		1				1	1	20	2000	1.0
Emilia coccines			1	2		3	2	40	6000	3.1
Eriosema sp.				3		3	1	20	6000	3.1
Euphorbia hirta					1	1	1	20	2000	1.0
Euphorbia sp. purple					1	1	1	20	2000	1.0
Euphorbia sp. not pink		1				1	1	20	2000	1.0
Euphorbia spicata					2	2	1	20	4000	2.1
Heliotropium strigosum	1					1	1	20	2000	1.0
Ipomoea sp.				1		1	1	20	2000	1.0
Justicia exigua				2		2	1	20	4000	2.1
Justicia spicata					6	6	1	20	12000	6.2
Leucas martinicensis			1			1	1	20	2000	1.0
Odenlandia sp.					1	1	1	20	2000	1.0
Polycarpea sp.				1		1	1	20	2000	1.0
Polygala amboniensis				1	1	2	2	40	4000	2.1
Sida sp.	1					1	1	20	2000	1.0
Spermacoce sp. small leaves		2				2	1	20	4000	2.1
Spermacoce sp. large lvs		1				1	1	20	2000	1.0
Tragia furialis	1					1	1	20	2000	1.0
Waltheria sp.	2					2	1	20	4000	2.1
Zornia glochidiata				1		1	1	20	2000	1.0
GRASSES										
Brachiaria sp. hairy					1	1	1 -	20	2000	1.0
Eragrostis panicoides		2				2	1	20	4000	2.1
Eragrostis patiens				2		2	1	20	4000	2.1
Heteropogon contortus	6		A			6	1	20	12000	6.2
Hyparrhenia sp.	10	10	3			23	3	60	46000	23.7
Hyparrhenia rufa	9	8			2	19	3	60	38000	19.5
Microchloa sp.		2				2	1	20	4000	2.1
Panicum maximum					1	1	1	20	2000	1.0
Setaria broad leaves					1	1	1	20	2000	1.0
Sporobolus panicoides				2		2	1	20	4000	2.1
SHRUBS						0				
Bridelia cathartica	2			1		3	2	40	300	0.15
Combretum adenogonium	2	5		4	2	13	4	80	1300	0.67
Combretum constrictum		1				1	1	20	100	0.05
Combretum molle					1	1	1	20	100	0.05
Combretum padioides				1		1	1	20	100	0.05
Commiphora africana			1	1		2	2	40	200	0.10
Crossopteryx febrifuga				2		2	1	20	200	0.10
Dichrostachys cinerea		3		1		4	2	40	400	0.21
Harrisonia abyssinica		1			1	2	2	40	200	0.10
Lippia sp.		1				1	1	20	100	0.05
Markhamia obtusifolia		2				2	1	20	200	0.10
Maytenus holstii	3					3	1	20	300	0.15
Ochna sp.			1			1	1	20	100	0.05
Pericopsis angolensis	2		1			3	2	40	300	0.15
Sterculia africana	2					2	1	20	200	0.10
Terminalia sericea				1		1	1	20	100	0.05
Vismia sp.	1					1	1	20	100	0.05
Ziziphus mucronata			1			1	1	20	100	0.05
TREES										
Commiphora campestris		1				1	1	20	1	0.0005
Dalbergia melanoxylon	1	1				2	2	40	2	0.0010
Ozoroa insignis		2				2	1	20	2	0.0010
Vepris glomerata			1			1	1	20	1	0.0005

Notes: "A" indicates 70 or more individuals. In calculations, "A" was assumed to equal 70.
Corrected counts muliply the total number of individuals of a species in the smaller plots (herbs, grasses, shrubs) by a correction factor to allow for comparison with the larger (tree) plot, and calculation of relative abundance within the entire transect. Herb and grass counts were multiplied by a correction factor of 2000, shrubs by 100.

TABLE 4-41
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE DWARF *ACACIA DREPANOLOBIUM* WOODED GRASSLAND VEGETATION CATEGORY: DATA FROM TRANSECTS 1 (PLOTS 4 TO 8) AND 4 (PLOTS 2 TO 8)

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
HERBS		
Acacia drepanolobium	14.29	0.1
Blepharis longifolia	14.29	0.2
Blepharis maderaspatensis	14.29	0.1
Cassia mimosoidea	57.14	0.9
Chlorophytum sp.	57.14	1.0
Commelina bengalensis	14.29	0.1
Corchorus fascicularis	14.29	0.1
Craterostigma plantagineum	28.57	0.3
Cyanotis sp.cf. barbnata	14.29	0.1
Dichrostachys cinerea	14.29	0.1
Dicoma anomala	28.57	0.3
Euphorbia sp.	14.29	0.1
Gomphreana celasioides	14.29	0.1
Hibiscus sp.	14.29	0.1
Ipomoea albinervia	14.29	0.1
Ipomoea plebeia ssp.africana	14.29	0.1
Justicia betonica	14.29	0.4
Justicia sp.	14.29	0.3
Lannea humilis	14.29	0.1
Leucas martinicensis	14.29	0.3
Meremia medium	14.29	0.1
Ormocarpum trichocarpum	14.29	0.1
Oxygonum sinuatum	14.29	0.1
Sida cordifolia	14.29	0.1
Sida sp.	28.57	0.4
Spermacoce congensis	14.29	0.1
Waltheria indica	14.29	0.1
Zornia glochidiata	28.57	0.3
GRASSES		
Andropogon sp.	14.29	0.1
Aristida adoensis	14.29	0.5
Aristida sp.	14.29	0.2
Brachiaria sp. (hairy)	57.14	16.6
Chloris sp.	14.29	0.1
Dactyloctenium aegyptium	14.29	0.2
Dichathium sp.	28.57	0.9
Digitaria milanjiana	14.29	0.4
Eragrostis ?grey	14.29	0.3
Eragrostis sp.	14.29	0.1
Heteropogon contortus	42.86	23.1
Hyparrhenia rufa	28.57	1.2
Hyparrhenia small	100.00	27.1
Microlepis sp.	42.86	8.7
Sporobolus sp.	14.29	0.1
Urochloa cf.ochinolaenoides	100.00	13.1
SHRUBS		
Acacia drepanolobium	85.71	0.12
Bridellia cathartica ssp.melanthesioides	14.29	0.01
Catunaregan spinosa	14.29	0.01
Combretum adenogonium	85.71	0.10
Combretum molle	57.14	0.03
Combretum sp. liana	14.29	0.01
Commiphora africana	14.29	0.01
Commiphora sp. (Scented)	14.29	0.01
Crossopteryx febrifuga	28.57	0.01
Dalbergia melanoxylon	42.86	0.04
Dichrostachys cinerea	28.57	0.01
Grewia discolor	14.29	0.01
Harrisonia abyssinica	14.29	0.01
Lannea mossambicensis	42.86	0.03
Lannea schimperii	14.29	0.01
Lannea sp.	14.29	0.01
Olax sp.	14.29	0.01
Ormorcarpum trichocarpum	57.14	0.04
Piliostigma thoningii	28.57	0.02
Rhoicissus sp.	14.29	0.01
Senna singuena	42.86	0.04
Sida sp.	28.57	0.02
Solanum goetzii	14.29	0.01
Ziziphus mucronata	14.29	0.01
TREES		
Acacia tortilis	14.29	0.0001
Albizia petersiana	14.29	0.0001
Commiphora sp.	14.29	0.0001
Lannea schweinfurthii	14.29	0.0001
Ziziphus mucronata	14.29	0.0001

[1] Extremely abundant species (>70 individuals/plot) were reported as "A" (Abundant) in the field. For the purposes of calculation, these counts were assumed to be 70, which may result in an underestimation of abundance.

TABLE 4-42
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE *COMBRETUM* COPPICING OPEN BUSHLAND VEGETATION CATEGORY:
DATA FROM TRANSECT 4 (PLOTS 9 AND 10)

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
HERBS		
Cassia mimosoidea	50	1.2
Evolvulus alsinoides	100	1.2
Heliotropium strigosum	50	0.6
Indigofera cissalis	50	0.6
Indigofera spicata	100	2.4
Justicia exigua	50	1.8
Justicia spicata	50	0.6
Oxygonum sinuatum	50	1.2
Tephrosia pumila	50	0.6
GRASSES		
Hyparrhenia rufa	50	1.2
Hyparrhenia small	50	41.8
Loudetia arundinacea	50	3.6
Urochloa ochinolaenoides	50	41.8
SHRUBS		
Bridellia cathartica	50	0.03
Combretum adenogonium	50	0.09
Combretum molle	50	0.09
Combretum padioides	50	0.03
Commiphora africana	50	0.12
Commiphora sp. Scented 3-leaved	50	0.03
Crossopteryx febrifuga	50	0.03
Dombeya kirkii	50	0.03
Hymenodictyon parvifolium	50	0.03
Indigofera sp.	50	0.03
Lannea mossambicensis	50	0.30
Senna singuena	50	0.03
Solanum incanum	50	0.30
Sterculia africana	50	0.03
Zanthoxylum chalybeum	50	0.24
TREES		
Grewia conocarpa	50	0.0003
Lannea discolor	50	0.0003
Tamarindus indica	50	0.0003

TABLE 4-43
SUMMARY OF MEAN TREE DATA FROM TRANSECT 4

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (m)
Albizia petersiana	15	14	4
Balanites aegypticum	23	7	4
Grewia conocarpa	25	7	3
Lannea discolor	15	6	5
Lannea schweinfurthii	60	25	10
Tamarindus indica	30	10	5
Ziziphus mucronata	25	8	3

TABLE 4-44
SUMMARY OF MEAN TREE DATA FROM TRANSECT 5

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (m)
Annona senegalensis	11	4	1
Combretum padioides	42	22	10
Dalbergia melanoxylon	14	8	4
Lannea sp. (pinnate leaves)	28	4	1
Pericopsis angolensis	28	7	2
Strychnos sp.	26	8	1
Ziziphus mucronata	35	18	6

TABLE 4-45
SUMMARY OF MEAN TREE DATA FROM TRANSECT 6

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (m)
Acacia nilotica	6	12	3
Combretum adenogonium	11	5	1
Commiphora africana	30	10	7
Lannea sp.	15	3	1
Ozoroa insignis	20	5	1
Pericopsis angolensis	26	5	2
Phyllanthus sp.	6	12	3
Senna singuena	5	10	3
Thilachium sp.	14.5	6.5	2
Ziziphus mucronata	6	12	1

TABLE 4-46
SUMMARY OF MEAN TREE DATA FROM TRANSECT 7

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (m)
Acacia etbaica	60	12	4
Albizia harveyi	16	4	1
Combretum zeyheri	30	5	8
Lannea sp.	27	10	4
Ozoroa insignis	20	4	4
Parinari curatellifolia	25	8	4
Pericopsis angolensis	36	8	4
Pseudolachynostylis maproneufolia	12	10	3
Sclerocarya birrea	23	7	2
Senna singuena	13	5	4

TABLE 4-47
SUMMARY OF MEAN TREE DATA FROM TRANSECT 8

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (m)
Commiphora sp. 3-leaved	6	18	3
Dalbergia melanoxylon	12	3	3
Rhus natalensis	12	5	3
Xerroderis stuhlmanii	12	5	2
Zanthoxylum chalybeum	6	16	2

TABLE 4-48
SUMMARY OF TREE DATA FROM TRANSECT 9

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (m)
Ozoroa insignis	20	6	3
Zanthoxylum chalybeum	25	8	5

TABLE 4-49
SUMMARY OF TREE DATA FROM TRANSECT 10

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (m)
Commiphora campestris	17	6	2
Dalbergia melanoxylon	22	8	4
Ozoroa insignis	13	6	2
Vepris glomerata	15	8	4

TABLE 4-50
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE DISTURBED *COMBRETUM* OPEN SHRUBLANDS VEGETATION CATEGORY:
DATA FROM TRANSECTS 5, 6, 7, 8, 9, 10

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
HERBS		
Abutilion sp.	1.67	0.04
Acanthospermum hispidum	5.00	0.28
Achyranthes aspera	1.67	0.04
Achyranthes sp.	1.67	0.04
Ageratum conyzoides	3.33	0.32
Amaranthus hybridus	5.00	0.12
Asparagus africana	1.67	0.04
Aspilia sp.	5.00	0.12
Aspilia sp. (yellow flowers)	3.33	0.20
Astripomoea malvacea	1.67	0.12
Berkhea sp. composite	1.67	0.04
Bidens pilosa	1.67	0.08
Cassia mimosoides	33.33	2.06
Chlorophytum sp.	1.67	0.04
Cissampelos pumila	1.67	0.04
Commelina bengalensis	1.67	0.04
Commelina sp.	1.67	0.16
Commelina sp. Yellow flowers	1.67	0.04
Commiphora africana	1.67	0.04
Composite (yellow bracts)	1.67	0.12
Composite sp. big lvs	3.33	0.20
Crabbea velutina.	10.00	0.32
Crebbia sp.	6.67	0.20
Cyamopsis sp.	1.67	0.12
Cyanotis sp.	5.00	0.28
Dicoma anomala	1.67	0.04
Dyschoriste sp.	6.67	0.47
Emilia coccines	25.00	1.07
Eriosema sp.	1.67	0.12
Euphorbia sp. red	3.33	0.16
Euphorbia hirta	15.00	1.15
Euphorbia hyssopifolia	3.33	0.08
Euphorbia sp. purple	1.67	0.04
Euphorbia sp. not pink	1.67	0.04
Euphorbia sp. (red)	1.67	0.04
Euphorbia spicata	1.67	0.08
Evolvulvus alsinoides	5.00	0.12
Gardenia sp.	1.67	0.40
Gomphreana celasioides	1.67	0.36
Harrisonia abyssinica	3.33	0.16
Heliotropium strigosum	3.33	0.08
Hibiscus ethiopicus	1.67	0.04
Hibiscus sp.	1.67	0.04
Hypoestes forskalii	3.33	0.24
Indigofera cissalis	1.67	0.12
Indigofera fisalis	1.67	0.04
Indigofera sp.	6.67	0.32
Indigofera spicata	5.00	0.12
Ipomoea sp yellow flowers	1.67	0.04
Ipomoea sp.	8.33	0.20
Ipomoea sp. (pinkish flower)	1.67	0.04
Justicia spicata	1.67	0.12
Justicia bracteata	3.33	0.08
Justicia exigua	8.33	0.32

TABLE 4-50
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE DISTURBED *COMBRETUM* OPEN SHRUBLANDS VEGETATION CATEGORY: DATA FROM TRANSECTS 5, 6, 7, 8, 9, 10

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
Justicia sp.	6.67	0.32
Justicia spicata	3.33	0.28
Launaea comuta	1.67	0.16
Leucas martinicensis	13.33	0.32
Meremia medium	1.67	0.08
Monechma subsessile	11.67	0.63
Ocimum americana	1.67	0.04
Odenlandia sp.	13.33	0.67
Oxalis sp.	1.67	0.08
Oxygonum sp.	3.33	0.08
Oxygonum sinuatum	6.67	0.16
Pandiaka sp.	6.67	0.20
Pavonia sp.	1.67	0.04
Phyllanthus sp.	21.67	1.34
Piliostigma thoningii	1.67	0.04
Polycarpaea eriantha	1.67	0.32
Polycarpaea sp.	1.67	0.04
Polycarpon sp.	1.67	0.04
Polygala amboniensis	6.67	0.24
Polygala erioptera	6.67	0.36
Portulaca oleracea	1.67	0.04
Rhinacanthus gracilis	1.67	0.28
Secamone sp.	5.00	0.16
Senna senguena	1.67	0.04
Sida sp.	26.67	1.03
Sida sp. (grey)	1.67	0.20
Sida sp. (purple)	1.67	0.24
Sida sp.(a)	5.00	0.28
Solanum incanum	3.33	0.08
Solanum nigram	1.67	0.04
Spermacoce sp. small leaves	1.67	0.08
Spermacoce dibracteate	3.33	0.12
Spermacoce natalensis	10.00	0.40
Spermacoce sp.	6.67	0.20
Spermacoce sp. large lvs	1.67	0.04
Spermacoce sphaerostigma	1.67	0.08
Spermacoce subvulgata	5.00	0.32
Stylosanthes sp.	1.67	0.08
Tephrosia nana	11.67	0.47
Tephrosia pumila	1.67	0.04
Tephrosia sp.	1.67	0.16
Tragia furialis	8.33	0.24
Tridax procumbens	1.67	0.04
Triumfetta rhomboidea	3.33	0.20
Triumfetta sp.	6.67	0.32
Vernonia cinerascensis	1.67	0.04
Vernonia posckeana	1.67	1.19
Vernonia sp.	3.33	0.12
Vernonia unduta	11.67	0.71
Waltheria sp.	5.00	0.32
Zornia glochidiata	10.00	0.36

TABLE 4-50
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE DISTURBED *COMBRETUM* OPEN SHRUBLANDS VEGETATION CATEGORY:
DATA FROM TRANSECTS 5, 6, 7, 8, 9, 10

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
GRASSES		
Alloteropsis cimicina	3.33	0.12
Andropogon africanus	1.67	0.08
Andropogon ascinodis	3.33	0.08
Andropogon fastigiatus	16.67	15.31
Andropogon sp.	1.67	0.04
Aristida adoensis	1.67	0.24
Aristida adscensionis	1.67	0.04
Aristida sp.	1.67	0.04
Bathriochloa insculpta	1.67	2.77
Beckeropsis sp.	15.00	0.75
Brachiaria sp. (hairy)	10.00	0.55
Brachiaria sp. (glabrous)	1.67	0.16
Brachyaria sp.	1.67	0.04
Chloris pachnothrix	15.00	3.68
Chloris mossambicensis	1.67	0.12
Chloris sp.	3.33	0.20
Cyanodon dactyroptenium	1.67	0.04
Dactyroctenium sp.	1.67	0.04
Dicanthium sp.	3.33	0.24
Eleusine indica ssp. africana	1.67	0.04
Eleusine sp.	3.33	0.24
Eragrostis cilianensis	1.67	0.12
Eragrostis exasperata	5.00	0.24
Eragrostis impatiens	3.33	0.32
Eragrostis panicoides	1.67	0.08
Eragrostis patiens	3.33	0.12
Eragrostis sp.	5.00	0.16
Eriochloa fatmensis	1.67	0.04
Eulalia aurea	1.67	0.04
Heteropogon contortus	26.67	5.97
Hyparrhenia anainesa	1.67	0.04
Hyparrhenia schimperi	1.67	0.04
Hyparrhenia sp.	23.33	11.75
Hyparrhenia collina	1.67	0.04
Hyparrhenia madaropa	5.00	0.20
Hyparrhenia rufa	40.00	8.47
Hyparrhenia small	6.67	8.70
Hyparrhenia sp.	13.33	1.58
Loudetia kagerensis	1.67	0.08
Microchloa kunthi	10.00	1.70
Microchloa sp.	3.33	0.20
Microlepis sp.	1.67	2.77
Panicum atrosanguineum	5.00	0.79
Panicum brevifolium	1.67	0.04
Panicum maximum	8.33	0.28
Pennisetum sp.	1.67	0.08
Rotboellia pser.	1.67	0.04
Setaria broad leaves	1.67	0.04
Setaria orthosticha	1.67	0.08
Setaria pumila	10.00	1.38
Setaria sp.	3.33	0.20
Setaria sp. (big leaves)	6.67	0.28
Sporobolus panicoides	1.67	0.08
Sporobolus sp.	11.67	0.91
Urochloa echinolaenoides	8.33	2.25

TABLE 4-50
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE DISTURBED *COMBRETUM* OPEN SHRUBLANDS VEGETATION CATEGORY:
DATA FROM TRANSECTS 5, 6, 7, 8, 9, 10

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
SHRUBS		
Abrus schimperii	1.67	0.002
Acacia drepanolobium	1.67	0.004
Acacia nilotica	3.33	0.004
Acacia tortilis	1.67	0.002
Albizia harveyi	1.67	0.002
Albizia petersiana	1.67	0.002
Annona senegalensis	5.00	0.006
Asparagus africana	5.00	0.006
Brachystegia spiciformis	1.67	0.004
Bridellia cathartica	18.33	0.049
Canthium burttii	1.67	0.002
Cassia singuena	5.00	0.006
Catunaregan spinosa	13.33	0.018
Combretum adenogonium	58.33	1.568
Combretum constrictum	10.00	0.012
Combretum molle	35.00	0.085
Combretum padioides	6.67	0.012
Combretum psiodioides	6.67	0.008
Combretum sp. climbing liana	3.33	0.008
Combretum sp. reddish brown fruit	1.67	0.004
Combretum sp. scandent shrub	1.67	0.002
Combretum sp. with purple fruits	3.33	0.010
Combretum sp.softly hairy lvs pressed	5.00	0.006
Combretum zeyheri	1.67	0.002
Commiphora africana	33.33	0.045
Commiphora schimperi	1.67	0.004
Commiphora sp.	1.67	0.008
Commiphora sp. scented	1.67	0.024
Crossopteryx febrifuga	20.00	0.040
Dalbergia melanoxylon	11.67	0.014
Dalbergia nitidula	3.33	0.004
Dichrostachys cinerea	15.00	0.044
Diplorrhynchus condilocarpon	1.67	0.002
Erythrococca kirkii	1.67	0.002
Euclea natalensis	1.67	0.002
Fadogia sp.	1.67	0.002
Gardenia jovis-tonantis	1.67	0.002
Grewia flavescens	1.67	0.004
Harrisonia abyssinica	25.00	0.045
Hymenodictyon parvifolium	1.67	0.004
Lannea humilia	1.67	0.008
Lannea sp.	3.33	0.010
Lannea sp. 9-leaflets	3.33	0.004
Lannea sp. large leaves	1.67	0.002
Lannea sp. pinnate lvs	3.33	0.004
Leonotis sp.	1.67	0.002
Lippia sp.	1.67	0.002
Margaritaria discoides	10.00	0.022
Markhamia obtusifolia	10.00	0.030
Maytenus holstii	18.33	0.040
Ochna sp.	3.33	0.004
Olax sp.	3.33	0.004
Olea europaea ssp. africana	1.67	0.002
Olea sp.	1.67	0.002
Onchoba spinosa	1.67	0.002

TABLE 4-50
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE DISTURBED *COMBRETUM* OPEN SHRUBLANDS VEGETATION CATEGORY:
DATA FROM TRANSECTS 5, 6, 7, 8, 9, 10

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
Ormorcarpum trichocarpum	1.67	0.002
Parinari curatellifolia	1.67	0.002
Pavetta schumanniana	1.67	0.002
Pericopsis angolensis	13.33	0.020
Phyllanthus reticulata	1.67	0.002
Phyllanthus welwitschianus	5.00	0.006
Pseudolachynostylis maproneufolia	6.67	0.010
Rhus natalensis	3.33	0.008
Senna obtusifolia	1.67	0.002
Senna singuena	13.33	0.016
Sida cordifolia	1.67	0.006
Solanum incanum	6.67	0.057
Sterculia africana	3.33	0.006
Tamarindus indica	1.67	0.002
Tapiphylum burnettii	1.67	0.002
Terminalia sericea	5.00	0.006
Thilachium sp.	1.67	0.002
Triumfetta rhomboidea	1.67	0.002
Triumfetta sp.	1.67	0.016
Vernonia bellinghanii	1.67	0.002
Vismia orientalis	1.67	0.002
Vismia sp.	3.33	0.006
Vitex doniana	1.67	0.002
Waltheria indica	3.33	0.026
Xeroderris stuhlmanii	3.33	0.006
Zanthoxylum chalybeum	1.67	0.002
Ziziphus mucronata	1.67	0.002
TREES		
Acacia etbaica	3.33	0.00004
Acacia nilotica	1.67	0.00004
Albizia harveyi	1.67	0.00002
Annona senegalensis	1.67	0.00002
Brachystegia spiciformis	1.67	0.00002
Combretum adenogonium	1.67	0.00002
Combretum padioides	3.33	0.00006
Combretum zeyheri	3.33	0.00004
Commiphora africana	1.67	0.00002
Commiphora campestris	1.67	0.00002
Commiphora sp. 3-leaved	1.67	0.00002
Dalbergia melanoxylon	6.67	0.00008
Lannea sp.	5.00	0.00006
Lannea sp. (pinnate leaves)	1.67	0.00002
Ozoroa insignis	6.67	0.00010
Parinari curatellifolia	1.67	0.00002
Pericopsis angolensis	10.00	0.00012
Phyllanthus sp.	1.67	0.00002
Pseudolachynostylis maproneufolia	1.67	0.00002
Rhus natalensis	1.67	0.00004
Sclerocarya birrea	3.33	0.00004
Senna singuena	3.33	0.00004
Strychnos sp.	1.67	0.00002
Thilachium sp.	1.67	0.00004
Vepris glomerata	1.67	0.00002
Xerroderis stuhlmanii	1.67	0.00002
Zanthoxylum chalybeum	3.33	0.00004
Ziziphus mucronata	3.33	0.00004

[1] Extremely abundant species (>70 individuals/plot) were reported as "A" (Abundant) in the field. For the purposes of calculation, these counts were assumed to be 70, which may result in an underestimation of abundance.

TABLE 4-51
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE CONTROL AREA
DATA FROM TRANSECTS 2 AND 3

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
HERBS		
Albizia petersiana (seedlings)	36.36	3.98
Asparagus africana	18.18	2.32
Aspilia sp. purple flowers	27.27	15.90
Barleria boehmii	9.09	0.33
Blepharis maderaspatensis ssp. rubiifolium	45.45	10.27
Cassia mimosoides	27.27	0.99
Chlorophytum sp.nov.	36.36	3.98
Cissampelos sp.	18.18	0.66
Combretum zeyheri	9.09	0.66
Commelina bengalensis	9.09	0.66
Crabbea velutina	18.18	0.66
Cyanotis sp.	9.09	0.66
Dalbergia melanoxylon	9.09	0.33
Dioscorea zanzibarensis	9.09	0.33
Dychoriste sp. nov.	9.09	0.33
Emilia coccines	27.27	3.98
Euphorbia tricauli	9.09	0.66
Haplocoelom foliolosum	9.09	0.33
Hibiscus sp.	27.27	4.31
Hibiscus sp. Lobed leaves	9.09	0.66
Indigofera spicata	9.09	0.33
Ipomoea involucrata var. burttii	27.27	1.99
Justicia exigua	27.27	1.99
Justicia forskerlii	18.18	0.66
Justicia sp. (bracteata)	9.09	0.66
Kohautia herbacea	9.09	0.66
Lannea humilis	18.18	0.66
Leucas martinicensis	18.18	0.66
Plectranthus sp.	9.09	0.33
Polycarpea eriantha	9.09	0.33
Secamone sp.	9.09	0.33
Spermacoce subvulgata	18.18	0.66
Vernonia sp.	18.18	0.66
Vernonia undata	27.27	5.30
GRASSES		
Andropogon sp.	18.18	1.66
Aristida adoensis	27.27	3.31
Brachiaria sp. hairy	9.09	0.33
Hyparrhenia ruffa	45.45	3.98
Hyparrhenia sp.	27.27	3.98
Melinichloa sp.	9.09	0.33
Panicum brevifolium	18.18	3.64
Panicum festum	9.09	0.33
Panicum maximum	18.18	2.32
Setaria pumila	18.18	1.99
Setaria sp.	18.18	1.33
Setaria spharcelata var. aurea	27.27	2.65
Sporobolus sp.	9.09	3.64
SHRUBS		
Abrus schimperii	9.09	0.07
Acacia brevispica	9.09	0.02
Albizia petersiana	18.18	0.10
Bridelia cathartica ssp. melanthesoides	9.09	0.02
Canthium sp.	9.09	0.02
Combretum molle	45.45	0.17
Combretum zeyheri	72.73	0.31
Commiphora africana	27.27	0.07

TABLE 4-51
RELATIVE FREQUENCY AND RELATIVE ABUNDANCE OF PLANT SPECIES IN THE CONTROL AREA
DATA FROM TRANSECTS 2 AND 3

SPECIES NAME	Relative Frequency (%)	Relative Abundance[1] (%)
Commiphora edulis	9.09	0.02
Cordia sp.	9.09	0.02
Croton dichogamus	18.18	0.05
Croton scheffleri	18.18	0.03
Dalbergia melanoxylon	9.09	0.02
Dichrostachys cinerea	9.09	0.13
Grewia bicolor	36.36	0.08
Grewia conocarpa	18.18	0.03
Grewia stuhlmannii	9.09	0.02
Haplocoelom foliolosum	27.27	0.05
Hymenodictyon parvifolium ssp. scabrum var. s	36.36	0.13
Markhamia obtusifolia	81.82	0.81
Omorcarpum trichocarpum	9.09	0.02
Rhinacanthus gracilis	45.45	0.63
Sterculia africana	27.27	0.05
Strophanthus eminii	9.09	0.03
Strychnos mitis Sp.	27.27	0.08
Strychnos sp. (unmatched)	18.18	0.03
Terminalia sericea	9.09	0.02
Tricalysia sp.	36.36	0.13
Vangueria sp.	9.09	0.03
Vepris glomerata	27.27	0.05
Zanthoxylum chalybeum	9.09	0.02
TREES		
Acacia polyacantha	9.09	0.0002
Albizia petersiana	45.45	0.0017
Combretum molle	9.09	0.0002
Combretum zeyheri	18.18	0.0003
Commiphora eminii	9.09	0.0002
Dalbergia melanoxylon	9.09	0.0002
Dichrostachys cinerea	9.09	0.0002
Entandrophragma bussei	9.09	0.0002
Grewia bicolor	18.18	0.0003
Grewia conocarpa	9.09	0.0002
Haplocoelom foliolosum	27.27	0.0008
Hymenodictyon parvifolium	18.18	0.0003
Manilkara mochsia	18.18	0.0003
Margaritaria discoides	18.18	0.0003
Markhamia obtusifolia	9.09	0.0002
Olax sp.	9.09	0.0002
Ozoroa insignis	9.09	0.0002
Strychnos sp.	9.09	0.0002
Thilachium africanum	9.09	0.0002
Vangueria sp.	9.09	0.0002

[1] Extremely abundant species (>70 individuals/plot) were reported as "A" (Abundant) in the field. For the purposes of calculation, these counts were assumed to be 70, which may result in an underestimation of abundance.

TABLE 4-52
SUMMARY OF MEAN TREE DATA
FROM TRANSECTS 2 AND 3 (CONTROL AREA)

TREE SPECIES	DBH (cm)	HEIGHT (m)	CROWN COVER (% of plot)
Acacia polyacantha	15	5	5
Albizia petersiana	20.1	9.4	4.7
Combretum molle	25	7	5
Combretum zeyheri	16.5	4.5	2.5
Commiphora eminii	40	15	10
Dalbergia melanoxylon	10	5	2
Dichrostachys cinerea	12	5	3
Entandrophragma bussei	40	20	5
Grewia bicolor	12.5	8	3.5
Grewia conocarpa	16	8	4
Haplocoelom foliolosum	15	6.9	4.1
Hymenodictyon parvifolium	11	6.5	1.5
Manilkara mochsia	20	5	3
Margaritaria discoides	10	6	2.5
Markhamia obtusifolia	10	6	2
Olax sp.	10	5	1
Ozoroa insignis	10	5	3
Strychnos sp.	30	4	0
Thilachium africanum	11	7	2
Vangueria sp.	10	6	2

TABLE 4-53
METALS IN PLANT TISSUE SAMPLED AT TRANSECT 7

PARAMETER	UNIT	DETECTION LIMIT	SPECIES NAME AND REPLICATE NUMBER																			
			Aspilia sp.				*Commiphora africana*				*Grewia sp.*				*Heteropogon sp.*				*Lonchocarpus cappasa*			
			1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]
Aluminum	µg/g	10	70	224	175	156	28	40	32	33	77	55	63	65	229	277	461	322.3	27	40	72	46
Antimony	µg/g	2	3	2	4	3	4	3	4	3.7	3	3	2	2.7	< 2	< 2	< 2	1	< 2	< 2	< 2	1.0
Arsenic	µg/g	8	< 8	< 8	< 8	4	< 8	< 8	< 8	4	< 8	< 8	< 8	4	< 8	< 8	< 8	4.0	9	< 8	< 8	6
Barium	µg/g	0.1	114	68.8	95.2	92.7	92.3	104	130	108.8	117	133	117	122.3	87.9	83.2	85.7	85.6	38.5	30.7	29.1	32.8
Beryllium	µg/g	0.1	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05
Bismuth	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Cadmium	µg/g	0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1	< 0.2	0.3	0.2	0.2	< 0.2	< 0.2	< 0.2	0	< 0.2	< 0.2	< 0.2	0.1
Calcium	µg/g	40	15400	16400	14400	15400	13000	14700	16800	14833	11400	13900	12100	12467	2380	1820	2050	2083	12500	10700	10100	11100
Chromium	µg/g	0.2	1.1	1.6	1.5	1.4	0.8	0.8	0.8	0.8	16.6	2	1.3	6.6	2.7	4.5	3.9	3.7	0.3	0.5	0.6	0.5
Cobalt	µg/g	0.3	0.5	0.4	0.5	0.47	< 0.3	0.3	0.5	0.3	1.1	0.8	0.8	0.9	0.4	0.7	0.7	0.6	4.4	4	3.8	4.1
Copper	µg/g	0.1	15.3	14	15.9	15.1	5.7	5.4	5.8	5.6	11.2	13.5	11.1	11.9	3.7	3.2	3.4	3	9.5	9.3	9.9	9.6
Iron	µg/g	10	159	584	455	399	107	87.9	89.4	95	233	149	143	175	393	573	781	582	87.8	111	174	124
Lead	µg/g	2	< 2	< 2	2	1.3	< 2	2	2	2	2	2	2	2	< 2	2	< 2	1	3	3	< 2	2
Magnesium	µg/g	10	4650	4280	4180	4370	3340	4010	3840	3730	4800	4530	4530	4620	2260	1570	1820	1883	6010	4550	3950	4837
Manganese	µg/g	0.2	163	129	150	147	142	163	234	180	596	629	557	594	147	116	144	136	5810	3660	3050	4173
Mercury	µg/g	0.05	< 0.05	< 0.05	< 0.05	0.025	< 0.05	< 0.05	< 0.05	0.025	< 0.05	< 0.05	< 0.05	0.025	< 0.05	< 0.05	< 0.05	0.0	< 0.05	< 0.05	< 0.05	0.025
Molybdenum	µg/g	0.4	1.8	2.3	2	2.0	0.5	0.8	0.7	0.7	0.4	0.5	< 0.4	0.4	< 0.4	< 0.4	< 0.4	0.2	< 0.4	< 0.4	< 0.4	0.2
Nickel	µg/g	0.8	1.5	1.4	2.1	1.7	1.4	1.2	1.7	1.4	5.1	6.1	5.3	5.5	2	2.3	2.2	2	8.7	9.3	11.8	9.9
Phosphorus	µg/g	4	3610	3340	3920	3623	3410	3040	3380	3277	1890	2020	1820	1910	826	686	820	777	1580	1530	1770	1627
Potassium	µg/g	40	25600	25900	26100	25867	12400	12500	11600	12167	16000	16700	16700	16467	9290	7540	8560	8463	6920	7380	10200	8167
Selenium	µg/g	3	< 3	< 3	< 3	2	< 3	< 3	< 3	2	< 3	< 3	< 3	2	< 3	< 3	< 3	1.5	< 3	< 3	< 3	2
Silver	µg/g	1	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	1	< 1	< 1	< 1	0.5
Sodium	µg/g	10	< 10	31	38	25	60	27	19	35	37	37	13	29	33	13	24	23	16	13	24	18
Strontium	µg/g	0.1	166	162	153	160	139	161	182	161	159	176	152	162	41.1	34	37.1	37	136	122	119	126
Sulphur	µg/g	3	1500	1430	1530	1487	1170	1120	1230	1173	1240	1260	1290	1263	1070	849	1040	986	1690	1880	1950	1840
Tellurium	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1	< 2	< 2	< 2	1.0
Thallium	µg/g	2	2	< 2	< 2	1.3	< 2	3	< 2	1.7	2	2	< 2	1.7	< 2	< 2	< 2	1	< 2	< 2	< 2	1.0
Tin	µg/g	2	42	49	44	45	11	11	15	12	2	< 2	< 2	1	142	182	160	161	12	8	9	9.7
Titanium	µg/g	0.3	< 0.3	4.6	3.7	2.8	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	6.1	8.4	13.5	9.3	< 0.3	< 0.3	1.1	0.5
Vanadium	µg/g	0.3	0.4	1.6	1.5	1.2	< 0.3	0.3	0.3	0.3	0.5	< 0.3	0.3	0.3	1	1.6	2.1	1.6	< 0.3	< 0.3	< 0.3	0.2
Zinc	µg/g	0.2	30.7	32.3	33.2	32.1	22.3	22.5	23.3	22.7	40.2	41.3	31.9	37.8	23.6	17.9	23.9	21.8	56.3	48.4	47.4	50.7
Zirconium	µg/g	0.3	0.3	0.8	0.5	0.5	0.3	0.3	< 0.3	0.3	< 0.3	< 0.3	< 0.3	0.2	0.4	< 0.3	0.6	0.4	< 0.3	< 0.3	< 0.3	0.2

[1]Averages calculated using 1/2 the detection limit where reported as "less than" (<)

TABLE 4-53
METALS IN PLANT TISSUE SAMPLED AT TRANSECT 7

PARAMETER	UNIT	DETECTION LIMIT	SPECIES NAME AND REPLICATE NUMBER																			
			Markhamia obtusifolia				*Phyllanthus suffretescens*				*Senna sp.*				*Setaria sphacelata*				*Tragia furialis*			
			1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]
Aluminum	µg/g	10	109	102	120	110	34	43	31	36	37	32	36	35	241	254	138	211	38	63	30	44
Antimony	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	3	< 2	< 2	1.7	< 2	< 2	3	1.7	2	3	< 2	2
Arsenic	µg/g	8	< 8	< 8	< 8	4	9	< 8	< 8	6	< 8	< 8	< 8	4	< 8	< 8	< 8	4	9	< 8	< 8	6
Barium	µg/g	0.1	37.4	31	35.2	34.5	66.5	70.2	79.4	72.0	75.3	121	98.2	98.2	78.9	89.7	92.3	87.0	207	219	241	222
Beryllium	µg/g	0.1	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05
Bismuth	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Cadmium	µg/g	0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1
Calcium	µg/g	40	9600	8790	9370	9253	10300	10900	11400	10867	9480	14900	12700	12360	3330	3980	4080	3797	19900	19500	18000	19133
Chromium	µg/g	0.2	1	0.9	1.1	1	0.6	0.7	0.7	0.67	0.9	0.6	1	0.8	3.6	6.4	3.8	4.6	0.8	0.8	0.6	0.73
Cobalt	µg/g	0.3	0.4	< 0.3	0.3	0.3	0.9	0.8	1.3	1.0	0.7	0.8	0.6	0.7	0.9	1	0.8	0.9	< 0.3	< 0.3	< 0.3	0.15
Copper	µg/g	0.1	10.1	9.5	9.9	9.8	7	6.6	7.6	7.1	3.3	3.5	3.5	3.4	3.5	3.6	3.1	3.4	4.6	4.4	6.1	5.0
Iron	µg/g	10	161	126	137	141	73.2	78.9	87.3	73	101	86.4	116	101	463	843	317	541	85.2	115	60.8	87
Lead	µg/g	2	< 2	< 2	2	1	< 2	2	3	2	3	< 2	3	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1.0
Magnesium	µg/g	10	3530	3410	3750	3563	3800	2590	3490	3293	2180	4040	2880	3033	1880	2060	2090	2010	3540	3410	3680	3543
Manganese	µg/g	0.2	728	705	698	710	1220	897	1280	1132	107	138	132	126	128	124	141	131	213	221	242	225
Mercury	µg/g	0.05	0.07	< 0.05	0.06	0.05	< 0.05	< 0.05	< 0.05	0.025	< 0.05	< 0.05	< 0.05	0.025	< 0.05	< 0.05	< 0.05	0.025	< 0.05	< 0.05	< 0.05	0.025
Molybdenum	µg/g	0.4	< 0.4	< 0.4	< 0.4	0.2	< 0.4	0.4	0.7	0.4	0.4	< 0.4	< 0.4	0.3	< 0.4	< 0.4	1.9	0.8	0.7	< 0.4	< 0.4	0.4
Nickel	µg/g	0.8	2.8	2.4	2.9	2.7	3.7	2.5	3.3	3.2	0.9	< 0.8	0.8	0.7	2	2	2.2	2.1	1	1.4	1.1	1.2
Phosphorus	µg/g	4	1490	1590	1580	1553	1670	1080	1440	1397	1050	1370	1200	1207	1350	1420	1680	1483	1590	1460	1440	1497
Potassium	µg/g	40	8370	8460	9160	8663	10600	6550	9630	8927	5630	9090	6880	7200	16700	15400	16000	16033	13400	13000	12200	12867
Selenium	µg/g	3	< 3	< 3	< 3	2	< 3	< 3	< 3	2	< 3	< 3	< 3	2	< 3	< 3	< 3	2	< 3	< 3	< 3	2
Silver	µg/g	1	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5
Sodium	µg/g	10	12	12	12	12	39	99	63	67	46	14	22	27	58	33	27	39	60	77	18	52
Strontium	µg/g	0.1	121	109	122	117	117	118	128	121	117	186	153	152	47.6	57.6	57.2	54	256	260	254	257
Sulphur	µg/g	3	1400	1450	1480	1443	1530	1140	1470	1380	1190	1670	1380	1413	848	868	867	861	1150	1120	1150	1140
Tellurium	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	3	1.7	< 2	< 2	< 2	1
Thallium	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Tin	µg/g	2	3	3	< 2	2	< 2	< 2	< 2	1	8	11	9	9	104	114	145	121	< 2	< 2	< 2	1
Titanium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	8.5	8.4	4.1	7.0	< 0.3	< 0.3	< 0.3	0.2
Vanadium	µg/g	0.3	0.4	< 0.3	0.4	0.3	< 0.3	< 0.3	< 0.3	0.2	0.4	< 0.3	< 0.3	0.2	1.6	2.6	1	1.7	< 0.3	< 0.3	< 0.3	0.2
Zinc	µg/g	0.2	32.5	30.1	29.7	30.8	22.3	28.6	29.8	26.9	9.7	8.4	9.4	9.2	21.2	19.1	20.1	20.1	18.3	17.3	17.7	17.8
Zirconium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	0.3	< 0.3	0.8	0.4	< 0.3	< 0.3	< 0.3	0.2

[1] Averages calculated using 1/2 the detection limit where reported as "less than" (<)

TABLE 4-54
METALS IN PLANT TISSUE SAMPLED AT TRANSECT 9

PARAMETER	UNIT	DETECTION LIMIT	SPECIES NAME AND REPLICATE NUMBER											
			Barleria sp.				*Combretum adenogonium*				*Combretum molle*			
			1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]
Aluminum	µg/g	10	75	89	75	80	42	52	38	44	57	61	87	68
Antimony	µg/g	2	3	2	3	3	2	2	< 2	2	< 2	< 2	3	2
Arsenic	µg/g	8	< 8	< 8	10	6	< 8	< 8	< 8	4	< 8	< 8	< 8	4
Barium	µg/g	0.1	225	219	291	245	34.7	36.7	33	35	34.3	30.2	35	33
Beryllium	µg/g	0.1	0.1	0.1	0.2	0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.1
Bismuth	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Cadmium	µg/g	0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1
Calcium	µg/g	40	24600	25300	35000	28300	11300	9280	9000	9860	12300	11000	13100	12133
Chromium	µg/g	0.2	1	1.1	1.1	1.1	0.7	1.5	0.6	0.9	1.2	1.7	1.4	1.4
Cobalt	µg/g	0.3	0.7	0.6	0.5	0.6	4.3	3.5	3.2	3.7	9.6	8.4	10.5	9.5
Copper	µg/g	0.1	8	8.3	8.9	8.4	5.3	3.5	3.5	4.1	4.9	4.1	5.2	4.7
Iron	µg/g	10	87.8	115	88.6	97.1	53.5	66.4	45	55.0	56.6	90.6	106	84.4
Lead	µg/g	2	3	< 2	< 2	2	< 2	3	< 2	2	2	2	< 2	2
Magnesium	µg/g	10	4490	4720	6620	5277	4330	4000	3720	4017	4760	3840	4760	4453
Manganese	µg/g	0.2	136	123	139	133	433	324	291	349	714	600	741	685
Mercury	µg/g	0.05	< 0.05	< 0.05	< 0.05	0.03	< 0.05	< 0.05	< 0.05	0.03	< 0.05	< 0.05	< 0.05	0.03
Molybdenum	µg/g	0.4	< 0.4	< 0.4	1.2	0.5	< 0.4	< 0.4	< 0.4	0.2	< 0.4	< 0.4	< 0.4	0.2
Nickel	µg/g	0.8	4.9	5.3	5.2	5.1	4	3.6	3.7	3.8	3.9	2.9	3.4	3.4
Phosphorus	µg/g	4	1050	1090	1070	1070	1100	1040	1040	1060	1000	832	1030	954
Potassium	µg/g	40	8810	10700	13200	10903	4820	4360	5230	4803	7670	6450	7910	7343
Selenium	µg/g	3	< 3	< 3	< 3	1.5	< 3	< 3	< 3	1.5	3	< 3	< 3	2.0
Silver	µg/g	1	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5
Sodium	µg/g	10	18	16	15	16.3	14	20	18	17.3	18	16	28	20.7
Strontium	µg/g	0.1	338	346	476	387	99.3	96.1	90	95	82.2	73.4	86.1	81
Sulphur	µg/g	3	862	870	937	890	937	916	891	915	895	747	912	851
Tellurium	µg/g	2	< 2	< 2	2	1.3	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Thallium	µg/g	2	< 2	2	< 2	1.3	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Tin	µg/g	2	11	10	6	9.0	6	4	6	5.3	2	4	< 2	2.3
Titanium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2
Vanadium	µg/g	0.3	0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	0.4	0.2
Zinc	µg/g	0.2	19.2	20.8	30.1	23	16.6	20.3	19	19	34.9	28.4	35.8	33
Zirconium	µg/g	0.3	< 0.3	< 0.3	0.6	0.3	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2

[1]Averages calculated using 1/2 the detection limit where reported as "less than" (<)

TABLE 4-54
METALS IN PLANT TISSUE SAMPLED AT TRANSECT 9

PARAMETER	UNIT	DETECTION LIMIT	SPECIES NAME AND REPLICATE NUMBER											
			Combretum psidioides				*Dalbergia melanoxylon*				*Justicia sp.*			
			1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]
Aluminum	µg/g	10	40	47	39	42	22	20	21	21	132	147	142	140
Antimony	µg/g	2	2	< 2	< 2	1	3	3	< 2	2	2	2	3	2
Arsenic	µg/g	8	< 8	< 8	< 8	4	< 8	< 8	< 8	4	10	< 8	8	7
Barium	µg/g	0.1	36.3	31.1	28.8	32	109	116	113	113	373	385	386	381
Beryllium	µg/g	0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.1	0.1	0.2	0.2	0.2
Bismuth	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Cadmium	µg/g	0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1
Calcium	µg/g	40	16400	14200	13100	14567	14200	14100	13700	14000	27200	25000	25400	25867
Chromium	µg/g	0.2	1.1	1.2	1	1.1	0.6	0.4	0.9	0.6	1.1	1.4	1.2	1.2
Cobalt	µg/g	0.3	9.1	7.5	6.7	7.8	0.4	0.4	0.5	0.4	2.5	3	2.9	2.8
Copper	µg/g	0.1	8.2	8.2	7.7	8.0	16.3	16.9	17.3	16.8	3.6	4	3.6	3.7
Iron	µg/g	10	49.3	60	51.3	53.5	59.1	53.7	53.3	55.4	116	153	99.6	122.9
Lead	µg/g	2	3	2	< 2	2	< 2	< 2	2	1	2	2	3	2
Magnesium	µg/g	10	6270	5050	4740	5353	4490	5020	4760	4757	13500	11900	12700	12700
Manganese	µg/g	0.2	860	715	654	743	515	598	553	555	654	687	694	678
Mercury	µg/g	0.05	< 0.05	< 0.05	< 0.05	0.03	< 0.05	< 0.05	< 0.05	0.03	< 0.05	< 0.05	< 0.05	0.03
Molybdenum	µg/g	0.4	< 0.4	< 0.4	< 0.4	0.2	< 0.4	< 0.4	< 0.4	0.2	< 0.4	< 0.4	< 0.4	0.2
Nickel	µg/g	0.8	7.1	6	6.3	6.5	9.7	10.4	9.8	10.0	5.4	7.1	5.1	5.9
Phosphorus	µg/g	4	1080	1210	1190	1160	1320	1230	1210	1253	1460	1590	1520	1523
Potassium	µg/g	40	5100	5650	5250	5333	9120	7690	8080	8297	16500	15900	15600	16000
Selenium	µg/g	3	< 3	< 3	< 3	1.5	< 3	< 3	< 3	1.5	< 3	< 3	< 3	1.5
Silver	µg/g	1	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5
Sodium	µg/g	10	< 10	14	< 10	8.0	17	18	62	32.3	< 10	19	10	11.3
Strontium	µg/g	0.1	124	106	97.8	109	155	169	162	162	428	397	411	412
Sulphur	µg/g	3	934	922	926	927	1360	1350	1330	1347	1290	1350	1240	1293
Tellurium	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Thallium	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	2	1.3
Tin	µg/g	2	12	19	13	14.7	4	3	4	3.7	13	13	8	11.3
Titanium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2
Vanadium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	0.4	0.5	0.4	0.4
Zinc	µg/g	0.2	12.9	13.1	12.4	13	20.9	30.8	33.3	28	15.4	18.1	15.7	16
Zirconium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2	< 0.3	< 0.3	< 0.3	0.2

[1]Averages calculated using 1/2 the detection limit where reported as "less than" (<)

TABLE 4-54
METALS IN PLANT TISSUE SAMPLED AT TRANSECT 9

PARAMETER	UNIT	DETECTION LIMIT	SPECIES NAME AND REPLICATE NUMBER											
			Panicum maximum				*Pericopsis angolensis*				*Secamone parvifolia*			
			1	2	3	Average[1]	1	2	3	Average[1]	1	2	3	Average[1]
Aluminum	µg/g	10	253	445	238	312	19	23	29	24	69	65	74	69
Antimony	µg/g	2	3	< 2	< 2	2	2	3	2	2	2	< 2	5	3
Arsenic	µg/g	8	< 8	< 8	< 8	4	8	< 8	< 8	5	< 8	< 8	< 8	4
Barium	µg/g	0.1	28.3	86.8	73.4	63	5.3	4.5	4.3	5	21.7	23	294	113
Beryllium	µg/g	0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	0.2	0.1
Bismuth	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Cadmium	µg/g	0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1
Calcium	µg/g	40	2820	5400	4160	4127	4970	5360	5630	5320	8750	8340	31900	16330
Chromium	µg/g	0.2	9.1	4.2	4.5	5.9	0.5	0.6	0.5	0.5	0.8	0.7	1.2	0.9
Cobalt	µg/g	0.3	0.4	0.6	0.6	0.5	< 0.3	0.4	< 0.3	0.2	0.7	< 0.3	0.7	0.5
Copper	µg/g	0.1	2.8	4.4	4.1	3.8	29.9	25.8	28.8	28.2	5	6.4	10.3	7.2
Iron	µg/g	10	486	827	475	596.0	72.9	73.2	93.1	79.7	117	124	61	100.7
Lead	µg/g	2	2	2	3	2	< 2	< 2	< 2	1	< 2	< 2	2	1
Magnesium	µg/g	10	2430	4320	4200	3650	2450	2880	2750	2693	3650	2320	4920	3630
Manganese	µg/g	0.2	124	137	108	123	855	1090	813	919	220	185	135	180
Mercury	µg/g	0.05	< 0.05	< 0.05	< 0.05	0.03	< 0.05	< 0.05	< 0.05	0.03	0.08	0.08	< 0.05	0.06
Molybdenum	µg/g	0.4	< 0.4	1.1	1	0.8	1.7	< 0.4	< 0.4	0.7	< 0.4	< 0.4	1.8	0.7
Nickel	µg/g	0.8	4	2.3	2.5	2.9	4.3	4.1	4.1	4.2	1.9	1.5	3.3	2.2
Phosphorus	µg/g	4	703	985	1110	933	1290	1220	1360	1290	1120	888	977	995
Potassium	µg/g	40	6850	14800	13800	11817	4110	3650	3670	3810	5000	2720	7350	5023
Selenium	µg/g	3	< 3	< 3	< 3	1.5	< 3	< 3	< 3	1.5	< 3	< 3	< 3	1.5
Silver	µg/g	1	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5
Sodium	µg/g	10	17	31	80	42.7	18	15	18	17.0	150	118	88	118.7
Strontium	µg/g	0.1	37.1	74.2	59.8	57	33.6	34.8	40.3	36	144	130	441	238
Sulphur	µg/g	3	424	974	1120	839	1190	1140	1150	1160	1260	1120	911	1097
Tellurium	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Thallium	µg/g	2	3	< 2	< 2	1.7	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Tin	µg/g	2	235	151	101	162.3	4	4	< 2	3.0	< 2	2	< 2	1.3
Titanium	µg/g	0.3	6.9	10.2	4.5	7.2	< 0.3	< 0.3	0.4	0.2	0.8	0.7	< 0.3	0.6
Vanadium	µg/g	0.3	1.2	2.1	1.3	1.5	< 0.3	< 0.3	< 0.3	0.2	0.3	< 0.3	< 0.3	0.2
Zinc	µg/g	0.2	18.6	30.2	19.8	23	13.3	12.2	12.7	13	15.9	18.8	31.8	22
Zirconium	µg/g	0.3	0.4	0.5	0.3	0.4	0.5	< 0.3	< 0.3	0.3	< 0.3	< 0.3	0.7	0.3

[1]Averages calculated using 1/2 the detection limit where reported as "less than" (<)

TABLE 4-54
METALS IN PLANT TISSUE SAMPLED AT TRANSECT 9

PARAMETER	UNIT	DETECTION LIMIT	SPECIES NAME AND REPLICATE NUMBER							
			Sporobolus festivus				*Tragia furialis*			
			1	2	3	Average[1]	1	2	3	Average[1]
Aluminum	µg/g	10	385	1130	702	739	352	410	184	315
Antimony	µg/g	2	< 2	< 2	< 2	1	< 2	2	< 2	1
Arsenic	µg/g	8	< 8	< 8	< 8	4	< 8	< 8	< 8	4
Barium	µg/g	0.1	54.3	83.9	80.7	73	215	247	237	233
Beryllium	µg/g	0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	0.1	0.1	0.1
Bismuth	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Cadmium	µg/g	0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1
Calcium	µg/g	40	1540	1700	1490	1577	18300	24700	22300	21767
Chromium	µg/g	0.2	13.5	8.4	21.3	14.4	5.8	5.1	1.8	4.2
Cobalt	µg/g	0.3	1.1	2	1.3	1.5	0.7	0.7	0.6	0.7
Copper	µg/g	0.1	3.5	4.3	3	3.6	5.7	5.2	5.2	5.4
Iron	µg/g	10	700	1810	1400	1303.3	1180	1560	583	1107.7
Lead	µg/g	2	2	2	2	2	< 2	< 2	< 2	1
Magnesium	µg/g	10	635	821	643	700	3000	2950	2640	2863
Manganese	µg/g	0.2	80.8	144	86.1	104	266	261	296	274
Mercury	µg/g	0.05	< 0.05	< 0.05	< 0.05	0.03	< 0.05	< 0.05	< 0.05	0.03
Molybdenum	µg/g	0.4	1	1	0.5	0.8	< 0.4	0.4	< 0.4	0.3
Nickel	µg/g	0.8	6.5	3	9.5	6.3	2	1.7	1.6	1.8
Phosphorus	µg/g	4	400	446	321	389	1410	1500	1510	1473
Potassium	µg/g	40	2270	3430	2710	2803	13400	16000	15300	14900
Selenium	µg/g	3	< 3	< 3	< 3	1.5	< 3	< 3	< 3	1.5
Silver	µg/g	1	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5
Sodium	µg/g	10	92	133	76	100.3	87	92	37	72.0
Strontium	µg/g	0.1	19.4	23	19.8	21	286	375	339	333
Sulphur	µg/g	3	488	576	384	483	1050	1100	1090	1080
Tellurium	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Thallium	µg/g	2	< 2	< 2	< 2	1.0	< 2	< 2	< 2	1.0
Tin	µg/g	2	135	1840	313	762.7	3	< 2	3	2.3
Titanium	µg/g	0.3	11.3	34.6	20.7	22.2	5.1	5.4	0.9	3.8
Vanadium	µg/g	0.3	2	4.7	3.7	3.5	3.5	4.6	1.6	3.2
Zinc	µg/g	0.2	24.1	18.8	14.1	19	18	17	19.5	18
Zirconium	µg/g	0.3	0.4	1.2	0.6	0.7	0.5	0.5	< 0.3	0.4

[1]Averages calculated using 1/2 the detection limit where reported as "less than" (<)

TABLE 4-55
METALS IN PLANT TISSUE SAMPLED AT WS2

PARAMETER	UNIT	DETECTION LIMIT	SPECIES NAME AND REPLICATE NUMBER							
			Arabotrys monteiroae				*Syzygium guineense*			
			1	2	3	Average[1]	1	2	3	Average[1]
Aluminum	µg/g	10	20	23	26	23	38	36	36	36.7
Antimony	µg/g	2	2	2	< 2	1.7	< 2	< 2	< 2	1.0
Arsenic	µg/g	8	< 8	< 8	< 8	4	9	8	9	8.7
Barium	µg/g	0.1	29.7	32.2	26	29.3	79.7	93.2	104	92.3
Beryllium	µg/g	0.1	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.1	0.05
Bismuth	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Cadmium	µg/g	0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	< 0.2	< 0.2	0.1
Calcium	µg/g	40	7050	8180	6220	7150	6170	7730	7990	7297
Chromium	µg/g	0.2	0.6	0.7	0.7	0.67	0.8	0.7	0.7	0.73
Cobalt	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.15	0.4	< 0.3	< 0.3	0.2
Copper	µg/g	0.1	6.5	6.5	5.3	6.1	5.5	6	6.3	5.9
Iron	µg/g	10	68.2	56.3	57.1	60.5	87	96.8	96.6	93.5
Lead	µg/g	2	< 2	2	< 2	1	< 2	< 2	< 2	1
Magnesium	µg/g	10	2130	2260	1920	2103	2000	2370	2530	2300
Manganese	µg/g	0.2	23.5	25.2	19.2	22.6	346	446	489	427
Mercury	µg/g	0.05	< 0.05	< 0.05	< 0.05	0.03	0.08	0.11	0.12	0.10
Molybdenum	µg/g	0.4	< 0.4	< 0.4	< 0.4	0.2	< 0.4	< 0.4	< 0.4	0.2
Nickel	µg/g	0.8	1.1	1.1	0.8	1	3.2	4.5	4.4	4.0
Phosphorus	µg/g	4	900	913	686	833	566	743	722	677
Potassium	µg/g	40	5700	5700	5080	5493	3250	4100	4280	3877
Selenium	µg/g	3	< 3	< 3	< 3	1.5	< 3	< 3	< 3	1.5
Silver	µg/g	1	< 1	< 1	< 1	0.5	< 1	< 1	< 1	0.5
Sodium	µg/g	10	10	14	11	12	2390	3170	3350	2970
Strontium	µg/g	0.1	64.6	73.1	56.2	64.6	60	73.9	79.9	71.3
Sulphur	µg/g	3	912	957	814	894	790	1060	1080	977
Tellurium	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Thallium	µg/g	2	< 2	< 2	< 2	1	< 2	< 2	< 2	1
Tin	µg/g	2	4	4	3	4	5	< 2	2	3
Titanium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.15	0.5	< 0.3	< 0.3	0.27
Vanadium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.15	< 0.3	< 0.3	< 0.3	0.15
Zinc	µg/g	0.2	7.6	7.9	5.9	7.1	7.1	7.3	7.8	7.4
Zirconium	µg/g	0.3	< 0.3	< 0.3	< 0.3	0.15	< 0.3	< 0.3	< 0.3	0.15

[1]Averages calculated using 1/2 the detection limit where reported as "less than" (<)

TABLE 4-56
WEEDY PLANTS RECORDED FROM
BULYANHULU AREA

SPECIES NAME	COMMON NAME
Acanthospermus hispidum	Starbur
Achyranthes aspera	Devil's Horsewhip
Ageratum conyzoides	Goat weed
Amaranthus hybridus	Pig weed
Bidens pilosa	Black Jack
Boerhavia diffusa	Tar Vine
Chenopodium opulifolium	Round-leaved Goosefoot
Commelina benghalensis	Wandering Jew
Cynodon dactylon	Star Grass, Couch, Bermuda Grass
Dactyloctenium aegyptium	Crows-foot Grass
Datura stramonium	Thorn Apple
Eleusine indica	Wild Finger-Millet
Euphorbia hirta	Asthma Weed
Harpachne schimperi	-
Heliotropium steudneri	-
Hibiscus cannabinus	Kenaf, Deccan Hemp
Indigofera spicata	Creeping Indigo
Launaea cornuta	Wild Lettuce
Leonotis nepetifolia	Lion's Ear /Lion's tail
Leucas martinicensis	Bobbin Weed
Oxygonum sinuatum	Double Thorn
Portulaca oleraceae	Purslane
Rhynchelytrum repens	Natal Grass
Ricinus communis	Castor Oil Plant
Setaria pumila	Pale Foxtail
Sida acuta	Pricky sida
Sida alba	Pricky sida
Sida cordifolia	Pricky sida
Solanum incanum	Sodom Apple
Solanum nigrum	Black Nightshade
Tagetes minuta	Mexican Marigold
Tridax procumbens	P.W.D. Weed
Triumfetta rhomboidea	-

TABLE 4-57
PLANT GENERA OF THE PROJECT AREA
LISTED AS RARE OR VULNERABLE IN TANZANIA (HEDBERG, 1979)

Family	Genus
Capparaceae	*Thylachium*
Combretaceae	*Combretum*
Convolvulaceae	*Astripomea* *Ipomea*
Ebenaceae	*Diospyros*
Gramineae	*Digitaria* *Eragrostis* *Pennisetum*
Guttiferae	*Vismia*
Mimosideae	*Acacia* *Albizia*
Papilionoideae	*Eriosema* *Indigofera* *Rhynchosia* *Tephrosia* *Zornia*
Aloeceae	*Aloe*
Olacaceae	*Olax*
Oxalidaceae	*Biophytum*
Polygonaceae	*Oxygonum*
Rubiaceae	*Oldenlandia* *Pavetta* *Spermacoce*
Sapotaceae	*Tapiphyllum* *Mimusops*
Sterculiaceae	*Dombeya*

TAB. 58
SPECIES WITH CONS_RVATION VALUES AND THEIR STATUS IN THE BULYANHULU PROJECT AREA

Species Name	Status[1]	Comments
Acacia spp.	Vulnerable	Preferred for charcoal burning and building bomas
Albizia petersiana	Threatened	Source of fuelwood and building poles
Aloe christianii	Endangered	Prized for horticultural value and danger of over collection (Appendix 1 of CITES)
Aloe lateritia	Endangered	Prized for horticultural value and danger of over collection (Appendix 1 of CITES)
Combretum spp	Threatened	Highly demanded for fuelwood and building poles
Dalbergia melanoxylon	Threatened	Used for carvings and charcoal burning
Entandrophragma bussei	Threatened	Many uses: beehives, beds, chairs, milk containers
Haplocoelom foliolosum	Threatened	Source of fuelwood and building poles
Oryza longistaminata	Threatened	The habitat is threatened in favour of cultivated rice
Ozoroa insignis	Vulnerable	High demand for fuelwood
Phoenix reclinata	Vulnerable	Heavily exploited for basketry
Sclerocarya birrea	Vulnerable	Medicinal (bark) and the fruits are edible

[1] From Okullo (1997)

TABLE 4-59
EDIBLE PLANTS FOUND IN THE PROJECT AREA

Family	Species	Part of Plant Eaten
Anacardiaceae	*Sclerocarya birrea*	Fruit
Annonaceae	*Anona senegalensis*	Fruit
Burseraceae	*Commiphora africana*	Roots
Caesalpiniaceae	*Piliostigma thonningii*	Pods and Pulp
Euphorbiaceae	*Acalypha ornata*	Fruit
Gramineae	*Dactyloctenium aegyptium*	Seeds

TABLE 4-60
BACKGROUND MAMMALS DATA FOR BULYANHULU PROJECT AREA AND SURROUNDING DISTRICTS

ORDER	FAMILY	GENUS	SPECIES	ENGLISH NAME	Project Site (1997)	Kahama District (1951)	Shinyanga District (1951)	Mwanza District (1951)	Rodgers (1967)
ARTIODACTYLA	BOVIDAE	*Aepyceros*	*melampus*	Impala		X	X	X	
ARTIODACTYLA	BOVIDAE	*Alcelaphus*	*buselaphus*	Hartebeest, Kongoni			X		
ARTIODACTYLA	BOVIDAE	*Alcelaphus*	*lichtensteinii*	Lichtenstein's Hartebeest, Kongoni		X		X	GK
ARTIODACTYLA	BOVIDAE	*Damaliscus*	*lunatus*	Topi				X	GKS
ARTIODACTYLA	BOVIDAE	*Gazella*	*granti*	Grant's Gazelle				X	
ARTIODACTYLA	BOVIDAE	*Gazella*	*thomsonii*	Thomson's Gazelle				X	
ARTIODACTYLA	BOVIDAE	*Hippotragus*	*equinus*	Roan Antelope		X			G
ARTIODACTYLA	BOVIDAE	*Hippotragus*	*niger*	Sable Antelope				?	GK
ARTIODACTYLA	BOVIDAE	*Kobus*	*ellipsiprymnus*	Common Waterbuck			X	X	
ARTIODACTYLA	BOVIDAE	*Madoqua*	*kirkii*	Kirk's Dik-dik	X	X	X	X	GKS
ARTIODACTYLA	BOVIDAE	*Oreotragus*	*oreotragus*	Klipspringer		X	X		
ARTIODACTYLA	BOVIDAE	*Ourebia*	*ourebi*	Oribi				X	
ARTIODACTYLA	BOVIDAE	*Redunca*	*arundinum*	Southern Reedbuck		X			
ARTIODACTYLA	BOVIDAE	*Redunca*	*redunca*	Bohor Reedbuck			X		GKS
ARTIODACTYLA	BOVIDAE	*Rhaphicerus*	*sharpei*	Sharpe's Grysbok		X			
ARTIODACTYLA	BOVIDAE	*Sylvicapra*	*grimmia*	Common Duiker, Bush Duiker		U	U	U	GKS
ARTIODACTYLA	BOVIDAE	*Syncerus*	*caffer*	African Buffalo		X	X	X	GK
ARTIODACTYLA	BOVIDAE	*Taurotragus*	*oryx*	Common Eland		X	X	?	GKS
ARTIODACTYLA	BOVIDAE	*Tragelaphus*	*scriptus*	Bushbuck		X	X	X	GKS
ARTIODACTYLA	BOVIDAE	*Tragelaphus*	*strepsiceros*	Greater Kudu		X	X		GKS
ARTIODACTYLA	GIRAFFIDAE	*Giraffa*	*camelopardalis*	Giraffe		X	X		GKS
ARTIODACTYLA	HIPPOPOTAMIDAE	*Hippopotamus*	*amphibius*	Hippopotamus		?	?	X	
ARTIODACTYLA	SUIDAE	*Phacochoerus*	*africanus*	Warthog		U	U	U	GKS
ARTIODACTYLA	SUIDAE	*Potamochoerus*	*larvatus*	Bushpig (River Hog)		U	U	U	GKS
CARNIVORA	CANIDAE	*Canis*	*adustus*	Side striped Jackal			X	X	
CARNIVORA	CANIDAE	*Canis*	*mesomelas*	Black backed (Silver backed)			X		
CARNIVORA	CANIDAE	*Lycaon*	*pictus*	Hunting Dog		X	X	X	GKS
CARNIVORA	CANIDAE	*Otocyon*	*megalotis*	Bat eared Fox			X		
CARNIVORA	FELIDAE	*Acinonyx*	*jubatus*	Cheetah			X		
CARNIVORA	FELIDAE	*Felis*	*caracal*	Caracal			X	X	
CARNIVORA	FELIDAE	*Felis*	*serval*	Serval			X		
CARNIVORA	FELIDAE	*Felis*	*silvestris*	African Wild Cat			X		
CARNIVORA	FELIDAE	*Panthera*	*leo*	Lion		U	U	U	
CARNIVORA	FELIDAE	*Panthera*	*pardus*	Leopard		U	U	U	GK
CARNIVORA	HERPESTIDAE	*Galerella*	*sanguinea*	Slender Mongoose				X	
CARNIVORA	HERPESTIDAE	*Helogale*	*parvula*	Dwarf Mongoose	X		X		
CARNIVORA	HERPESTIDAE	*Ichneumia*	*albicauda*	White tailed Mongoose			X		
CARNIVORA	HERPESTIDAE	*Mungos*	*mungo*	Banded Mongoose			X	X	
CARNIVORA	HYAENIDAE	*Crocuta*	*crocuta*	Spotted Hyaena		U	U	U	GKS
CARNIVORA	HYAENIDAE	*Hyaena*	*hyaena*	Striped Hyaena			U		

TABLE 4-60
BACKGROUND MAMMALS DATA FOR BULYANHULU PROJECT AREA AND SURROUNDING DISTRICTS

ORDER	FAMILY	GENUS	SPECIES	ENGLISH NAME	Project Site (1997)	Kahama District (1951)	Shinyanga District (1951)	Mwanza District (1951)	Rodgers (1967)
CARNIVORA	HYAENIDAE	*Proteles*	*cristatus*	Aardwolf			X		
CARNIVORA	MUSTELIDAE	*Aonyx*	*capensis*	African Clawless Otter				X	
CARNIVORA	MUSTELIDAE	*Mellivora*	*capensis*	Honey Badger, Ratel		U	U	U	
CARNIVORA	VIVERRIDAE	*Civettictis*	*civetta*	East African Civet		U	U	U	
CHIROPTERA	MEGADERMATIDAE	*Lavia*	*frons*	Yellow winged Bat	X				
CHIROPTERA	MOLOSSIDAE	*Chaerephon*	*pumila*	Little Free tailed Bat				X	
CHIROPTERA	NYCTERIDAE	*Nycteris*	*hispida*	Hairy Slit faced Bat				X	
HYRACOIDEA	PROCAVIIDAE	*Dendrohyrax*	*arboreus*	Southern Tree Hyrax			X		
HYRACOIDEA	PROCAVIIDAE	*Heterohyrax*	*brucei*	Yellow spotted Rock Hyrax				X	
HYRACOIDEA	PROCAVIIDAE	*Procavia*	*capensis*	East African Rock Hyrax				X	
INSECTIVORA	ERINACEIDAE	*Atelerix*	*albiventris*	Four toed (White bellied) Hedgehog	X		X		
INSECTIVORA	SORICIDAE	*Suncus*	*lixus*	Greater Dwarf Shrew				X	
LAGOMORPHA	LEPORIDAE	*Lepus*	*victoriae*	Savanna Hare	X		X		
MACROSCELIDEA	MACROSCELIDIDAE	*Elephantulus*	*rufescens*	Rufous (Spectacled) Elephant Shrew				X	
MACROSCELIDEA	MACROSCELIDIDAE	*Petrodromus*	*tetradactylus*	Four toed Elephant Shrew			X		
PERISSODACTYLA	EQUIDAE	*Equus*	*burchellii*	Plains (Burchell's) Zebra		U	U	U	
PERISSODACTYLA	RHINOCEROTIDAE	*Diceros*	*bicornis*	Black (Muzzle lipped) Rhinoceros		X	X		
PHOLIDOTA	MANIDAE	*Manis*	*temminckii*	Ground Pangolin			X		
PRIMATES	CERCOPITHECIDAE	*Cercopithecus*	*aethiops*	Vervet Monkey	X			X	
PRIMATES	CERCOPITHECIDAE	*Papio*	*cynocephalus*	Olive/Yellow Baboon				X	
PRIMATES	GALAGONIDAE	*Galago*	*senegalensis*	Senegal (Lesser) Galago, Bushbaby				X	
PRIMATES	GALAGONIDAE	*Otolemur*	*crassicaudatus*	Large eared Greater Galago				X	
PROBOSCIDEA	ELEPHANTIDAE	*Loxodonta*	*africana*	African Elephant		U	U	U	GKS
RODENTIA	BATHYERGIDAE	*Heliophobius*	*argenteocinereus*	Silvery Mole rat			X		
RODENTIA	GERBILLIDAE	*Tatera*	*robusta*	Fringe tailed Gerbil	(X)			X	
RODENTIA	HYSTRICIDAE	*Hystrix*	*cristata*	Crested Porcupine			X		
RODENTIA	MURIDAE	*Aethomys*	*kaiseri*	Kaiser's Bush Rat				X	
RODENTIA	MURIDAE	*Lemniscomys*	*barbarus*	Barbary Striped Grass Rat				X	
RODENTIA	MURIDAE	*Lophuromys*	*flavopunctatus*	Eastern Brush furred Rat				X	
RODENTIA	MURIDAE	*Mastomys*	*natalensis*	Natal Multimammate Rat	(X)		X	X	
RODENTIA	MURIDAE	*Mus*	*minutoides*	Pygmy Mouse				X	
RODENTIA	MURIDAE	*Rattus*	*rattus*	Black Rat	X	X	X	X	
RODENTIA	PEDETIDAE	*Pedetes*	*capensis*	Springhare	X	X	X		
RODENTIA	THRYONOMYIDAE	*Thryonomys*	*swinderianus*	Common (Marsh) Cane Rat				X	

x = definite occurrence
(x) = some doubt as to identification
u = ubiquitous
? = unconfirmed presence

G = Geita district
K = Kahama district
S = Shinyanga district

TABLE 4-61
TRAPPING EFFORT AND CAPTURE OF SMALL MAMMALS FOR BUCKET PITFALL LINES AND SNAP TRAPS FOR THE WET SEASON (MAY, 1997)

Date, 1997	BPF Traps	Snap Traps	BPFL Catch	Snap Trap Catch	Comments
15-May	44	0	0	0	
16-May	77	108	0	0	12 snap traps stolen
17-May	66	170	*Mastomys*, BPFL 2	0	11 BPFTs stolen night of 16 May
18-May	66	170	0	0	
19-May	66	170	0	0	
20-May	66	170	0	*Tatera*, #79	
21-May	66	170	0	*Tatera*, shamba trapline; *Atelerix*, #71	
22-May	66	167	0	*Tatera*, #4	3 snap traps stolen
23-May	66	158	0	*Tatera*, #79	9 snap traps stolen; trapping ceased after night of May 22
Totals:	583	1283	1 *Mastomys*	4 *Tatera*, 1 *Atelerix*	
Capture Rates:	1/583=0.17%	5/1283=0.39%			

TABLE 4-62
SMALL MAMMAL TRAPPING RESULTS FROM OCTOBER, 1997

Date	Catch Records	Comments
2-Oct	2 elephant shrews 2 *Tatera*	
3-Oct	2 *Mus* 6 *Tatera* 2 *Mastomys*	
4-Oct	3 elephant shrews 7 *Tatera* 1 *Mastomys* 1 bush shrike	
5-Oct	5 *Tatera* 1 red-billed hornbill	
6-Oct	6 Tatera	
7-Oct	1 *Mus* 5 *Tatera* 1 *Mastomys*	1 trap missing (no. 146), near BPFL 4
Totals	3 *Mus* 5 elephant shrews 28 *Tatera* 4 *Mastomys*	210 BPFTs 889 snap trap nights
Trapping Percents	3/210 = 1.4% 37/889 = 4.2%	

TABLE 4-63
MAMMALS RECORDED/REPORTED AT THE BULYANHULU SITE AND ITS IMMEDIATE SURROUNDINGS, 1997

* = seen/reported outside the fenced area of the Project site

Order	Family	Genus and species	Common Name	Comments
Insectivora	Erinaceidae	*Atelerix albiventris*	Four-toed Hedgehog	
Chiroptera	Megadermatidae	*Lavia frons*	Yellow-winged Bat	
Lagomorpha	Lepuridae	*Lepus victoriae*	*African Hare	
Rodentia	Gerbillidae	*Tatera c.f. robusta*	Gerbil	trapped in snap trap
	Muridae	*Mastomys natalensis* *Rattus rattus* *Mus sp.*	Natal Multimammate Mouse Black Rat Unspecified Mouse	BPFT
	Pedetidae	*Pedetes capensis*	*Springhare	reported by informants as occurring near airstrip
Macroscelidia	Macroscelididae	*Elephantulus brachyrhynchus*	Short-snouted Elephant-Shrew	
Artiodactyla	Suidae	*Potamochoerus porcus* *Phacochoerus aethiopicus*	Bushpig Warthog	
	Bovidae	*Madoqua kirkii* *Tragelephus scriptus*	Kirk's Dik-dik Bushbuck	
Carnivora	Herpestidae	*Helogale parvula*	Dwarf Mongoose	
Primates	Cercopithecus	*Cercopithecus aethiops*	Vervet Monkey	

TABLE 4-64
CHECKLIST OF THE BIRD SPECIES OF THE PROJECT AREA AND ITS SURROUNDINGS

Order	Family	Common Name	Latin Name	May (wet)	Oct (dry)
Ciconiiformes	Ardeidae	Grey Heron	*Ardea cinerea*	C, Fl, nr	
Ciconiiformes	Ardeidae	Little Egret	*Egretta garzetta*	C, Fl, 4	C, Fl, 1
Ciconiiformes	Scopidae	Hammerkop	*Scopus umbretta*	Lc, Fl, 1	Lc, Fl, 3
Ciconiiformes	Ciconiidae	Marabou	*Leptoptilos crumeniferus*	C, 1	C, Fl, 1
Falconiformes	Accipitridae	Eagle	*Aquila c.f. rapax*		Lc, 1
Falconiformes	Accipitridae	Brown Snake-Eagle	*Circaaetus cinereus*		Lc, Fl, 1
Falconiformes	Accipitridae	Marsh Harrier	*Circus sp.*		Lc, 1
Falconiformes	Accipitridae	Fish Eagle	*Haliaeetus vocifer*		Lc, Fl, 1
Falconiformes	Accipitridae	Dark Chanting-Goshawk	*Melierax metabates*	Lc, 1	
Falconiformes	Accipitridae	Black Kite	*Milvus migrans*		C, Fl, 1
Falconiformes	Accipitridae	Harrier Hawk	*Polyboroides radiatus*	Lc, 1	Lc, 1
Falconiformes	Accipitridae	Bateleur	*Terathopius ecaudatus*	C, Fl, 1	Lc, 1
Falconiformes	Falconidae	African Hobby	*Falco cuvieri*		Lc, 1
Galliformes	Phasianidae	Red-necked Spurfowl	*Francolinus afer*	C, 1	C, 1
Galliformes	Phasianidae	Helmeted Guineafowl	*Numida meleagris*	Lc, 1	
Columbiformes	Columbidae	Namaqua Dove	*Oena capensis*	C, 2	C, 1
Columbiformes	Columbidae	Red-eyed Dove	*Streptopelia semitorquata*	Lc, 1	Lc, 3
Columbiformes	Columbidae	Laughing Dove	*Streptopelia senegalensis*	C, Br, 2	C, 2
Columbiformes	Columbidae	Ring-necked Dove	*Streptopelia capicola*	C, Br, 2	
Columbiformes	Columbidae	Green Pigeon	*Treron australis*	Lc, 1	Lc, 3
Columbiformes	Columbidae	Emerald-spotted Wood-Dove	*Turtur tympanistria*	C, 2	C, 3
Cuculiformes	Cuculidae	Black and White Cuckoo	*Clamator jacobinus*	Lc, 1	
Cuculiformes	Cuculidae	Klaas' Cuckoo	*Clamator klaas*	C, 1	
Cuculiformes	Cuculidae	White-browed Coucal	*Centropus superciliosus*	C, 1	Lc, 1
Cuculiformes	Cuculidae	Didric Cuckoo	*Chrysococcyx caprius*	Lc, 1	
Cuculiformes	Cuculidae	Great Spotted Cuckoo	*Clamator glandarius*	Lc, 1	
Cuculiformes	Musophagidae	Bare-faced Go-away-bird	*Corythaixoides concolor*	C, 1	Lc, 1
Psittaciformes	Psittacidae	Red-headed Lovebird	*Agapornis pullaria*	Lc	nr
Psittaciformes	Psittacidae	Fischer's Lovebird	*Agapornis fischeri*	Lc, 1	
Coraciiformes	Coraciidae	Lilac-breasted Roller	*Coracias caudata*	Lc, 1	Lc, 1
Coraciiformes	Alcedinidae	Grey-headed Kingfisher	*Halcyon leucocephala*	C, 1	
Coraciiformes	Alcedinidae	Striped Kingfisher	*Halcyon chelicuti*	Lc, 1	
Coraciiformes	Alcedinidae	Pygmy Kingfisher	*Ispidna picta*	Lc, 1	
Coraciiformes	Meropidae	Little Bee-eater	*Merops pusillus*	C, 1	
Coraciiformes	Bucerotidae	Grey Hornbill	*Tockus nasutus*	C, 1	
Coraciiformes	Bucerotidae	Red-billed Hornbill	*Tockus erythrorhynchus*	Lc, 1	Lc, 1
Coraciiformes	Phoeniculidae	Green Wood-Hoopoe	*Phoeniculus purpureus*	Lc, 1	
Strigiformes	Strigidae	Owl	*Bubo c.f. africanus*		Lc, 1
Caprimulgiformes	Caprimulgidae	Nightjar	*Caprimulgus sp.*	C, 1	
Caprimulgiformes	Caprimulgidae	Pennant-winged Nightjar	*Macrodipteryx vexillarius*		Lc, Br, 1
Caprimulgiformes	Apodidae	Palm Swift	*Cypsiurus parvus*		Lc, nr
Coliiformes	Coliidae	Speckled Mousebird	*Colius striatus*	C, 2	C, 1
Coliiformes	Coliidae	Blue-naped Mousebird	*Urocolius macrourus*	C, 2	C, 3
Piciformes	Capitonidae	Spotted-flanked Barbet	*Lybius lacrymosus*	Lc, 1	
Piciformes	Capitonidae	Red-fronted Tinkerbird	*Pogoniulus pusillus*	Lc, 1	
Piciformes	Capitonidae	d'Arnaud's Barbet	*Trachyphonus darnaudii*	C, 1	Lc, 1
Piciformes	Indicatoridae	Black-throated Honeyguide	*Indicator indicator*	Lc, 1	Lc, 1
Passeriformes	Alaudidae	Fisher's Sparrow-Lark	*Eremopterix leucoparela*	C, 3	
Passeriformes	Alaudidae	Flappet Lark	*Mirafra rufocinnamomea*	C, 3	C, 3
Passeriformes	Hirundinidae	Lesser Striped Swallow	*Hirundo abyssinica*	C, Br, 3	
Passeriformes	Hirundinidae	Barn Swallow	*Hirundo rustica*		Lc, 3
Passeriformes	Hirundinidae	Black Rough-wing Swallow	*Psalidoprocne pristoptera*	Lc, 1	
Passeriformes	Hirundinidae	White-headed Rough-wing Swallow	*Psalidoprocne albiceps*	Lc, 1	
Passeriformes	Motacillidae	African Pied Wagtail	*Motacilla aguimp*	C, 2	C, 1
Passeriformes	Camephagidae	Black Cuckoo-Shrike	*Campephaga flava*	Lc, 1	
Passeriformes	Laniidae	Shrike	*Lanius sp.*		Lc, 1
Passeriformes	Pycnonotidae	Garden Bulbul	*Pycnonotus barbatus*	C, 2	C, 1
Passeriformes	Malaconotidae	Black-backed Puffback	*Dryoscopus cubla*	C, 1	Lc, 2
Passeriformes	Malaconotidae	Slate-coloured Boubou	*Laniarius funebris*	C, 2	C, 1
Passeriformes	Malaconotidae	Sulphur-breasted Bush-Shrike	*Malaconotus sulfureopectus*	Lc, 1	
Passeriformes	Malaconotidae	Brown-headed Tchagra	*Tchagra australis*	C, 2	C, 2
Passeriformes	Turdidae	White-browed Scrub-Robin	*Cercotrichas leucophrys*	C, 2	C, 2
Passeriformes	Turdidae	Spotted Morning-Thrush	*Cichladusa guttata*	C, 2	C, 2
Passeriformes	Turdidae	White-browed Robin-Chat	*Cossypha heuglini*	C, 2	C, 2
Passeriformes	Turdidae	Sooty Chat	*Myrmecocichla nigra*	Lc, 1	
Passeriformes	Timaliidae	Black-lored Babbler	*Trichastoma melanops*	Lc, 2	
Passeriformes	Sylviidae	Yellow-breasted Apalis	*Apalis flavida*		Lc, 1
Passeriformes	Sylviidae	Chin-spot Batis	*Batis molitor*		Lc, 1
Passeriformes	Sylviidae	Green-backed Camaroptera	*Camaroptera brachyura*		Lc, 1

TABLE 4-64
CHECKLIST OF THE BIRD SPECIES OF THE PROJECT AREA AND ITS SURROUNDINGS

Order	Family	Common Name	Latin Name	May (wet)	Oct (dry)
Passeriformes	Sylviidae	Grey-backed Camaroptera	*Camaroptera brevicaudata*		Lc, 1
Passeriformes	Sylviidae	Rattling Cisticola	*Cisticola chiniana*	C, Br, 2	Lc, 1
Passeriformes	Sylviidae	Red-capped Cisticola	*Cisticola fulvicapilla*	C, 2	
Passeriformes	Sylviidae	Silverbird	*Empidornis sempartitus*		Lc, 1
Passeriformes	Sylviidae	Tawny-flanked Prinia	*Prinia subflava*		Lc, 2
Passeriformes	Sylviidae	Red-faced Crombec	*Sylvietta whytii*	Lc, 1	Lc, 1
Passeriformes	Sylviidae	Warbler		C, 2	
Passeriformes	Muscicapidae	Ashy Flycatcher	*Muscicapa caerulescens*	Lc, 1	Lc, 1
Passeriformes	Muscicapidae	Spotted Flycatcher	*Muscicapa striata*	Lc, 1	
Passeriformes	Muscicapidae	Dusky Flycatcher	*Alseonax adustus*		
Passeriformes	Nectariniidae	Scarlet-chested Sunbird	*Nectarinia senegalensis*	Lc, 1	C, 1
Passeriformes	Nectariniidae	Variable Sunbird	*Nectarinia venusta*	C, Br, 2	C, 1
Passeriformes	Nectariniidae	Red-chested Sunbird	*Nectarinia erythrocerla*	Lc, 1	Lc, 1
Passeriformes	Nectariniidae	Mariqua Sunbird	*Nectarinia mariquensis*	C, Br, 2	C, 1
Passeriformes	Emberizidae	Golden-breasted Bunting	*Emberiza flaviventris*	C, 2	C, 2
Passeriformes	Fringillidae	Yellow-fronted Canary	*Serinus mozambicus*	C, 3	C, 1
Passeriformes	Fringillidae	Yellow-rumped Seed-eater	*Serinus atrogularis*	C, Br, 3	C, 2
Passeriformes	Fringillidae	Black-eared Serin	*Serinus mennelli*		Lc, 2
Passeriformes	Estrididae	Zebra Waxbill	*Amandava subflava*	C, 2	
Passeriformes	Estrididae	Cut-throat Waxbill	*Anadina fasciata*	C, Br, 3	
Passeriformes	Estrididae	Crimson-rumped Waxbill	*Estrilda rhodopyga*	C, Br, 2	
Passeriformes	Estrididae	Bronze Mannikin	*Lonchura cucullata*	Lc, 2	C, 2
Passeriformes	Estrididae	Green-winged Pytilia	*Pytilia melba*	C, Br, 2	Lc, 2
Passeriformes	Estrididae	Blue-capped Cordon-bleu	*Uraeginthuscyanocephalus*	C, Br, 3	C, 2
Passeriformes	Estrididae	Purple Grenadier	*Uraeginthus ianthinogaster*	C, 2	C, 1
Passeriformes	Estrididae	Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	C, Br, 2	Lc, 2
Passeriformes	Estrididae	Pin-tailed Whydah	*Vidua macroura*	Lc, Br, 1	
Passeriformes	Estrididae	Paradise Whydah	*Vidua paradisaea*	C, Br, 2	
Passeriformes	Estrididae	Straw-tailed Whydah	*Vidua fischeri*	Lc, Br, 1	
Passeriformes	Ploceidae	Black-winged Red-Bishop	*Euplectes hordeaceus*	C, Br, 2	
Passeriformes	Ploceidae	Yellow-mantled Widowbird	*Euplectes macrourus*	Lc, 1	
Passeriformes	Ploceidae	White-winged Widowbird	*Euplectes albonotatus*	C, Br, 2	C, 1
Passeriformes	Ploceidae	Indigobird	*Hypochera sp.*	C, 1	C, 1
Passeriformes	Ploceidae	Jameson's Firefinch	*Lagonosticta rhodopareia*	C, 2	C, 1
Passeriformes	Ploceidae	Grey-headed Sparrow	*Passer griseus*	C, Br, 3	C, 2
Passeriformes	Ploceidae	Black-necked Weaver	*Ploceus nigricollis*	C, 2	
Passeriformes	Ploceidae	Little Weaver	*Ploceus luteolus*		Lc, 1
Passeriformes	Ploceidae	Speckle-fronted Weaver	*Sporopipes frontalis*	C, 2	C, Br, 2
Passeriformes	Sturnidae	Violet-backed Starling	*Cinnyricinclus c.f. leucogaster*		C, 1
Passeriformes	Sturnidae	Ashy Starling	*Cosmopsarus unicolor*	C, 2	C, 2
Passeriformes	Sturnidae	Ruppell's Long-tailed Starling	*Lamprotornis purpuropterus*	Lc, 1	
Passeriformes	Sturnidae	Blue-eared Glossy Starling	*Lamprotornis chalybaeus*	Lc, 1	Lc, 2
Passeriformes	Oriolidae	Black-headed Oriole	*Oriolus larvatus*	C, 1	C, 2
Passeriformes	Dicruridae	African Drongo	*Dicrurus adsimilis*	C, 2	C, 1
Passeriformes	Corvidae	Pied Crow	*Corvus albus*	C, 1	C, 1

Symbol explanation:
C = common, seen on most days
Lc = less common, seen on 5 or fewer occasions
Br = recorded breeding
Fl = flying above

Abundance code:
1 = 1 to 10 individuals
2 = 11 to 100 individuals
3 = 101 to 1000 individuals
4 = >1000 individuals
nr = number of individuals not recorded

TABLE 4-65a
TIMED SPECIES COUNT LOCATION 1 (MAY, 1997)
Eastern Corner to Behind Skanksa Camp

Species		Series 1	2	3	4	Mean
Ring necked Dove	*Streptopelia capicola*	6	6	6	6	6
Laughing Dove	*Streptopelia senegalensis*	6	6	6	6	6
Red eyed Dove	*Streptopelia semitorquata*	0	6	0	0	1.5
Emerald-spotted Wood-dove	*Turtur tympanistria*	5	6	6	6	5.75
Fischer's Lovebird	*Agapornis fischeri*	0	0	0	1	0.25
Bare-faced Go-away-bird	*Corythaixoides concolor*	0	2	6	6	3.5
Klaas' Cuckoo	*Chrysococcyx klaas*	3	6	6	0	3.25
Black and White Cuckoo	*Clamator jacobinus*	0	0	4	0	1
White-browed Coucal	*Centropus superciliosus*	4	5	2	0	2.75
Blue-naped Mousebird	*Urocolius macrourus*	0	0	0	3	0.75
Speckled Mousebird	*Colius striatus*	5	5	5	6	5.25
Grey-headed Kingfisher	*Halcyon leucocephala*	0	3	0	0	0.75
Pygmy Kingfisher	*Ispidna picta*	0	0	0	3	0.75
Little Bee-eater	*Merops pusillus*	0	1	4	0	1.25
Red-fronted Tinkerbird	*Pogoniulus pusilus*	4	0	0	0	1
d' Arnaud's Barbet	*Trachyphonus darnaudii*	0	0	0	2	0.5
Fisher's Sparrow-Lark	*Eremopterix leucopareia*	1	0	0	0	0.25
Flappet Lark	*Mirafra rufocinnamomea*	6	0	0	0	1
Striped Swallow	*Hirundo abyssinica*	6	6	6	5	5.75
White-headed Rough-winged Swallow	*Psalidoprocne albiceps*	0	1	0	0	0.25
Black Rough-winged Swallow	*Psalidoprocne pristoptera*	0	0	1	6	1.75
Drongo	*Dicrurus adsimilis*	0	6	6	6	4.5
Oriole	*Oriolus sp.*	0	5	0	5	2.75
Black-lored Babbler	*Trichastoma melanops*	0	3	0	6	2.25
Black Cuckoo-Shrike	*Campephaga flava*	6	0	0	0	1.5
Common Bulbul	*Pycnonotus barbatus*	6	3	6	0	3.75
White-browed Scrub-Robin	*Cercotrichas leucophrys*	1	0	0	0	0.25
Spotted Morning Thrush	*Cichladusa guttata*	6	5	6	6	5.75
Sooty Chat	*Myrmecocichla nigra*	0	6	6	5	4.25
Grey-backed Camaroptera	*Cameroptera brevicaudata*	4	6	6	6	5.5
Rattling Cisticola	*Cisticola chiniana*	6	6	6	5	5.75
Warbler		5	0	0	1	1.5
Red-fronted Warbler		4	0	0	0	1
Black-backed Puffback	*Dryoscopus cubla*	5	3	0	0	2
Slate-coloured Boubou	*Laniarius funebris*	6	6	6	6	6
Sulphur-breasted Bush-Shrike	*Malaconotus sulfureopectus*	2	0	0	0	0.5
Brown-headed Tchagra	*Tchagra australis*	3	5	6	5	4.75
Ashy Starling	*Cosmopsarus unicolor*	5	4	0	6	3.75
Mariqua Sunbird	*Nectarinia mariquensis*	6	0	0	6	3
Scarlet-chested Sunbird	*Nectarinia senegalensis*	3	0	0	0	0.75
Variable Sunbird	*Nectarinia venusta*	3	6	6	6	5.25
Paradise Whydah	*Vidua paradisaea*	6	0	6	6	4.5
Straw-tailed Whydah	*Vidua fischeri*	0	0	0	4	1
White-winged Widowbird	*Euplectes albonotatus*	4	6	6	0	4
Black-winged Red Bishop	*Euplectes hordeaceus*	6	6	6	6	6
Black-headed Weaver	*Ploceus nigricollis*	6	0	0	6	3
Little Weaver	*Ploceus luteolus*	0	4	6	6	4
Grey-headed Sparrow	*Passer griseus*	6	6	6	6	6
Crimson-rumped Waxbill	*Estrilda rhodopyga*	6	0	0	0	1.5
Jameson's Firefinch	*Lagonosticta rhodopareia*	5	0	0	6	2.75
Green-winged Pytilia	*Pytilia melba*	4	0	6	6	4
Red-cheeked Codon-bleu	*Uraeginthus bengalus*	6	0	0	5	2.75
Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	0	6	6	6	4.5
Bronze Mannikin	*Lonchura cucullata*	2	0	0	0	0.5
Yellow-fronted Canary	*Serinus mozambicus*	3	0	4	2	2.25

TABLE 4-65b
TIMED SPECIES COUNT LOCATION 2 (MAY, 1997)
Behind Skanksa Camp to Kakola Gate

Species		Series 1
Ring-necked Dove	*Streptopelia capicola*	6
Laughing Dove	*Streptopelia senegalensis*	6
Emerald-spotted Wood-dove	*Turtur tympanistria*	5
Klaas' Cuckoo	*Chrysococcyx klaas*	3
Speckled Mousebird	*Colius striatus*	6
Flappet Lark	*Mirafra rufocinnamomea*	2
Striped Swallow	*Hirundo abyssinica*	6
Drongo	*Dicrurus adsimilis*	5
Common Bulbul	*Pycnonotus barbatus*	6
Spotted Morning-Thrush	*Cichladusa guttata*	6
Grey-backed Cameroptera	*Camaroptera brevicaudata*	4
Warbler		4
Rattling Cisticola	*Cisticola chiniana*	5
Red-capped Cisticola	*Cisticola fulvicapilla*	2
Slate-coloured Boubou	*Laniarius funebris*	6
Sulphur-breasted Bush Shrike	*Malaconotus sulfureopectus*	6
Brown-headed Tchagra	*Tchagra australis*	4
Paradise Whydah	*Vidua paradisaea*	6
Black-winged Red Bishop	*Euplectes hordeaceus*	5
Grey-headed Sparrow	*Passer griseus*	6
Green-winged Pytilia	*Pytilia melba*	2
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	6
Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	1
Golden-breasted Bunting	*Emberiza flaviventris*	6
Yellow-rumped Seed-eater	*Serinus atrogularis*	6

TABLE 4-65c
TIMED SPECIES COUNT LOCATION 3 (MAY, 1997)
Kakola Village to Former Doboro 1 Village

Species		Series 1
Grey Heron	*Ardea cinerea*	3
Bateleur	*Terathopius ecaudatus*	2
Dark Chanting-Goshawk	*Melierax metabates*	2
Ring-necked Dove	*Streptopelia capicola*	6
Laughing Dove	*Streptopelia senegalensis*	5
Emerald-spotted Wood-dove	*Turtur tympanistria*	6
Speckled Mousebird	*Colius striatus*	6
Grey Hornbill	*Tockus nasutus*	5
d' Arnaud's Barbet	*Trachyphonus darnaudii*	3
Black-throated Honeyguide	*Indicator indicator*	6
Fisher's Sparrow-Lark	*Eremopterix leucopareia*	4
Flappet Lark	*Mirafra rufocinnamomea*	6
Striped Swallow	*Hirundo abyssinica*	2
Grey-backed Cameroptera	*Camaroptera brevicaudata*	4
Drongo	*Dicrurus adsimilis*	6
Common Bulbul	*Pycnonotus barbatus*	6
Slated-coloured Boubou	*Laniarius funebris*	6
Brown-headed Tchagra	*Tchagra australis*	6
Paradise Whydah	*Vidua paradisaea*	6
Speckle-fronted Weaver	*Sporopipes frontalis*	3
White-winged Widowbird	*Euplectes albonotatus*	6
Grey-headed Sparrow	*Passer griseus*	6
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	6
Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	6
Bronze Mannikin	*Lonchura cucullata*	5
Yellow-rumped Seed-eater	*Serinus atrogularis*	6
Yellow-fronted Canary	*Serinus mozambicus*	6

TABLE 4-65d
TIMED SPECIES COUNT LOCATION 4 (MAY, 1997)
Former Doboro Village to Northwestern Corner and Magazine

Species		Series				Mean
		1	2	3	4	
Little Egret	*Egretta garzetta*	0	0	0	1	0.25
Marabou	*Leptoptilos crumeniferus*	0	0	5	0	1.25
Bateleur	*Terathopius ecaudatus*	3	0	0	0	0.75
Dark Chanting-Goshawk	*Melierax metabates*	6	0	0	0	1.5
Namaqua Dove	*Oena capensis*	6	0	6	0	3.0
Ring-necked Dove	*Streptopelia capicola*	6	6	6	6	6.0
Laughing Dove	*Streptopelia senegalensis*	6	3	3	5	4.25
Emerald-spotted Wood-dove	*Turtur tympanistria*	5	6	6	6	4.75
Klaas' Cuckoo	*Chrysococcyx klaas*	0	0	0	6	1.5
White-browed Coucal	*Centropus superciliosus*	0	6	0	6	3.0
Blue-naped Mousebird	*Urocolius macrourus*	0	0	3	0	0.75
Speckled Mousebird	*Colius striatus*	2	6	6	6	3.5
Grey Hornbill	*Tockus nasutus*	4	0	0	0	1.0
Red-fronted Tinkerbird	*Pogoniulus pusilus*	3	0	0	0	0.75
d' Arnaud's Barbet	*Trachyphonus darnaudii*	2	0	4	0	1.5
Fischer's Sparrow-Lark	*Eremopterix leucopareia*	5	0	0	0	1.25
Flappet Lark	*Mirafra rufocinnamomea*	6	5	0	6	4.25
Striped Swallow	*Hirundo abyssinica*	0	6	4	6	3.5
Drongo	*Dicrurus adsimilis*	0	0	0	1	0.25
Oriole	*Oriolus sp.*	0	6	0	0	1.5
Pied Crow	*Corvus albus*	0	5	0	0	1.25
Common Bulbul	*Pycnonotus barbatus*	2	6	5	6	4.75
White-browed Scrub-Robin	*Cercotrichas leucophrys*	4	0	0	0	1.0
Spotted Morning Thrush	*Cichladusa guttata*	0	6	2	0	2.0
White-browed Robin-Chat	*Cossypha heuglini*	4	0	0	1	1.25
Grey-backed Cameroptera	*Camaroptera brevicaudata*	2	3	4	6	3.75
Rattling Cisticola	*Cisticola chiniana*	3	6	6	1	4.0
Red-capped Cisticola	*Cisticola fulvicapilla*	5	5	2	0	3.0
Tawny-flanked Prinia	*Prinia subflava*	0	0	6	6	3.0
Dusky Flycatcher	*Alseonax adustus*	5	0	0	0	1.25
Spotted Flycatcher	*Muscicapa striata*	2	0	0	0	0.5
Black-backed Puffback	*Dryoscopus cubla*	2	0	0	0	0.5
Slate-coloured Boubou	*Laniarius funebris*	6	6	6	6	6.0

TABLE 4-65e
TIMED SPECIES COUNT LOCATION 5 (MAY, 1997)
Magazine to Northern Corner then to Main Gate

Species		Series 1
Fish Eagle	*Haliaeetus vocifer*	4
Marabou	*Leptoptilos crumeniferus*	1
Ring-necked Dove	*Streptopelia capicola*	6
Laughing Dove	*Streptopelia senegalensis*	6
Emerald-spotted Wood-dove	*Turtur tympanistria*	5
Didric Cuckoo	*Chrysococcyx caprius*	3
Red-fronted Tinkerbird	*Pogoniulus pusilus*	3
d' Arnaud's Barbet	*Trachyphonus darnaudii*	4
Flappet Lark	*Mirafra rufocinnamomea*	6
Striped Swallow	*Hirundo abyssinica*	5
Oriole	*Oriolus sp.*	6
Common Bulbul	*Pycnonotus barbatus*	5
Green-backed Cameroptera	*Camaroptera brachyura*	3
Spotted Morning Thrush	*Cichladusa guttata*	6
Red-capped Cistocola	*Cisticola fulvicapilla*	5
Rattling Cisticola	*Cisticola chiniana*	6
Dusky Flycatcher	*Alseonax adustus*	1
African Pied Wagtail	*Motacilla aguimp*	1
Slate-coloured Boubou	*Laniarius funebris*	6
Ashy Starling	*Cosmopsarus unicolor*	1
Variable Sunbird	*Nectarinia venusta*	5
Paradise Whydah	*Vidua paradisaea*	6
Indigobird	*Hypochera sp.*	2
White-winged Widowbird	*Euplectes albonotatus*	6
Black-winged Red-Bishop	*Euplectes hordeaceus*	6
Grey-headed Sparrow	*Passer griseus*	6
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	6
Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	6
Purple Grenadier	*Uraeginthus ianthinogaster*	3

TABLE 4-66
BULYANHULU PROJECT TIMED SPECIES COUNT RESULTS FOR BIRDS, OCTOBER, 1997

Common Name	Latin Name	Series					Mean
		1	2	3	4	5	
Grey Heron	*Ardea cinerea*	0	0	0	0	0	0
Little Egret	*Egretta garzetta*	0	0	0	0	0	0
Hammerkop	*Scopus umbretta*	0	0	0	0	0	0
Marabou	*Leptoptilos crumeniferus*	0	0	0	0	0	0
Marsh Harrier	*Circus sp.*	0	0	0	0	0	0
Harrier Hawk	*Polyboroides radiatus*	0	0	0	0	0	0
Brown Snake-Eagle	*Circaaetus cinereus*	0	0	0	0	0	0
Bateleur	*Terathopius ecaudatus*	0	0	0	0	6	1.2
Eagle	*Aquila c.f. rapax*	0	0	0	0	6	1.2
Dark Chanting-Goshawk	*Melierax metabates*	0	0	0	0	0	0
Fish Eagle	*Haliaeetus vocifer*	0	0	0	0	0	0
Black Kite	*Milvus migrans*	0	0	0	4	6	2.0
African Hobby	*Falco cuvieri*	0	0	0	0	2	0.4
Red-necked Spurfowl	*Francolinus afer*	0	0	0	0	6	1.2
Helmeted Guineafowl	*Numida meleagris*	0	0	0	0	0	0
Namaqua Dove	*Oena capensis*	0	0	0	3	5	1.6
Ring-necked Dove	*Streptopelia capicola*	6	0	6	0	6	3.6
Red-eyed Dove	*Streptopelia semitorquata*	3	0	6	6	0	3.0
Laughing Dove	*Streptopelia senegalensis*	6	0	6	3	0	3.0
Emerald-spotted Wood-dove	*Turtur tympanistria*	6	0	5	0	0	2.2
Green Pigeon	*Treron australis*	6	0	0	0	0	1.2
Fischer's Lovebird	*Agapornis fischeri*	0	0	0	0	0	0
Red-headed Lovebird	*Agapornis pullaria*	0	0	0	0	0	0
Bare-faced Go-away-bird	*Corythaixoides concolor*	0	0	0	0	0	0
Didric Cuckoo	*Chrysococcyx caprius*	0	0	0	0	0	0
Klaas' Cuckoo	*Chrysococcyx klaas*	0	0	0	0	0	0
Great Spotted Cuckoo	*Clamator glandarius*	0	0	0	0	0	0
Black-and-white Cuckoo	*Clamator jacobinus*	0	0	0	0	0	0
White-browed Coucal	*Centropus superciliosus*	0	0	0	0	0	0
Owl	*Bubo c.f. africanus*	0	0	0	0	0	0
Pennant-winged Nightjar	*Macrodipteryx vexillarius*	0	0	0	0	0	0
Nightjar	*Caprimulgus sp.*	0	0	0	0	0	0
Palm Swift	*Cypsiurus parvus*	0	0	0	0	6	1.2
Speckled Mousebird	*Colius striatus*	5	0	6	4	0	3.0
Blue-naped Mousebird	*Urocolius macrourus*	0	0	0	0	0	0
Striped Kingfisher	*Halcyon chelicuti*	0	0	0	0	0	0
Gre-headed Kingfisher	*Halcyon leucocephala*	0	0	0	0	0	0
Pygmy Kingfisher	*Ispidna picta*	0	0	0	0	0	0
Little Bee-eater	*Merops pusillus*	0	0	0	0	0	0
Lilac-breasted Roller	*Coracias caudata*	0	0	0	0	0	0
Green Wood-Hoopoe	*Phoeniculus purpureus*	0	0	0	0	0	0
Red-billed Hombill	*Tockus erythrorhynchus*	0	0	0	0	0	0
Grey Hornbill	*Tockus nasutus*	0	0	0	0	0	0
Spotted-flanked Barbet	*Lybius lacrymosus*	0	0	0	0	0	0
Red-fronted Tinkerbird	*Pogoniulus pusillus*	0	0	0	0	0	0
d' Arnaud's Barbet	*Trachyphonus darnaudii*	2	0	0	0	0	0.4
Black-throated Honeyguide	*Indicator indicator*	0	0	0	0	0	0
Sparrow Lark	*Eremopterix leucopareia*	0	0	0	0	0	0
Flappet Lark	*Mirafra rufocinnamomea*	6	0	5	4	0	3.4
Striped Swallow	*Hirundo abyssinica*	0	0	0	0	0	0
Barn Swallow	*Hirundo rustica*	0	0	0	2	0	0.4
White-headed Rough-winged Swallow	*Psalidoprocne albiceps*	0	0	0	0	0	0
Black Rough-winged Swallow	*Psalidoprocne pristoptera*	0	0	0	0	0	0
Drongo	*Dicrurus adsimilis*	0	3	4	5	0	2.4
Black-headed Oriole	*Oriolus larvatus*	0	0	0	0	0	0
Pied Crow	*Corvus albus*	0	0	0	0	0	0
Black-lored Babbler	*Trichastoma melanops*	0	0	0	0	0	0
Black Cuckoo-Shrike	*Campephaga flava*	0	0	0	0	0	0
Common Bulbul	*Pycnonotus barbatus*	4	6	5	6	2	4.6

TABLE 4-66
BULYANHULU PROJECT TIMED SPECIES COUNT RESULTS FOR BIRDS, OCTOBER, 1997

Common Name	Latin Name	Series					Mean
		1	2	3	4	5	
White-browed Scrub-Robin	*Cercotrichas leucophrys*	0	5	0	5	0	2.0
Spotted Morning Thrush	*Cichladusa guttata*	6	0	5	5	0	3.2
White-browed Robin-Chat	*Cossypha heuglini*	0	3	0	0	0	0.6
Sooty Chat	*Myrmecocichla nigra*	0	0	0	0	0	0
Green-backed Camaroptera	*Camaroptera brachyura*	0	0	0	6	6	2.4
Yellow-breasted Apalis	*Apalis flavida*	0	0	0	0	0	0
Warbler	yellow with streaks on neck	0	0	0	5	0	1.0
Rattling Cisticola	*Cisticola chiniana*	0	0	0	4	4	1.6
Red-faced Cisticola	*Cisticola erythrops*	0	0	5	0	0	1.0
Red-capped Cisticola	*Cisticola fulvicapilla*	0	0	0	0	0	0
Tawny-flanked Prinia	*Prinia subflava*	0	0	0	2	0	0.4
Red-faced Crombec	*Sylvietta whytii*	0	0	3	0	0	0.6
Chin-spot Batis	*Batis molitor*	0	0	6	0	0	1.2
Silverbird	*Empidornis semipartitus*	0	0	0	0	0	0
Spotted Flycatcher	*Muscicapa striata*	0	0	0	0	0	0
Ashy Flycatcher	*Muscicapa caerulescens*	0	1	0	0	5	1.2
African Pied Wagtail	*Motacilla aguimp*	0	0	6	0	5	2.2
Black-backed Puffback	*Dryoscopus cubla*	0	0	4	0	0	0.8
Slate-coloured Boubou	*Laniarius funebris*	6	6	6	6	5	5.8
Brown-headed Tchagra	*Tchagra australis*	0	0	6	0	4	2.0
Sulphur-breasted Bush-Shrike	*Malaconotus sulfureopectus*	0	0	0	0	0	0
Shrike	*Lanius sp.*	0	0	0	0	0	0
Violet-backed Starling	*Cinnyricinclus leucogaster*	0	0	0	0	0	0
Ashy Starling	*Cosmopsarus unicolor*	6	4	6	4	0	4.0
Blue-eared Glossy Starling	*Lamprotornis chalybaeus*	0	0	5	0	0	1.0
Ruppell's Long-tailed Starling	*Lamprotornis purpuropterus*	0	0	0	0	0	0
Red-chested Sunbird	*Nectarinia erythroceria*	0	0	0	0	2	0.4
Mariqua Sunbird	*Nectarinia mariquensis*	0	0	0	0	0	0
Scarlet-chested Sunbird	*Nectarinia senegalensis*	5	0	0	0	0	1.0
Variable Sunbird	*Nectarinia venusta*	0	6	2	0	0	1.6
White-winged Widowbird	*Euplectes albonotatus*	0	0	0	0	0	0
Yellow-mantled Widowbird	*Euplectes macrourus*	0	0	0	0	0	0
Black-winged Red-Bishop	*Euplectes hordeaceus*	0	0	0	0	5	1.0
Unidentified Ploceus Weaver		0	6	0	4	0	2.0
Black-necked Weaver	*Ploceus nigricollis*	0	0	0	0	0	0
Grey-headed Sparrow	*Passer griseus*	5	0	4	3	0	2.4
Indigobird	*Hypochera sp.*	0	0	0	0	0	0
Straw-tailed Whydah	*Vidua fischeri*	0	0	0	0	0	0
Pin-tailed Whydah	*Vidua macroura*	0	0	0	0	0	0
Paradise Whydah	*Visua paradisaea*	0	0	0	0	0	0
Zebra Waxbill	*Amandava subflava*	0	0	0	0	0	0
Crimson-rumped Waxbill	*Estrilda rhodopyga*	0	0	0	0	0	0
Speckle-fronted Weaver	*Sporopipes frontalis*	0	0	5	0	0	1.0
Jameson's Firefinch	*Lagonosticta rhodopareia*	0	0	0	0	0	0
Green-winged Pytilia	*Pytilia melba*	0	0	0	0	0	0
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	0	6	0	6	0	2.4
Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	4	0	4	0	0	1.6
Purple Grenadier	*Uraeginthus ianthinogaster*	0	0	0	0	0	0
Cutthroat Waxbill	*Anadina fasciata*	0	0	0	0	0	0
Bronze Mannikin	*Lonchura cucullata*	1	0	6	0	2	1.8
Golden-breasted Bunting	*Emberiza flaviventris*	0	0	4	3	0	1.4
Yellow-rumped Seed-eater	*Serinus atrogularis*	0	0	4	0	0	0.8
Black-eared Serin	*Serinus mennelli*	0	0	0	0	0	0
Yellow-fronted Canary	*Serinus mozambicus*	4	0	0	1	1	1.2
unidentified:? button quail		0	0	0	0	1	0.2

TABLE 4-67
BIRD MIST NET RESULTS FOR MAY 1997

Date/Location/Time	Species	Latin Name	Number
22nd May, 1997	Cut-throat Waxbill	*Anadina fasciata*	4
Near Magazine, TSC area 4	Ashy Starling	*Cosmopsarus unicolor*	3
(08:30-12.00 hrs)	Green-backed Camaroptera	*Camaroptera brachyura*	5
	Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	7
	Purple Grenadier	*Uraeginthus ianthinogaster*	2
	Black-necked Weaver	*Ploceus nigricollis*	1
	Weaver, female (unspecified)		1
	Jameson's Fire-finch	*Lagonosticta rhodopareia*	3
	Blue-naped Mousebird	*Urocolius macrourus*	1
	Speckled Mousebird	*Colius striatus*	1
	Crimson-rumped Waxbill	*Estrilda rhodopyga*	5
(1700-18:30 hrs)	White-browed Robin-chat	*Cossypha heuglini*	1
	Speckled Mousebird	*Colius striatus*	1
	Bronze Mannikin	*Lonchura cucullata*	4
	Brown headed Tchagra	*Tchagra australis*	1
23rd May, 1997	Laughing Dove	*Streptopelia senegalensis*	1
TSC area 1	Variable Sunbird	*Nectarinia venusta*	1
(08:30 12.00 hrs)	Speckled Mousebird	*Colius striatus*	1
	Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	3
(1700 18:30 hrs)	Blue-capped Cordon-bleu	*Uraeginthus cyanocephalus*	2

TABLE 4-68
BUCKET PITFALL TRAP RESULTS FOR REPTILES AND AMPHIBIANS
MAY, 1997

Date 1997	No. of Traps	Catch Information	Notes
15-May	44	0	empty traps
16-May	77	BPFL 5: 1 lizard, 3 frogs	
17-May	66	BPFL 1: 1 frog BPFL 2: 1 snake BPFL 7, 1 frog, 1 snake	11 BPFTs stolen night of 16th;
18-May	66	0	empty traps
19-May	66	BPFL 7: 1 lizard	
20-May	66	BPFL 6,7: 3 frogs,1 lizard BPFL 2, 1 snake	
21-May	66	BPFL 6: 1 lizard	
22-May	66	0	empty traps
23-May	66	BPFL 4: 1 lizard BPFL 1, 1 frog	trapping ceased after night of 22 May.
Totals:	583	5 lizards, 9 frogs, 3 snakes	

TABLE 4-69
HERPETILE TRAPPING RESULTS FROM OCTOBER, 1997

Date	Trap Records	Comments
2-Oct	no trap success	
3-Oct	no trap success	
4-Oct	2 *Mabuya striata* (skink)	
5-Oct	no trap success	
6-Oct	2 *Mabuya striata* (skink) 1 Lacertid (lizard)	
7-Oct	1 *Bufo* (toad)	
Totals	5 reptiles 1 amphibian	210 BPFTs
Trapping Percents	6/210 = 2.9%	

TABLE 4-70
HERPETILES AT THE PROJECT SITE AND ITS SURROUNDINGS

Family	Genus and Species	Common Name	Comments
Class Amphibia			
Ranidae-True Frogs	*Tomopterna sp.* *Ptychadena anchietae* *Ptychadena sp.* *Phrynobatrachus sp.*	Sand Frog Plain Grass Frog Ridged Frog Puddle Frog	
Rhacophoridae-Foam-nest Frogs	*Chiromantis petersi*	Peters' Foam-nest Frog	
Hyperoliidae-Reed/tree Frogs	*Hyperolius sp.*	Reed/tree frog	heard only
Bufonidae-Toads	*Bufo gutturalis* *Bufo c.f. taitanus*	Guttural Toad Dwarf toad	species complex
Hemisotidae-Shovel-nosed Frogs	*Hemisus marmoratum*	Shovel-nosed frog	
Class Reptilia			
Gekkonidae-Geckos	*Pachydactylus sp.* *Hemidactylus sp.*	Thick-toed gecko probably House Gecko	 seen inside building, camp
Scincidae-Skinks	*Lygosoma afrum* *Mabuya brevicollis* *Mabuya striata*	Writhing Skink Short-necked Skink Common Striped Skink	several in BPFT
Varanidae-Monitor Lizards	*Varanus sp.*	probably Nile monitor	tracks seen river
Colubridae-Typical snakes	*Prosymna a. stuhlmanni* *Aparallactus capensis* *Rhamphiophis rostratus* *Psammophis phillipsi*	East-African Shovel-snout Cape Centipede-eater Beaked snake Phillips' Sand Snake	BPFT BPFT by hand, lived in termitarium in camp, killed in latrine BPFT
Elapidae-Cobras and Mambas	*Naja nigricollis* *Dendroaspis polylepis*	Black-necked Spitting-Cobra Black Mamba	three, DOR one DOR, one alive near airstrip

TABLE 4-71

HABITAT CAPABILITY RATINGS[1] FOR WILDLIFE OF MANAGEMENT CONCERN[2] FOUND IN THE BULYANHULU PROJECT AREA

SPECIES	LIFE HISTORY[3]	HABITAT TYPE[4]						AVERAGE BY SPECIES
		1	2	3	4	5	6	
BIRDS								
Tawny Eagle (*Aquila rapax*)	Resident of dry lowlands and plateaux. Nests are built atop a tree or utility pole. Prey usually consist of small mammals, reptiles, and large insects.	2.4	2.5	1.7	3.8	1.0	2.3	2.3
Brown Snake-Eagle (*Circaetus cinereus*)	Resident of woodlands and dense thornbush. Nests are built and lined with green leaves, atop a small tree on a hillside. Prey typically consists of cobras, mambas up to 3 m, puff adders, monitor lizards, and francolins.	3.0	2.7	1.9	2.8	1.0	2.3	2.3
Fish Eagle (*Haliaeetus vocifer*)	Resident of rivers, streams, lakes, seashores, and man-made reservoirs. Large stick nests are built in a tree or on a cliff nearby a waterbody. Prey consists almost entirely of fish.	1.0	1.0	1.0	4.0	0.8	1.6	1.6
Dark Chanting-Goshawk (*Melierax metabates*)	Resident of open, dry, bush country. Nests are built low in trees, lined with mud, rags, or dung, and covered with feathers or cobwebs. Prey generally consists of lizards, small birds, small mammals, and large insects.	2.5	2.9	2.4	2.8	1.5	2.4	2.4
African Harrier Hawk (*Polyboroides radiatus*)	Resident of woodlands, often close to a waterbody. Nests are constructed high in trees. Prey consists of the eggs and young of birds, bats, frogs, and insects; also the nuts of the oil palm.	2.5	2.0	1.7	3.5	1.0	2.1	2.1
Black Kite (*Milvus migrans*)	Resident of cities, villages, and watersides. Nests are built approximately 30 m up in a tree, and are lined with cloth and dung. rats, lizards, small birds, fish, and large insects; also carrion.	3.0	2.0	1.7	3.3	1.0	2.2	2.2
Bateleur (*Terathopius ecaudatus*)	Resident of open, broad-leafed woodlands with long grass, dense thornbush, acacia savannahs, semi-deserts, and open grassy plains. Nesting usually occurs hidden in a large tree. Prey consists of hares, dik-diks, guineafowl, bustards, doves, rollers, monitor lizards, and insects, as well as carrion.	3.3	2.9	2.5	2.8	1.7	2.6	2.6
African Hobby (*Falco cuvieri*)	Resident of forest edges, savannah country, and cultivated areas. Little is known about the nesting habits of this species. Prey consists mainly of insects, particularly termites.	3.1	3.2	2.8	2.8	1.8	2.7	2.7
Fischer's Lovebird (*Agapornis fischeri*)	Resident of savannah areas studded with large trees and thornbushes. Nesting occurs in colonies, within a tree hole or wall cavity. Food consists of seeds gleaned from the ground.	2.8	3.0	2.4	2.8	1.5	2.5	2.5
Red-headed Lovebird (*Agrapornis pullarius*)	Resident of open savannahs studded with trees and thornbushes. Nesting occurs in colonies, in tree holes or wall cavities. Food consists of seeds gleaned from the ground.	2.8	3.0	2.4	2.8	1.5	2.5	2.5

TABLE 4-71

HABITAT CAPABILITY RATINGS[1] FOR WILDLIFE OF MANAGEMENT CONCERN[2] FOUND IN THE BULYANHULU PROJECT AREA

SPECIES	LIFE HISTORY[3]	HABITAT TYPE[4]						AVERAGE BY SPECIES
		1	2	3	4	5	6	
Spotted Eagle-Owl (*Bubo africanus*)	Resident of rocky country and steep, bush clad ravines. Nesting occurs under the ledge of a rock on a hillside, or occasionally a large tree cavity. The spotted eagle-owl is a nocturnal species, preying on beetles, birds, and small reptiles.	2.0	1.7	1.7	2.3	1.0	1.7	1.7
Ashy Starling (*Cosmopsarus unicolor*)	Resident of bush country, riparian thickets, and baobab woodlands. Little is known about its nesting but it is suspected that this species is a cavity nester. Food consists of scraps, insects, fruit, and various other items.	2.4	2.1	1.8	3.2	1.7	2.2	2.2
Swahili Sparrow (*Passer suahilicus*)	Resident of bush country, cultivated areas, woodlands, and human dwellings. A nest of grasses and feathers is constructed in a tree or wall cavity. Food consists of seeds and insects gleaned from the ground.	3.3	3.3	2.7	3.3	1.3	2.7	2.7
AVERAGE FOR BIRDS		2.6	2.5	2.0	3.1	1.3	2.3	2.3
MAMMALS								
Vervet Monkey (*Cercopithecus aethiops*)	Found throughout the savannahs and steppes typically in open parkland, moist and dry savannahs, bushes, gallery forests, and bushy rock piles. They eat plants, insects, spiders, lizards, bird eggs, and young birds. They are diurnal, and sleep in trees.	3.0	2.5	1.65	3.5	1.0	2.33	2.3
REPTILES								
Nile Monitor Lizard (*Varanus niloticus*)	Typical habitats include rivers, lakes, and marshes, and their adjacent woodlands. Diet consists of unguarded crocodile and turtle eggs, crabs, mussels, frogs, fish, and birds. Their habits are not well documented but they are likely diurnal.	2.4	2.0	1.5	3.75	1.0	2.13	2.1
AVERAGE FOR ALL TAXA		2.6	2.4	2.0	3.2	1.2	2.3	2.3

[1] Ratings are based on a scale of 1 to 5, where 5 represents optimum habitat, and 1 represents very poor habitat

[2] Species observed in and around the project area which are listed in the Tanzanian Vertebrates of Conservation Concern (Howell, 1997)

[3] Compiled from Alden, *et al.* (1995), Whitaker (1992), Estes (1991), Fourie (1984), Haltenorth (1980), Benson, *et al.* (1971), FitzSimons (1970), Williams (1963), Maberly (1960), and Mackworth-Praed and Grant (1957)

[4] Numbered habitats correspond to the vegetation groups as follows:

1 - Dwarf *Acacia drepanolobium* wooded grasslandd
2 - *Combretum* coppicing open bushland with scattered thickets on termitaria
3 - Disturbed *Combretum* open shrub with grassland patches
4 - Riverine (Riparian) Vegetation
5 - Heavily Disturbed Areas
6 - Cultivation and Settlement Areas

TABLE 4-72
FREQUENCY AND DISTRIBUTION OF GRAVES ACCORDING TO SURVEY ZONE AND THE IDENTITIES OF THE DECEASED

Survey Zone	Artisan Miners	Peripheral Inhabitants	Unknown	Total
Zone I	7	--	--	7
Zone II	1	--	--	1
Zone III	14	2	--	16
Zone IV	--	2	4	6
Zone V	1	--	--	1
Zone VI	--	--	--	--
Zone VII	--	--	--	--
Total	23	4	4	31

TABLE 4-73
THE ESTIMATED AGE OF THE GRAVES

Survey Zone	<5 years	6-10 years	>10 years	Total
Zone I	7	--	--	7
Zone II	1	--	--	1
Zone III	12	3	1	16
Zone IV	2	--	4	6
Zone V	1	--	--	1
Zone VI	--	--	--	--
Zone VII	--	--	--	--
Total	23	3	5	31

TABLE 4-74

FOOD PRODUCTION DURING 1996 SEASON

Village	Households	Population	Able-bodied	Dependants	Available Food	Food Deficit
Bugarama	427	3325	1995	1330	85	821
Buyange	362	2056	1233	823	72	604
Kakola	477	986	591	395	42	268
Busindi	135	1115	669	446	27	302
lgwamanoni	250	923	553	370	50	240
Ilogi	280	1861	1116	745	56	506
Busulwangili	406	2130	1278	852	81	580
Total	**2337**	**12396**	**7435**	**4961**	**413**	**13321**

TABLE 4-75

LIVESTOCK NUMBERS IN BUGARAMA WARD DURING 1996

	Cattle	Goats	Sheep	Donkeys	Pigs
Bugarama	1354	596	117	11	
Buyange	1136	332	48	2	
Busindi	580	235	60	4	
Busulwangiii	2020	394	70	16	
liogi	1065	297	92	2	
lgwamanoni	524	140	14	3	
Kakola	1845	815	160	85	20
Total	8524	2809	561	123	20

Fig. 4-1(a). Temperature for Bulyanhulu (Mean Monthly), and Shinyanga (Mean Maximum and Minimum)

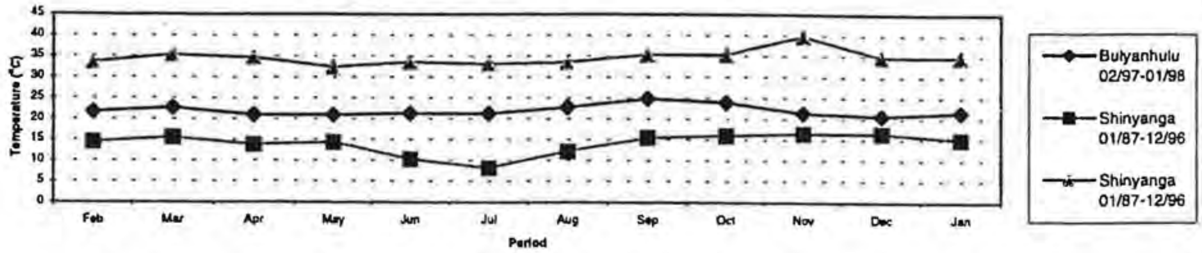


Fig. 4-1(b). Monthly Rainfall for Bulyanhulu and Mean Monthly Rainfall for Shinyanga

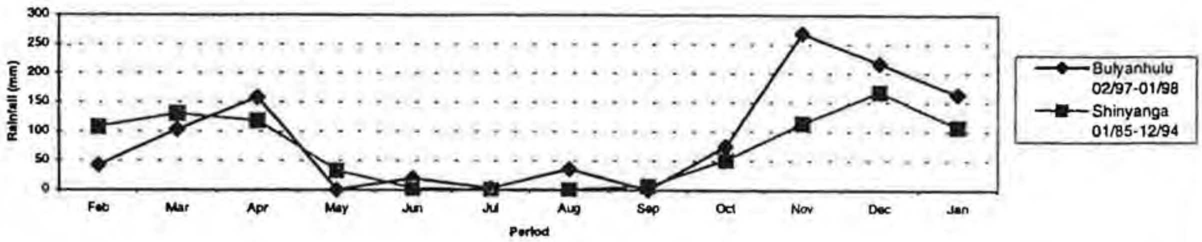


Fig. 4-1(c). Mean Wind Speeds for Bulyanhulu (24 hours monthly mean) and Shinyanga (monthly mean @ 12:00 GMT)

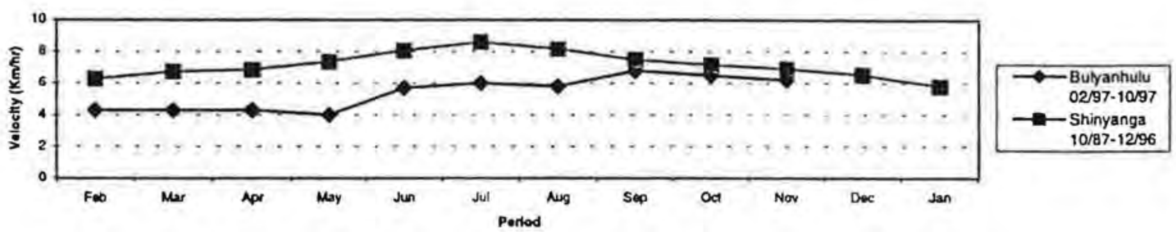
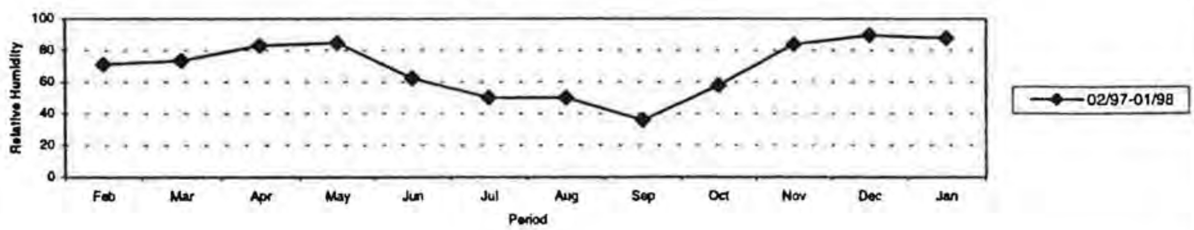


Fig. 4-1(d). Relative Humidity Distribution for Bulyanhulu



Monitoring Period: Shinyanga 1985 - 1996
Bulyanhulu 1997 - 1998

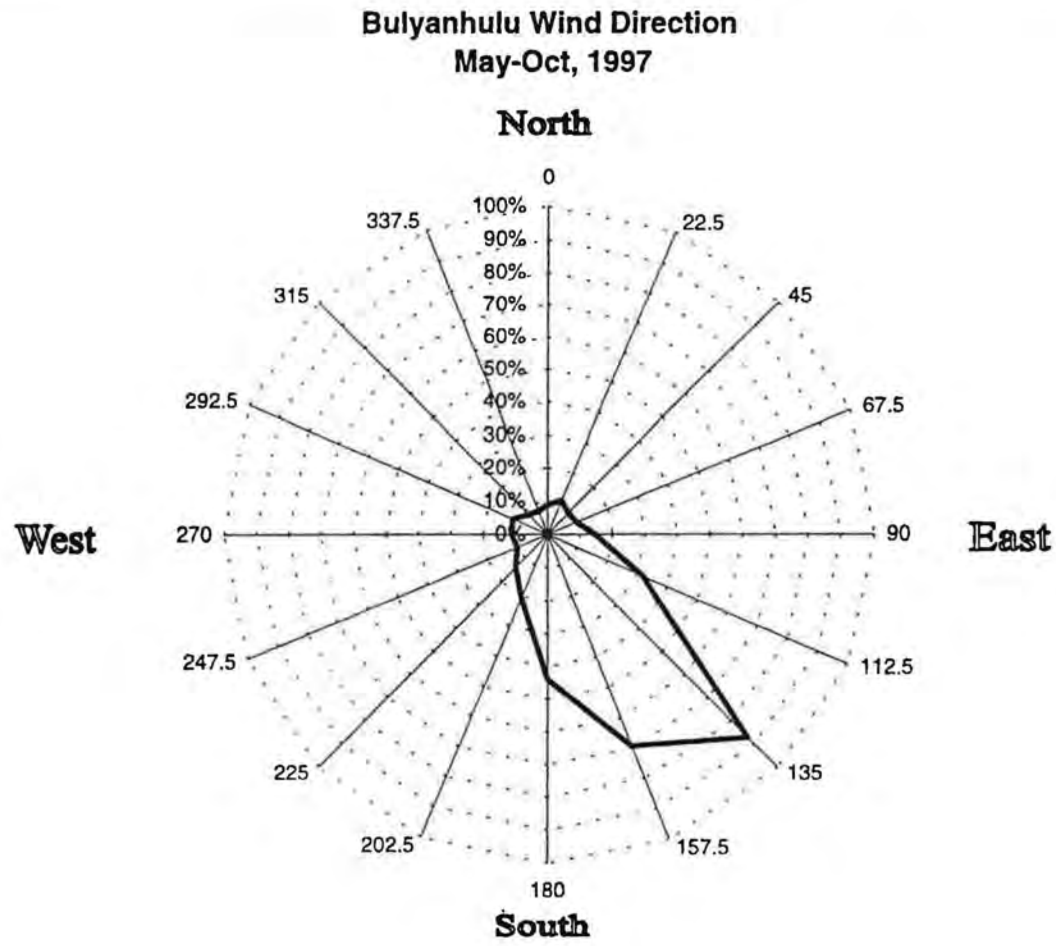
MONTHLY METEORLOGICAL DATA
FOR SHINYANGA AND BULYANHULU
BULYANHULU PROJECT
TANZANIA

KAHAMA MINING CO. LTD.

MAY 1998 | FIGURE 4-1

Job No.: 35367-001-310

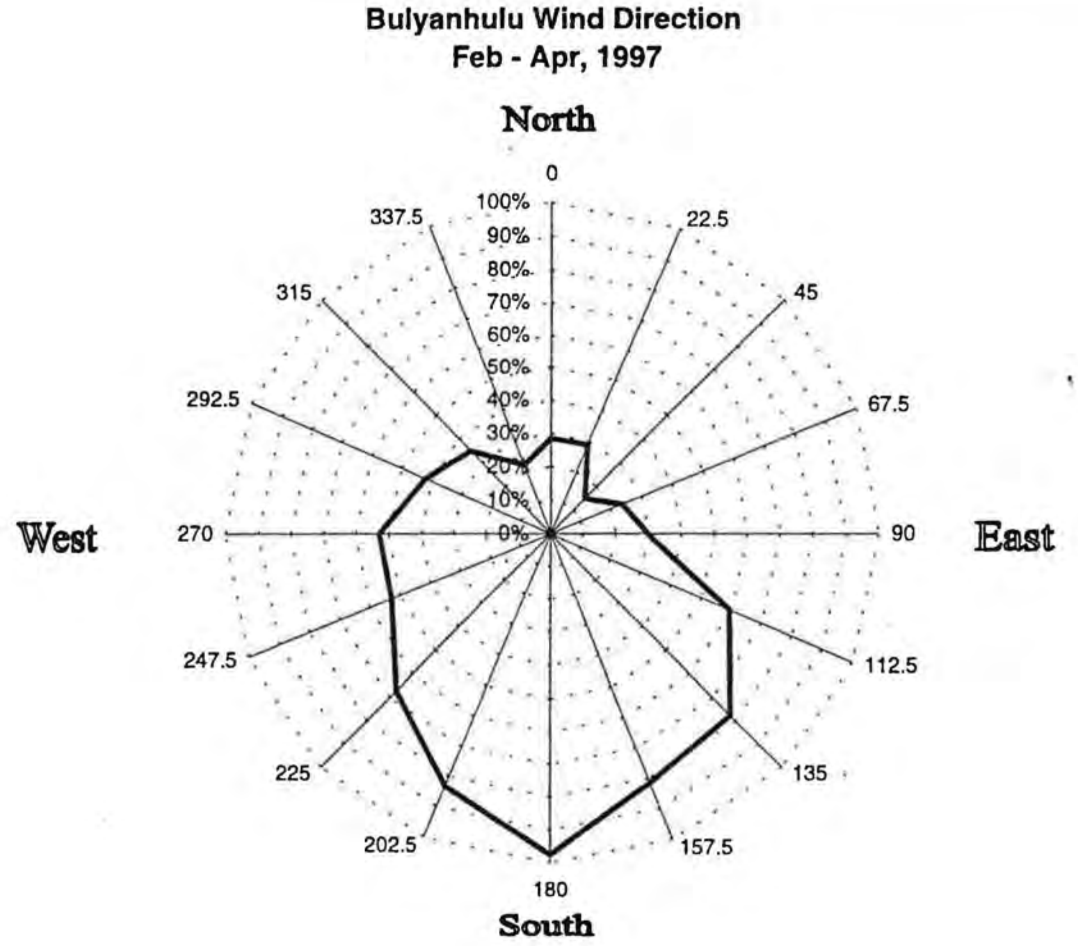
NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



WIND DIRECTION: MAY-OCT, 1997 BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-2

Job No.: 35367-001-310

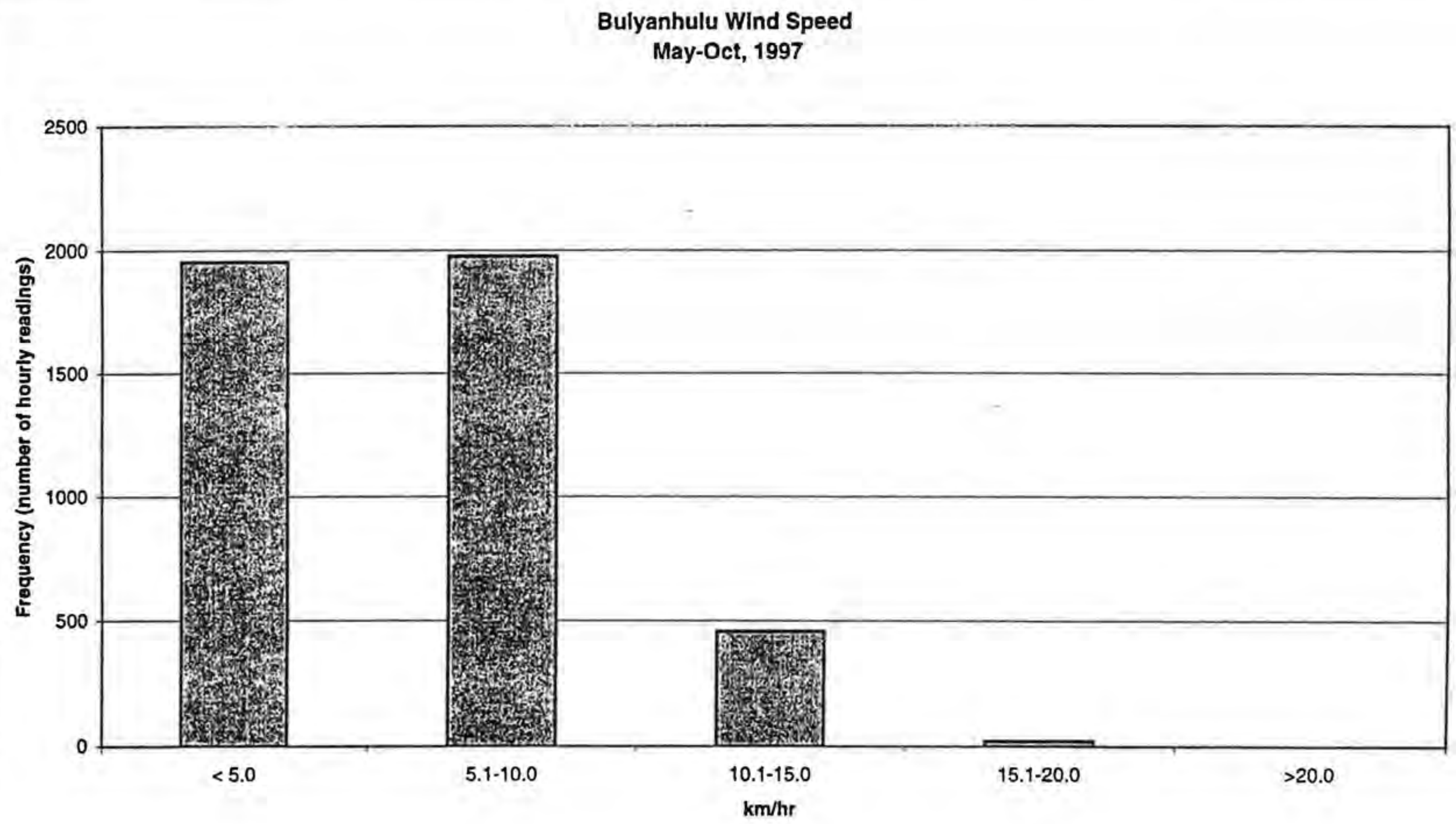
NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



WIND DIRECTION: FEB-APR, 1997 BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-3

Job No.: 35367-001-310

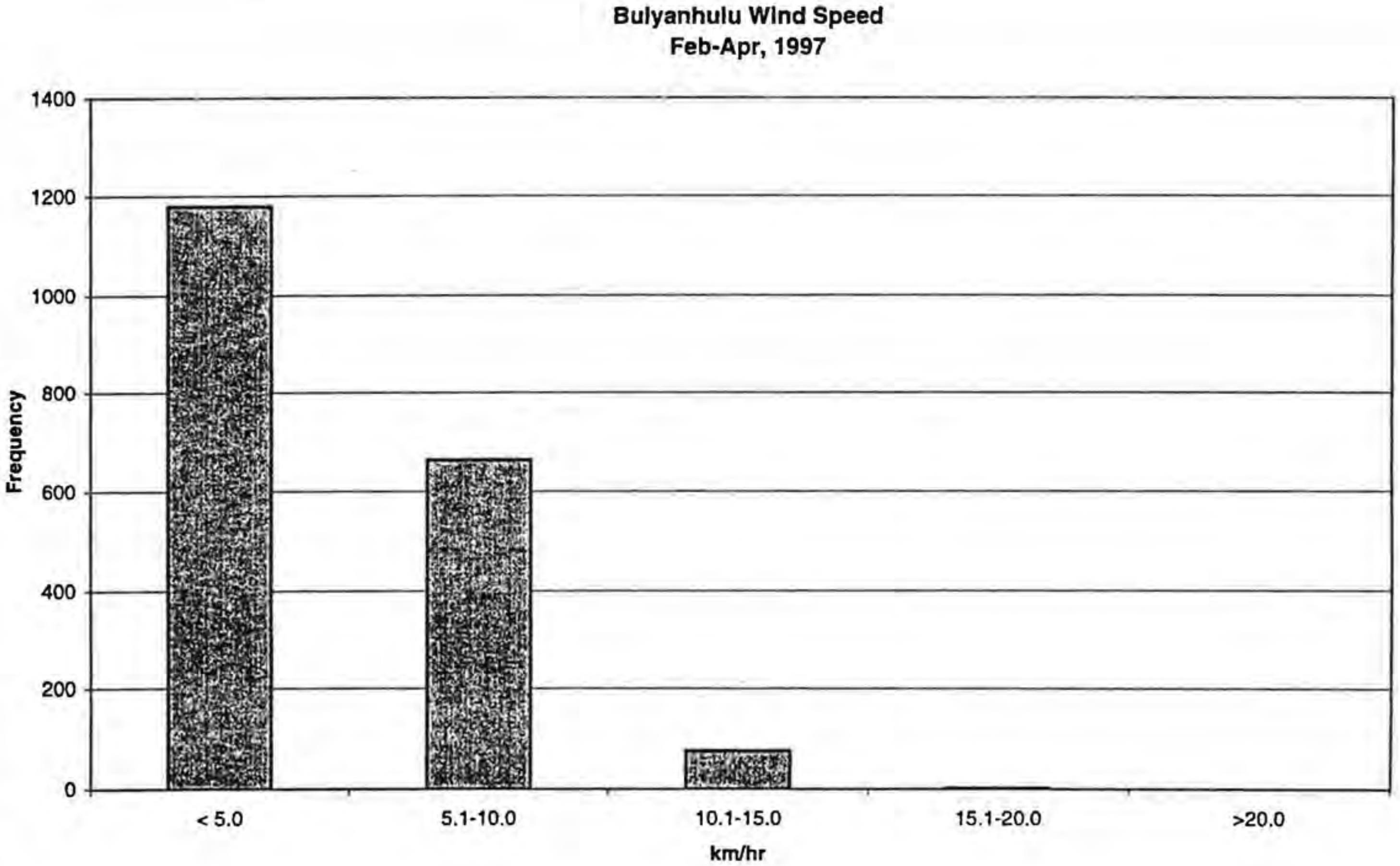
NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



WIND SPEED: MAY-OCT, 1997 BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-4

Job No.: 35367-001-310

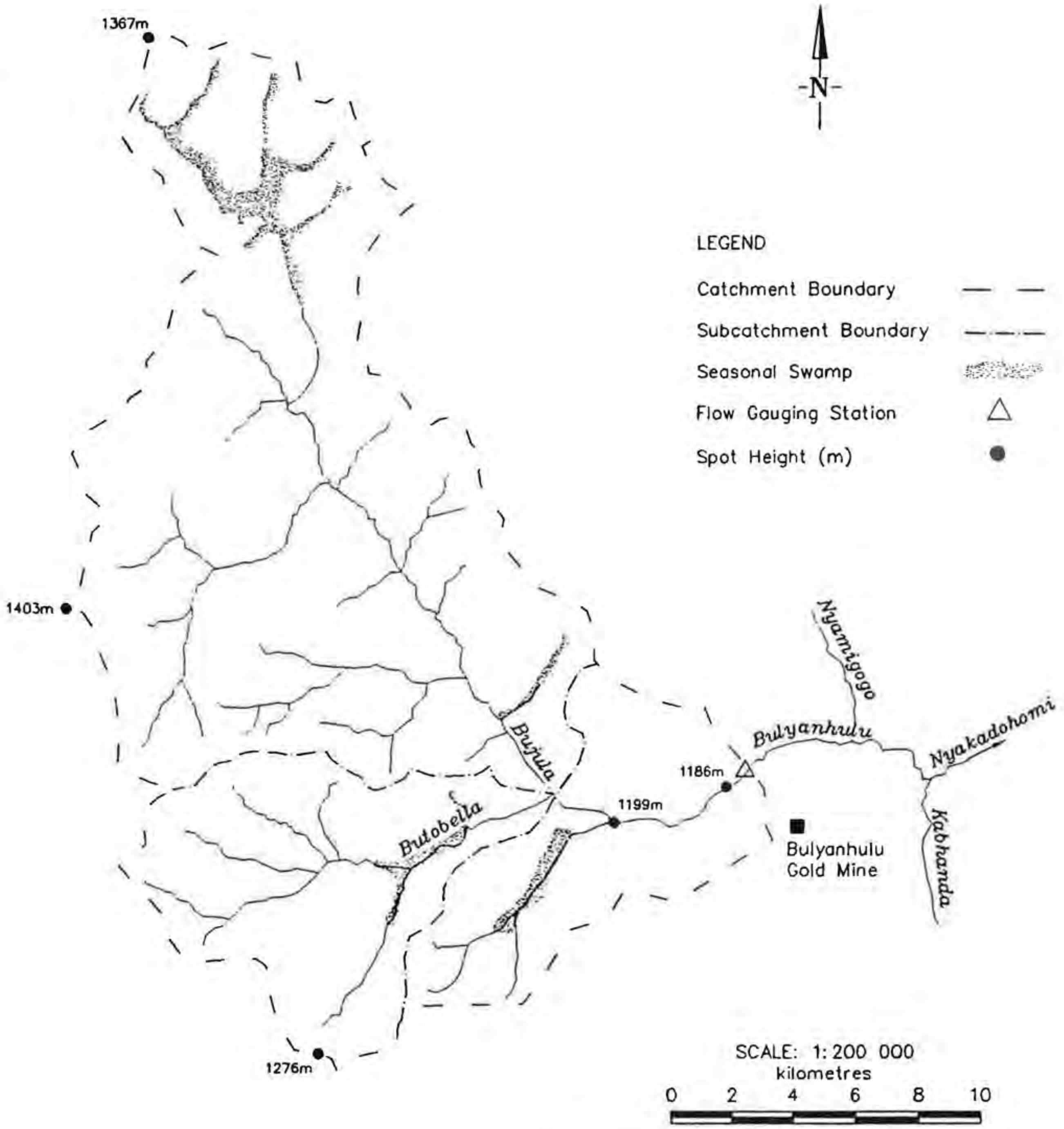
NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



WIND SPEED: FEB-APR, 1997 BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-5

Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



BULYANHULU CATCHMENT BASIN

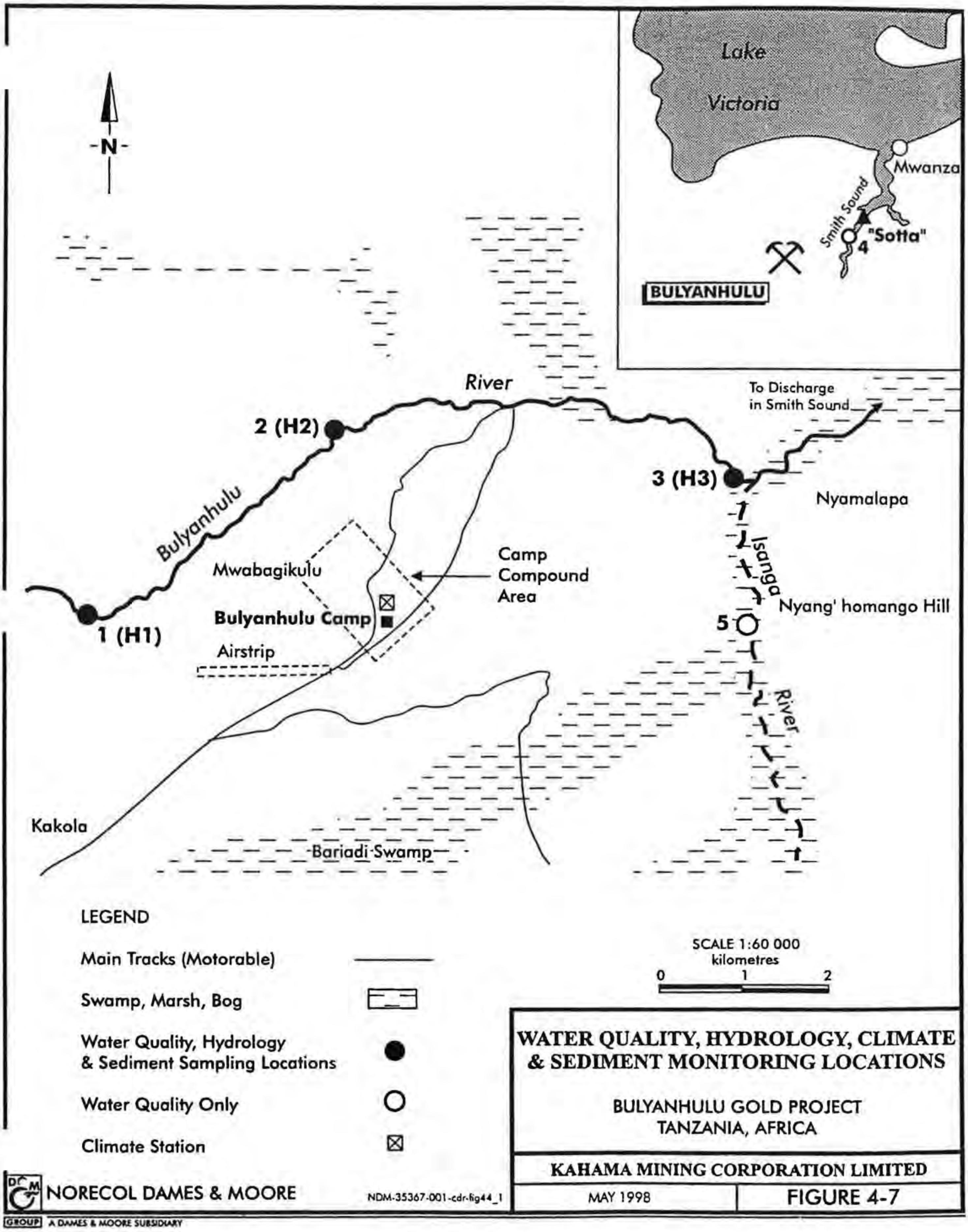
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-6

NORECOL DAMES & MOORE 35367-001-ndm-buly_catch

GROUP A DAMES & MOORE SUBSIDIARY

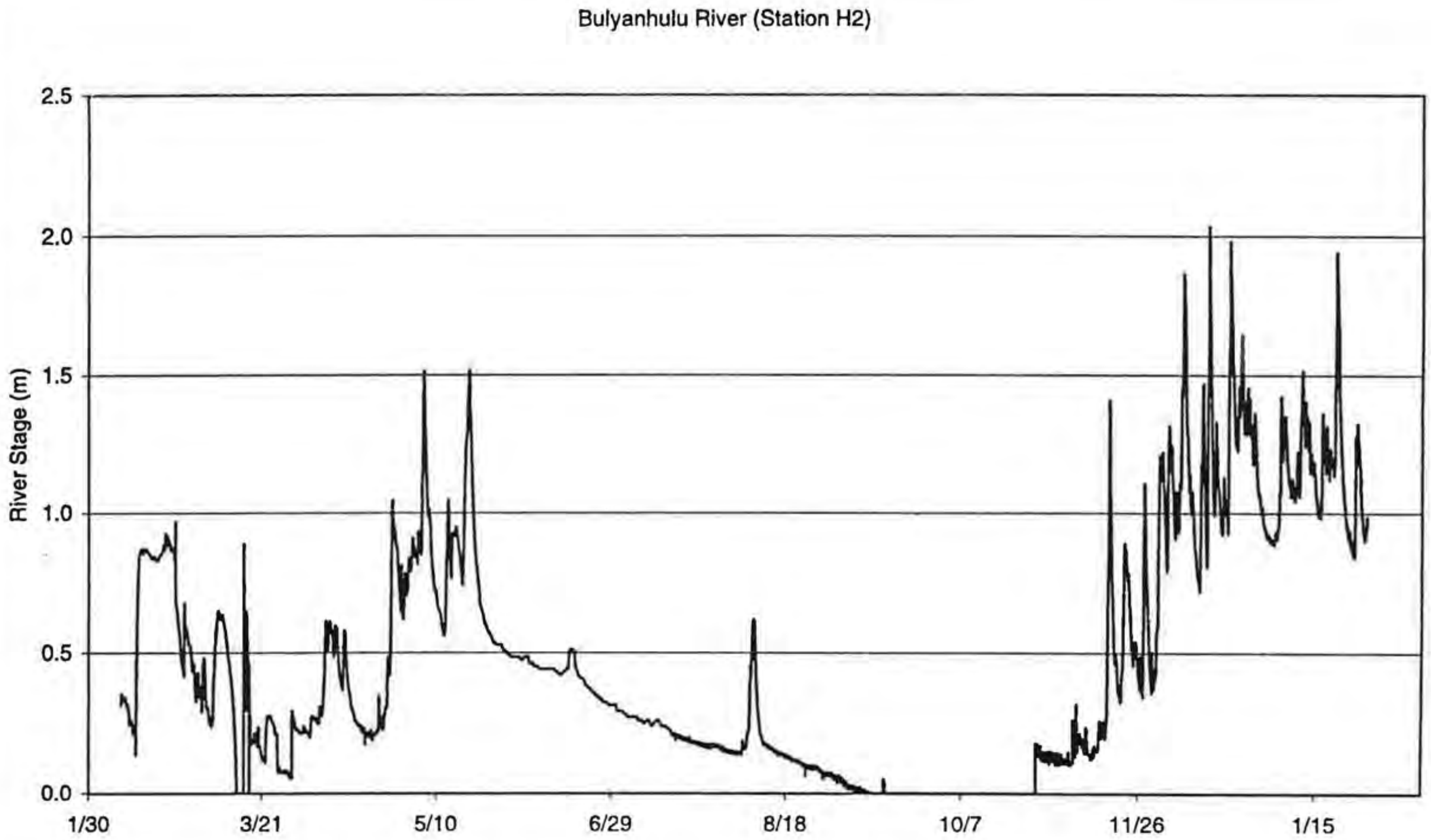


WATER QUALITY, HYDROLOGY, CLIMATE & SEDIMENT MONITORING LOCATIONS

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

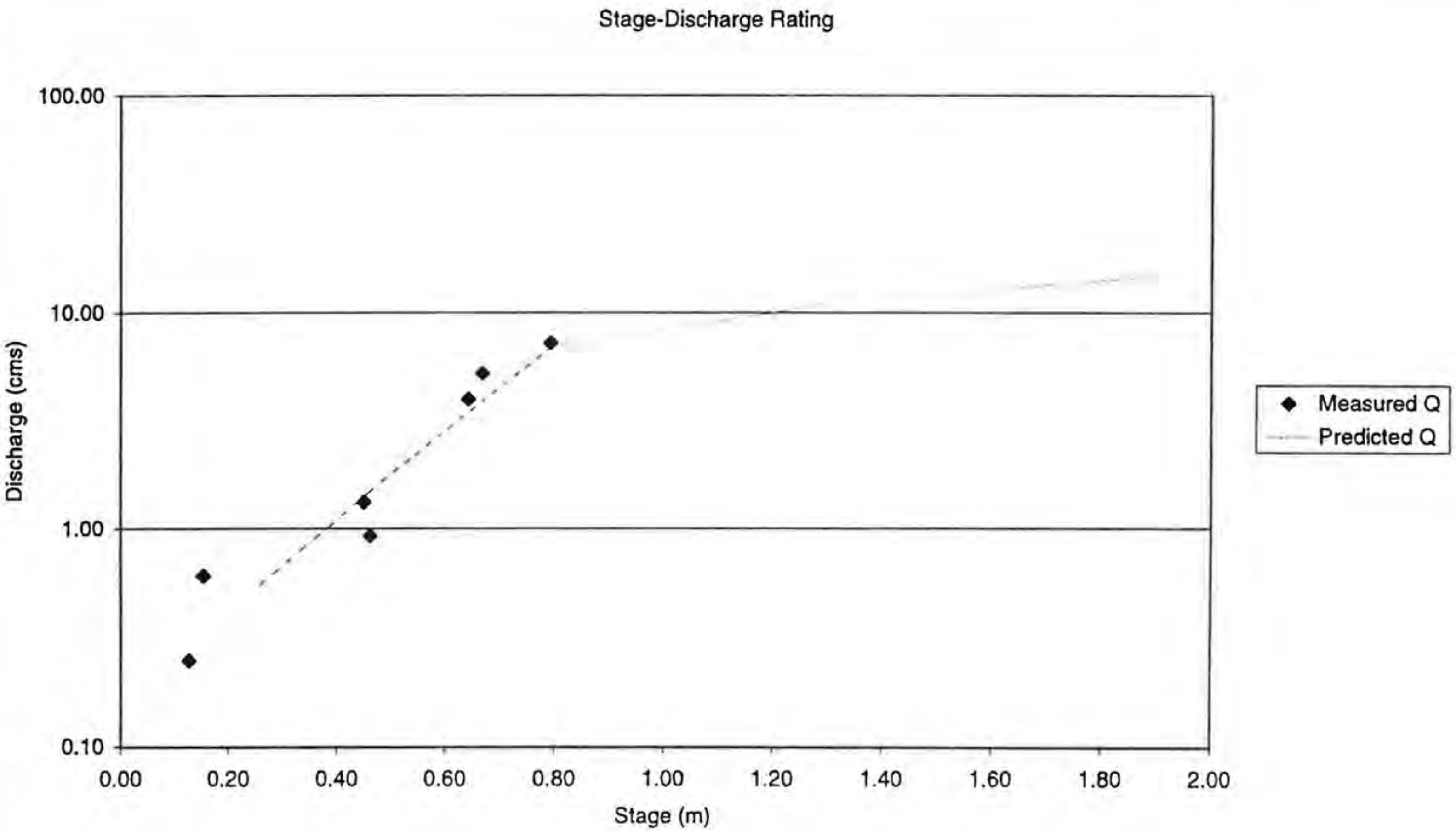
MAY 1998 | **FIGURE 4-7**



BULYANHULU RIVER STAGE AT H2
FEBRUARY 9, 1997 TO JANUARY 29, 1998
BULYANHULU PROJECT
TANZANIA

KAHAMA MINING CO. LTD.

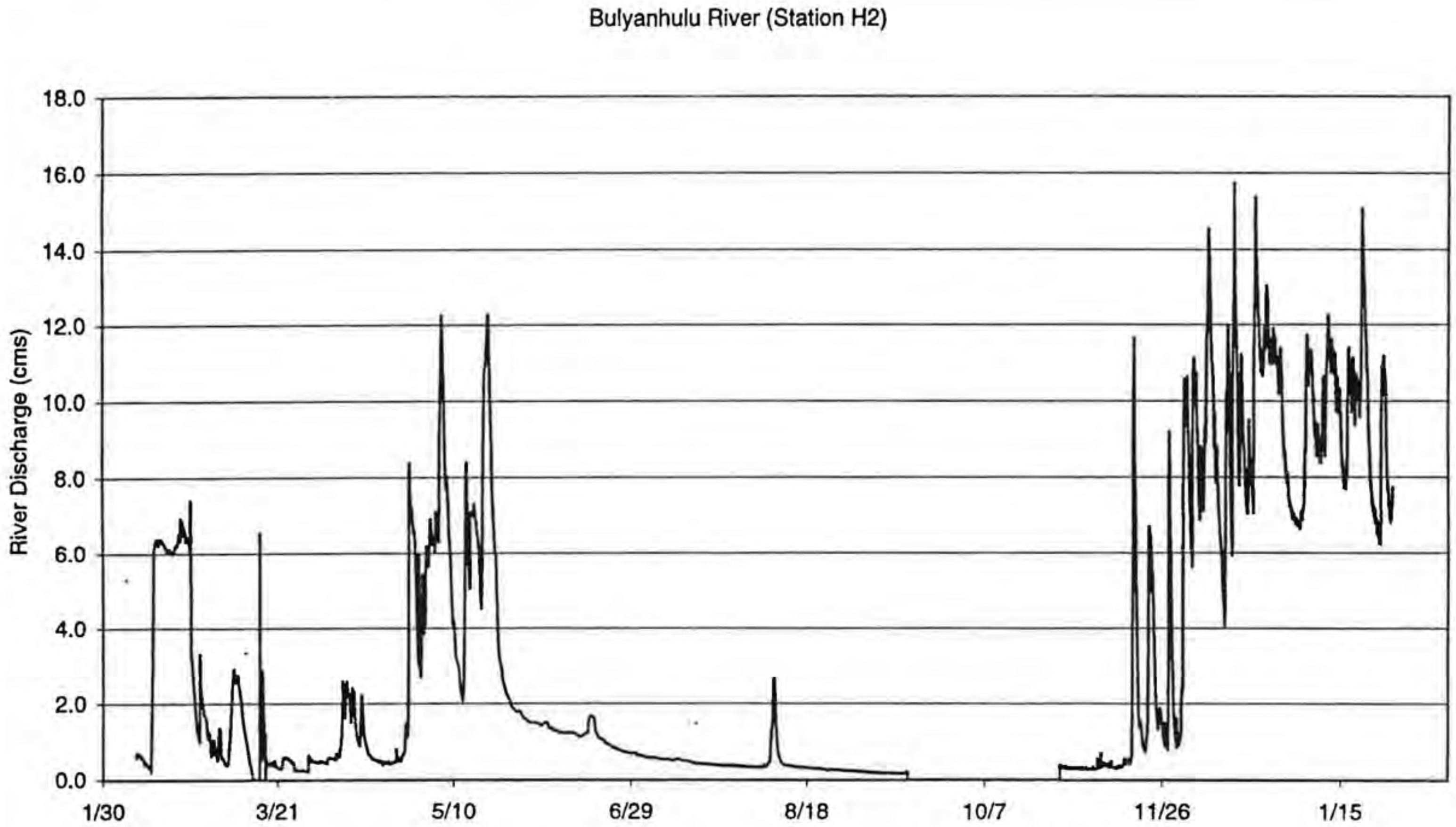
MAY 1998	FIGURE 4-8



STAGE-DISCHARGE RATING CURVE FOR BULYANHULU RIVER AT H2 BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-9

Job No.: 35367-001-310

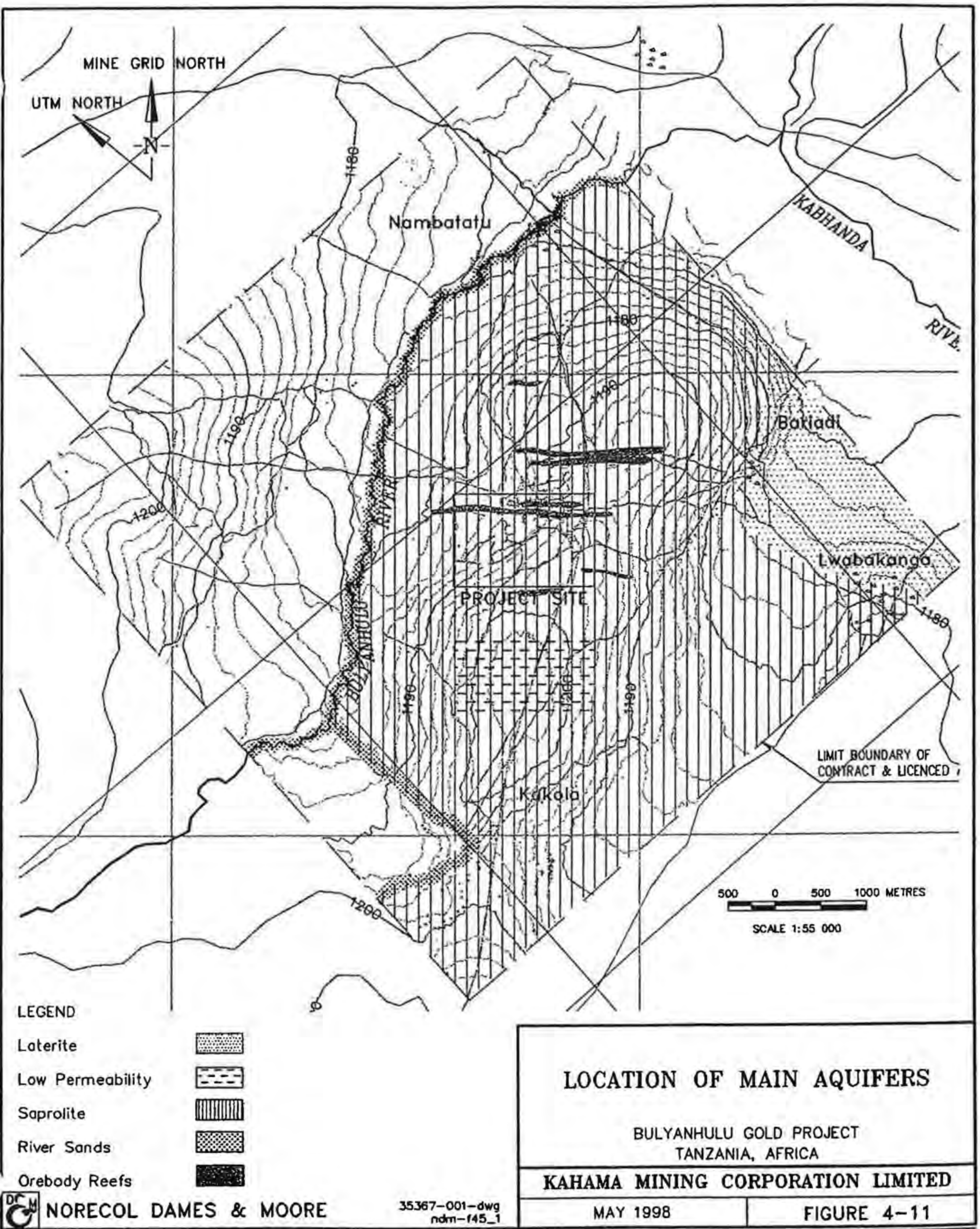
NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



BULYANHULU RIVER STREAMFLOW HYDROGRAPH AT H2 FEBRUARY 9, 1997 TO JANUARY 29, 1998 BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-10

Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



LOCATION OF MAIN AQUIFERS

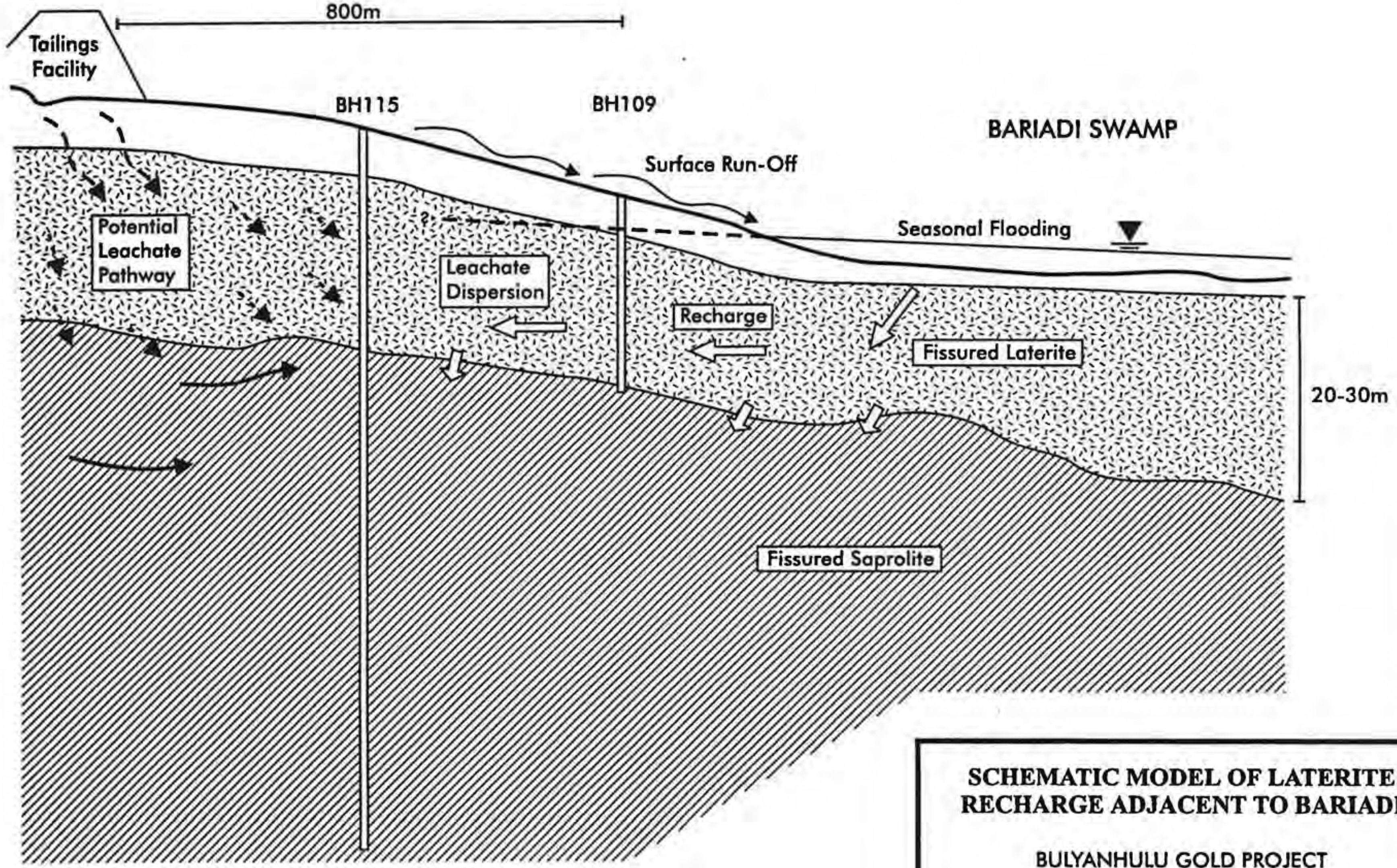
BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-11

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-dwg
ndm-f45_1



SCHEMATIC MODEL OF LATERITE RECHARGE ADJACENT TO BARIADI

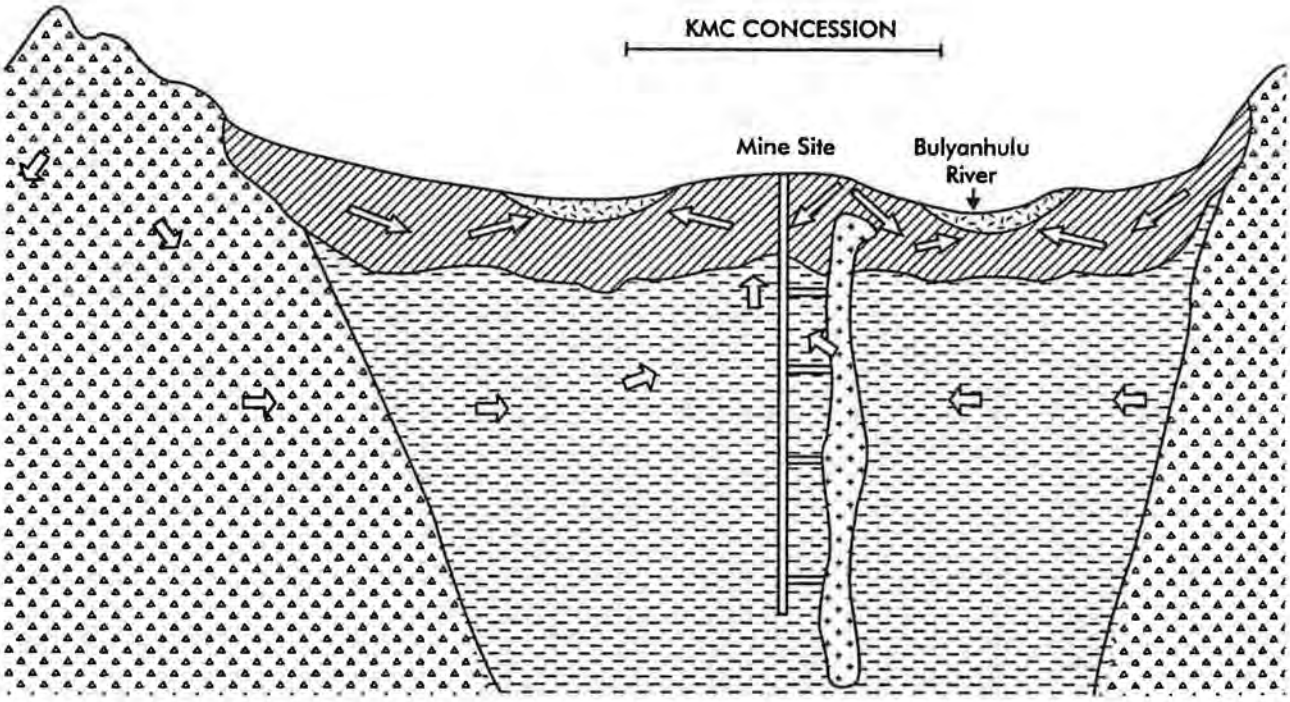
BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | **FIGURE 4-12**

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY

35367-001-NDM-cdr-f45_2



LEGEND

Laterite

Saprolite

Greenstone/Volcanic Bedrock

Granite

Mineralized Orebody

Inferred Regional Groundwater Flow
Saprolite
Greenstone

SCHEMATIC CROSS-SECTION OF REGIONAL GROUNDWATER FLOW

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

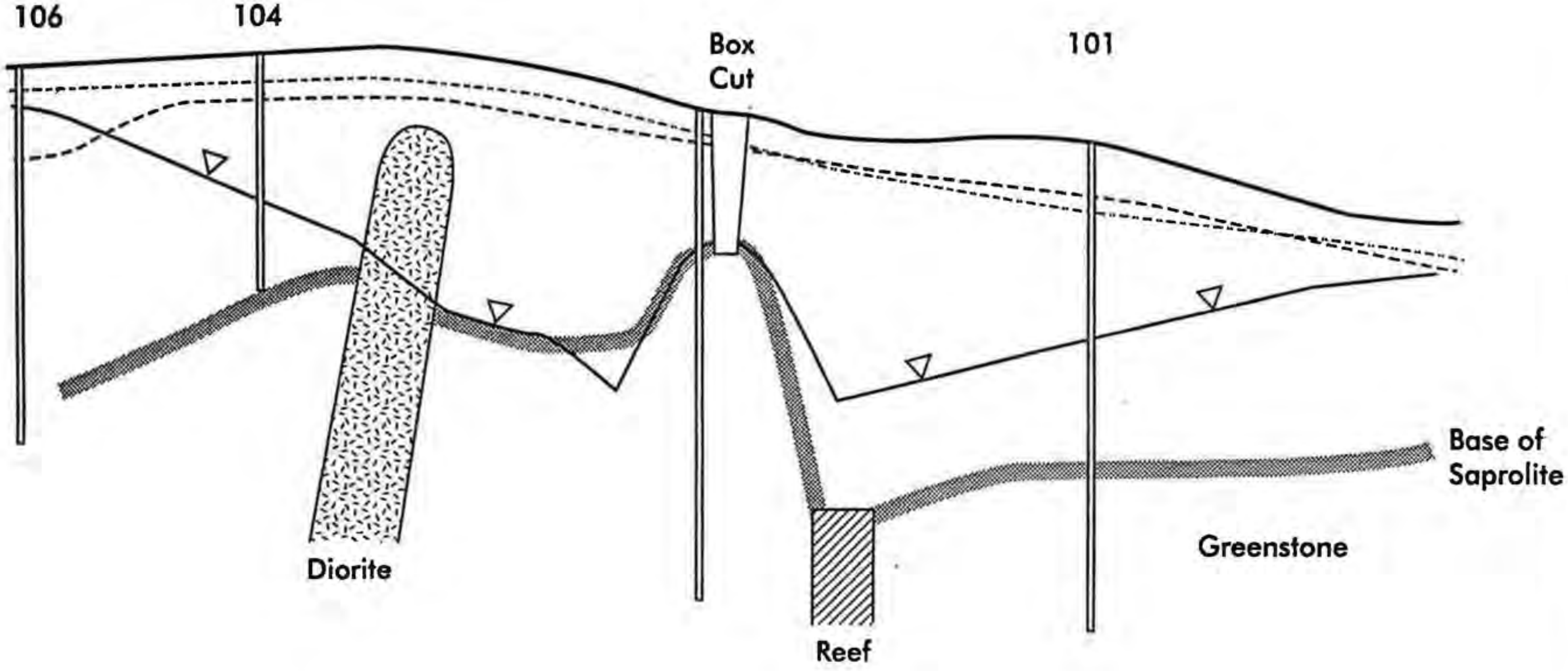
KAHAMA MINING CORPORATION LIMITED

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-adr-F45_3

MAY 1998

FIGURE 4-13



SCHEMATIC CROSS-SECTION WITH ESTIMATED CURRENT SAPROLITE GROUNDWATER HEADS

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

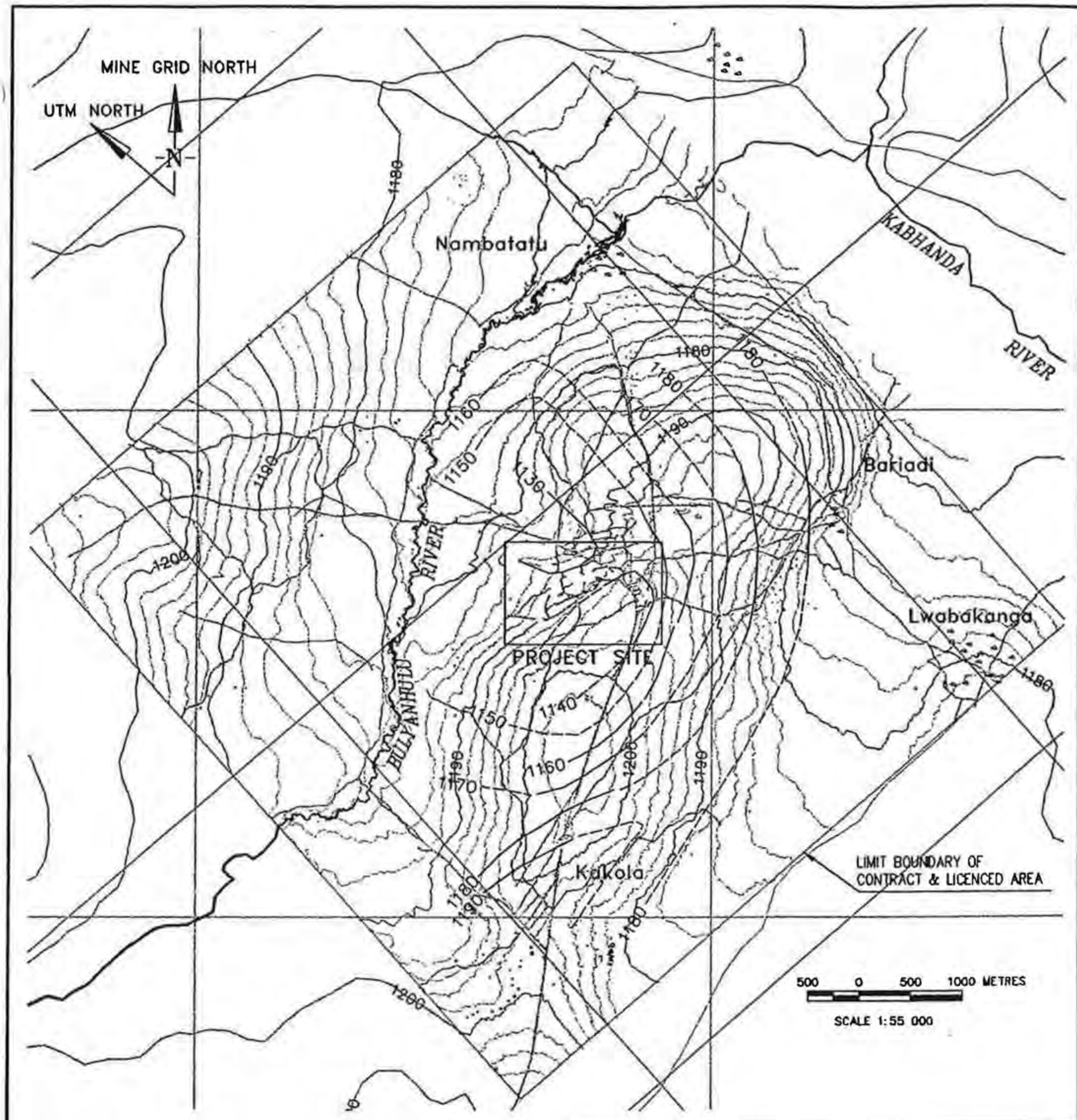
KAHAMA MINING CORPORATION LIMITED

MAY 1998

FIGURE 4-14

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-NDM-cdr-l45_4



SCHEMATIC BASELINE GROUNDWATER CONTOUR PLOT

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

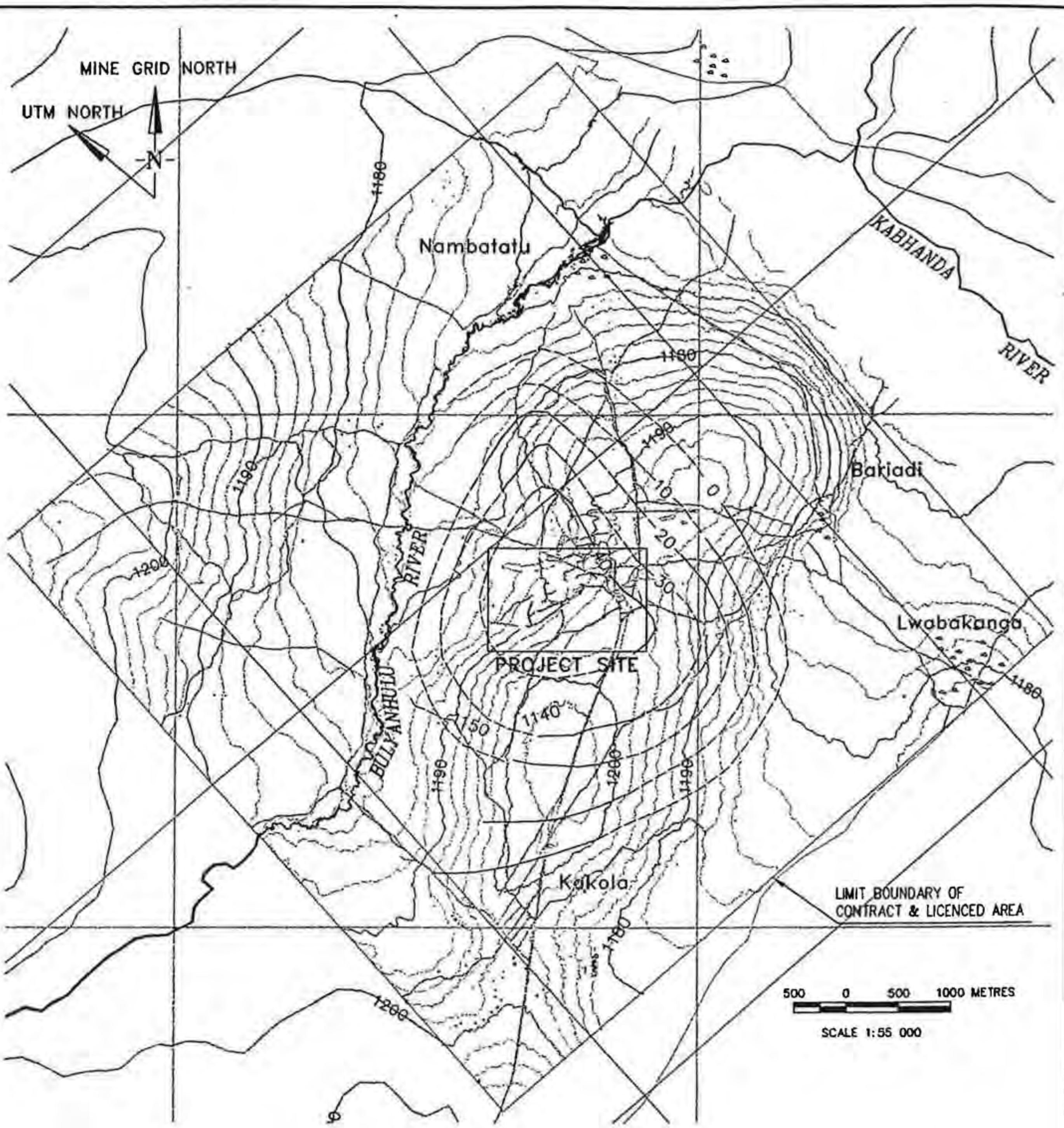
KAHAMA MINING CORPORATION LIMITED

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-dwg
ndm-f45_5

MAY 1998

FIGURE 4-15



Note: Based on initial rest water level 15 m bgl

ESTIMATED DRAWDOWN FROM CURRENT GROUNDWATER ABSTRACTION IN SAPROLITE

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

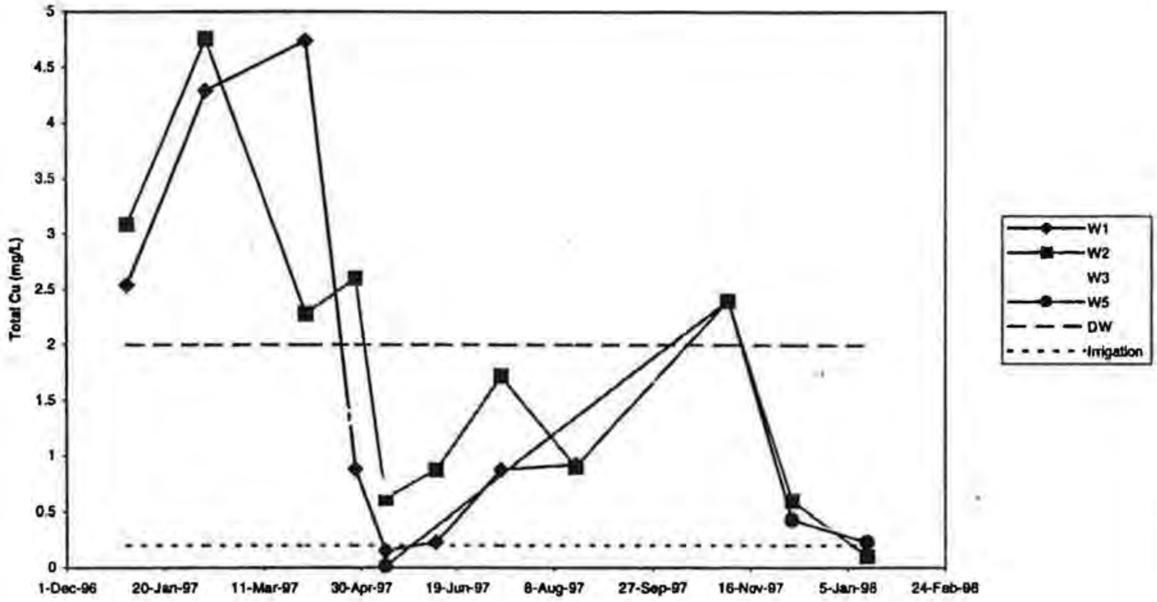
KAHAMA MINING CORPORATION LIMITED

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-dwg
ndm-f45_6

MAY 1998

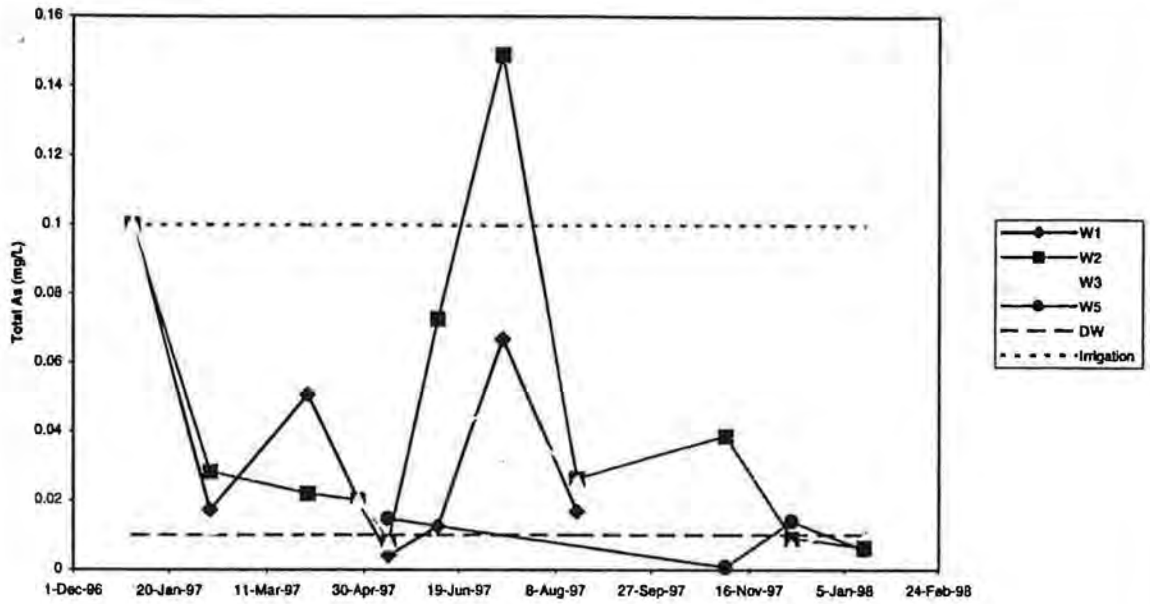
FIGURE 4-16

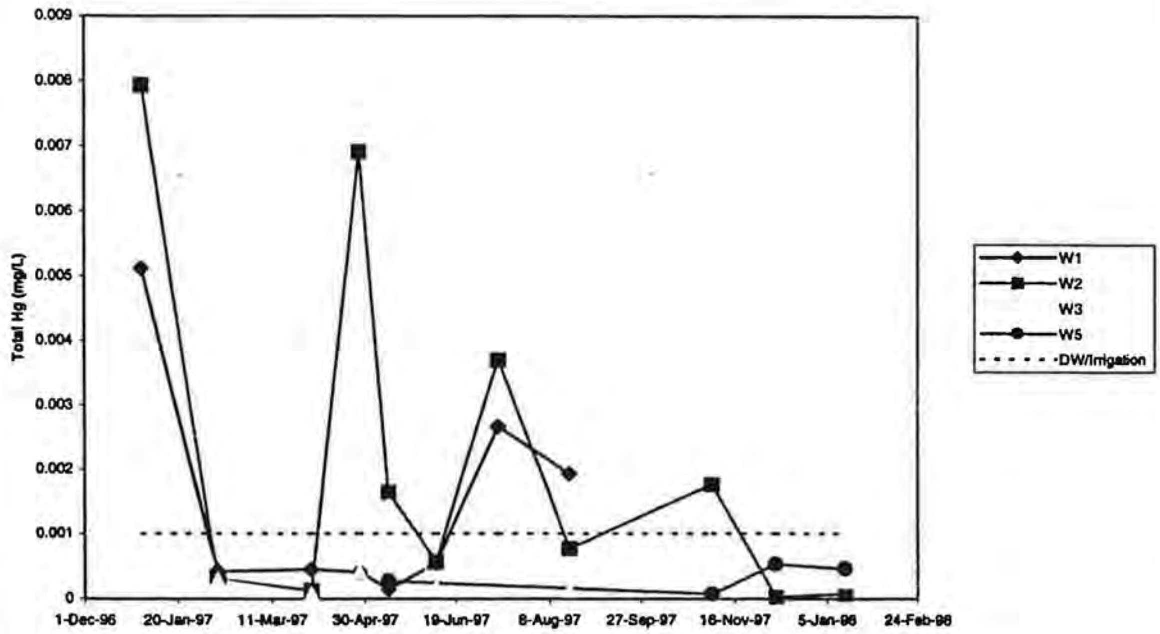


TOTAL COPPER VS TIME BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-17

Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY





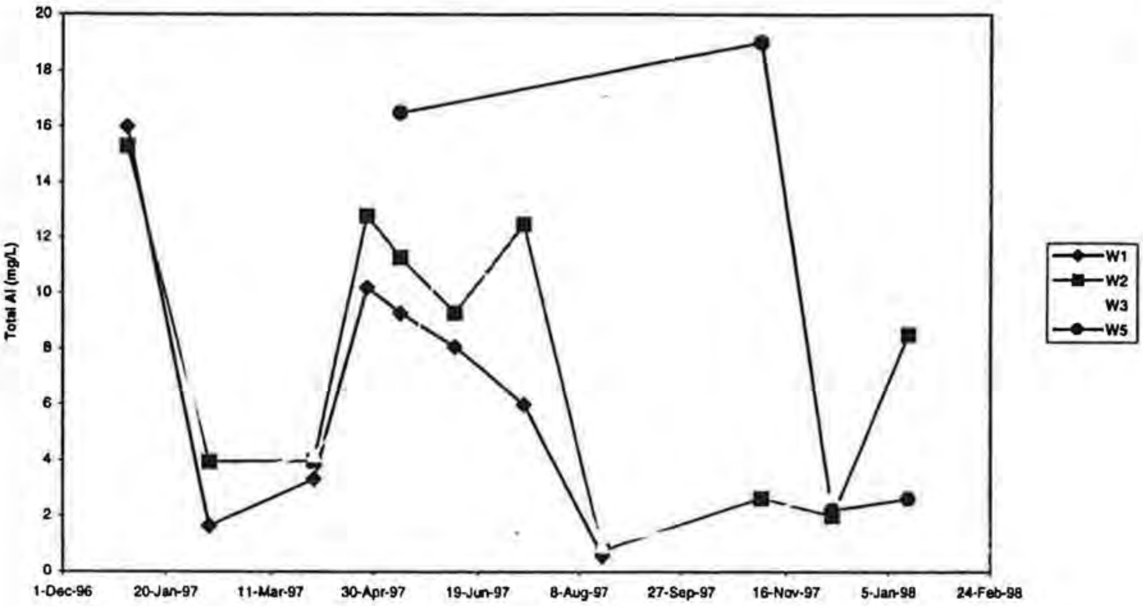
TOTAL As VS TIME
TOTAL Hg VS TIME
BULYANHULU PROJECT
TANZANIA

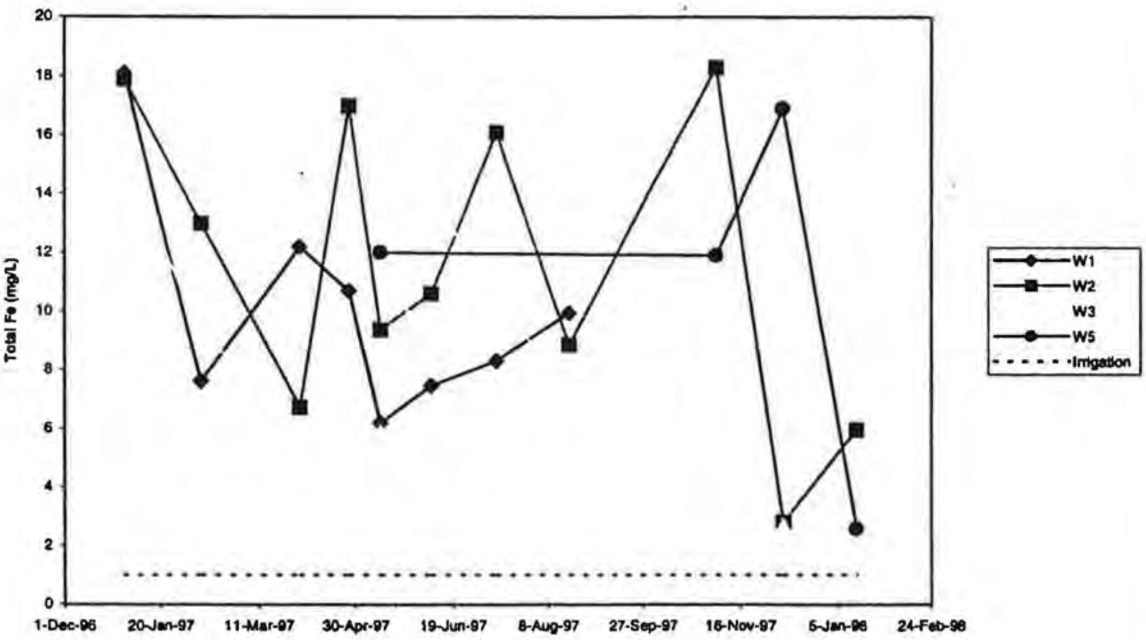
KAHAMA MINING CO. LTD.

MAY 1998 | FIGURE 4-18

Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY

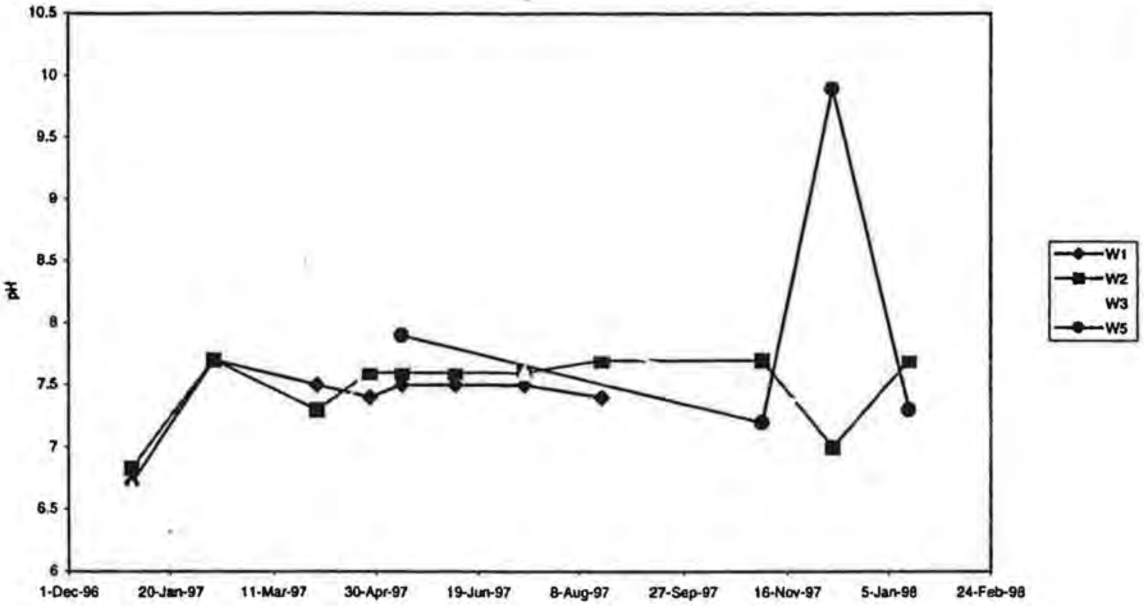


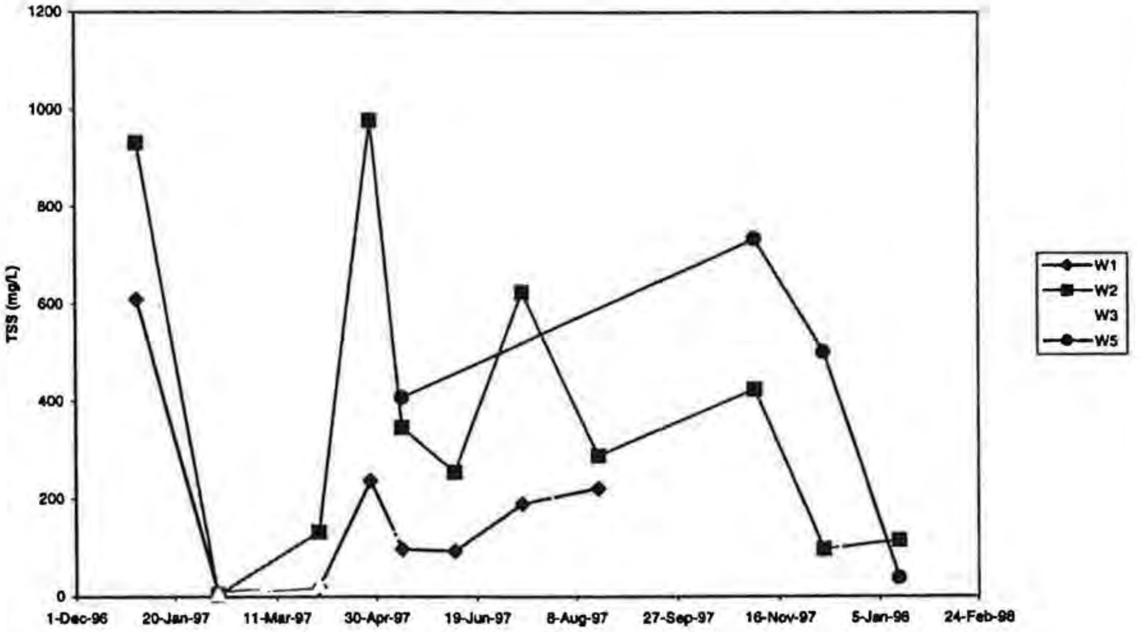


TOTAL Al VS TIME TOTAL Fe VS TIME BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-19

Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY

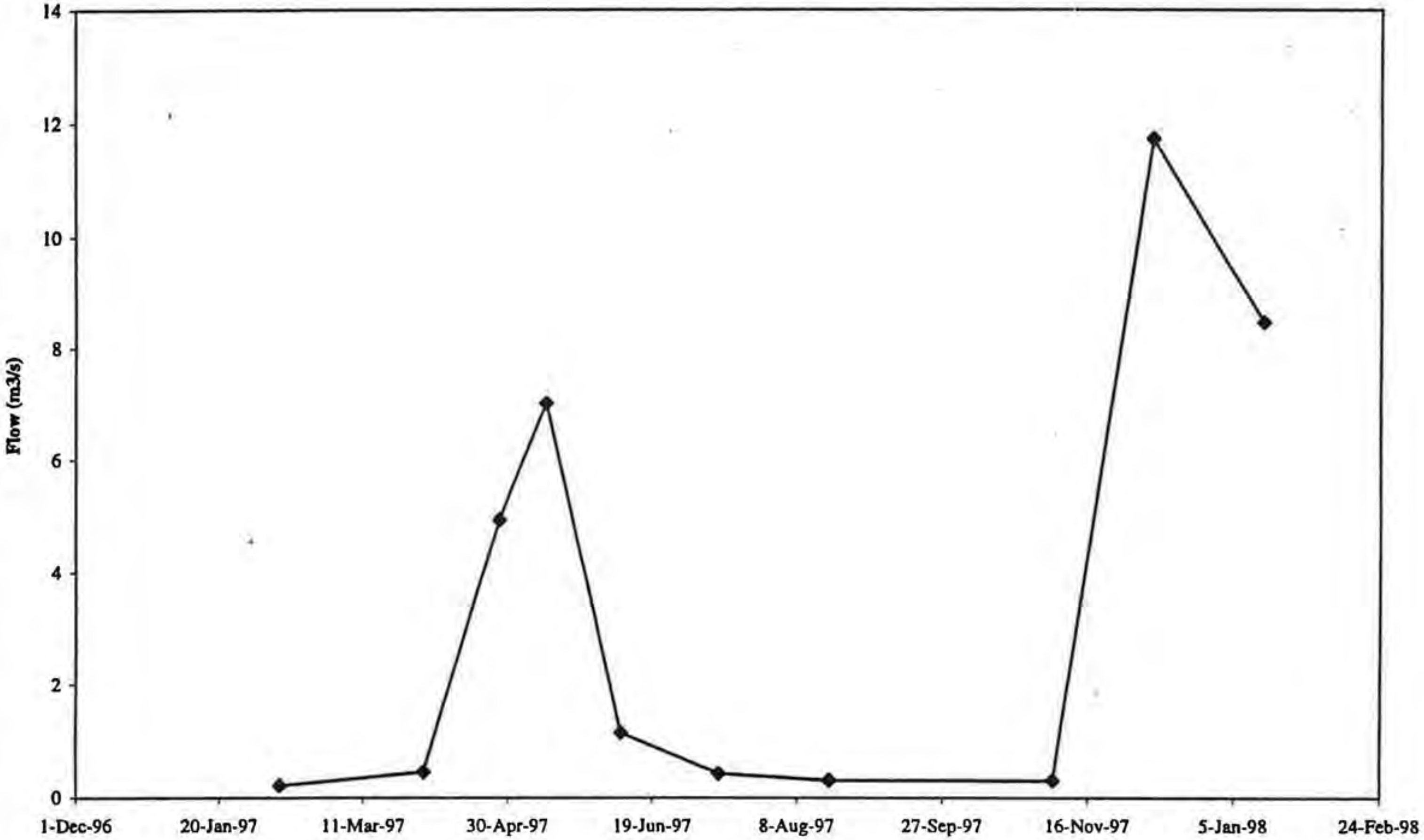




pH VS TIME TSS VS TIME BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-20

Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



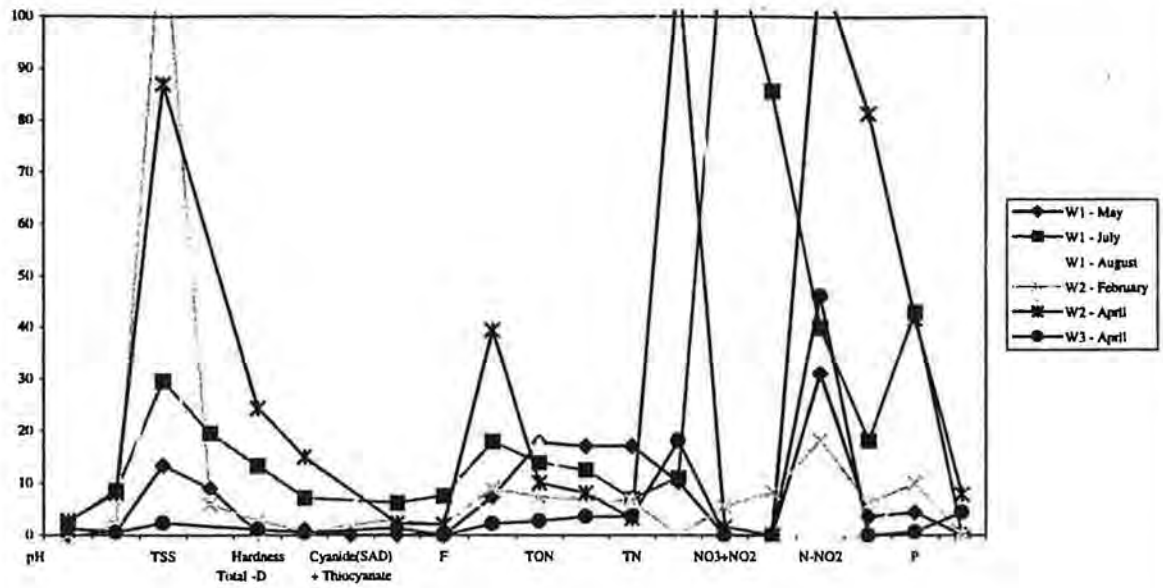
Flow data shown for sampling dates only.

FLOW DATA BULYANHULU PROJECT TANZANIA	
KAHAMA MINING CO. LTD.	
MAY 1998	FIGURE 4-21

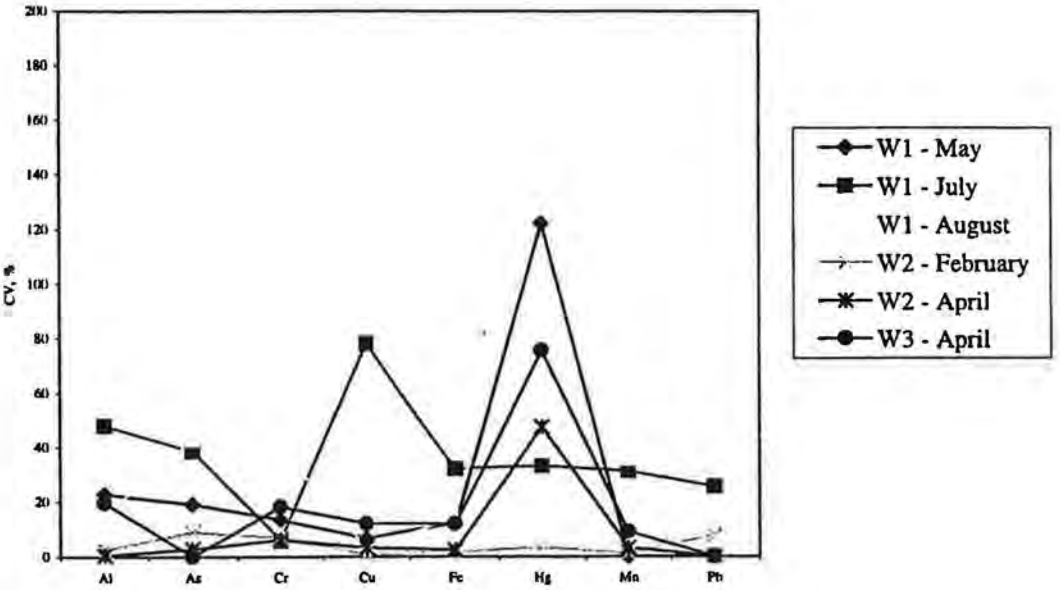
Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY

General Parameters



Total Metals



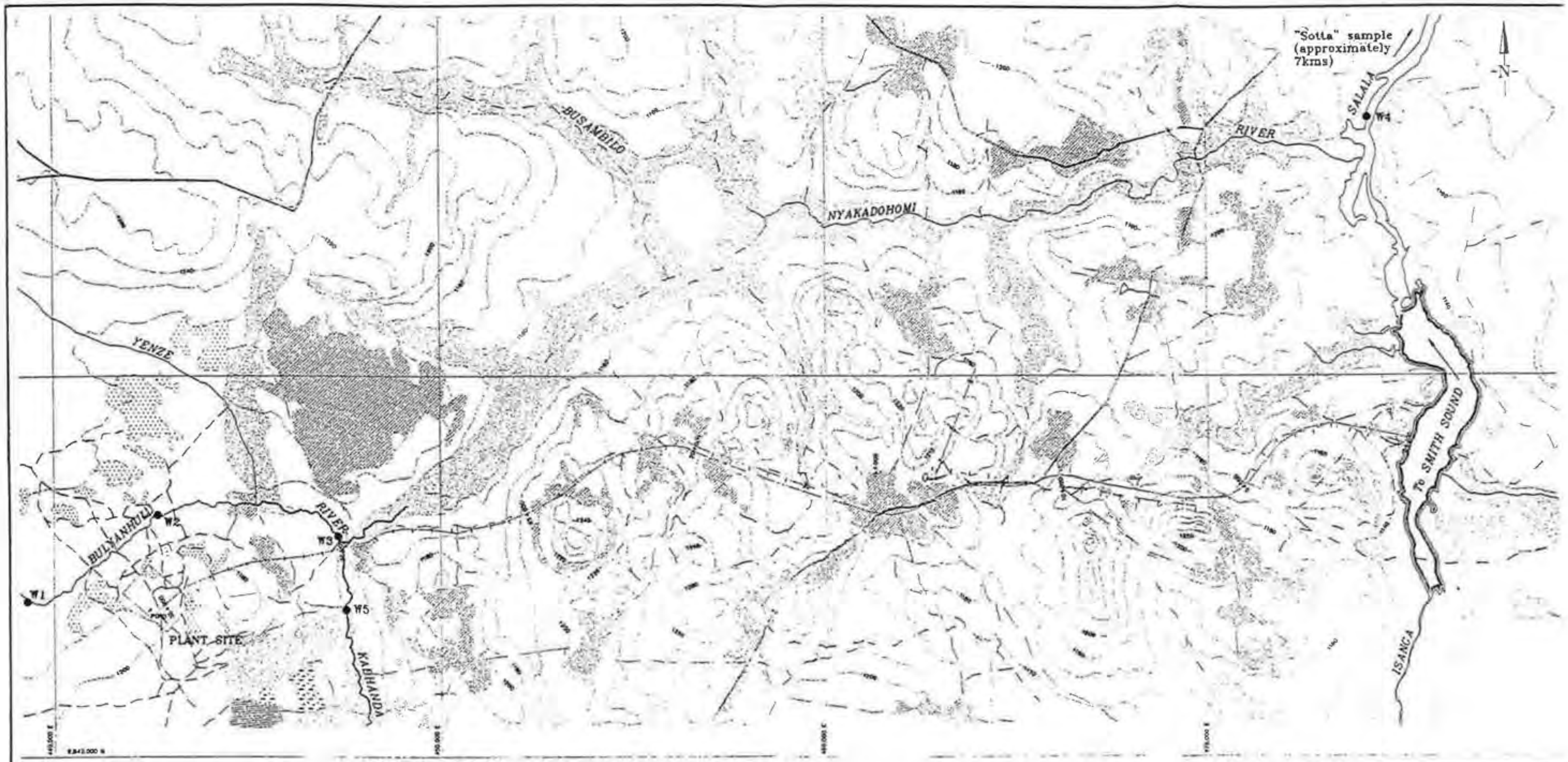
COEFFICIENTS OF VARIATION FOR DUPLICATES
BULYANHULU PROJECT
TANZANIA

KAHAMA MINING CO. LTD.

MAY 1998 | FIGURE 4-23

Job No.: 35367-001-310

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY



SURFACE WATER QUALITY SAMPLE SITES

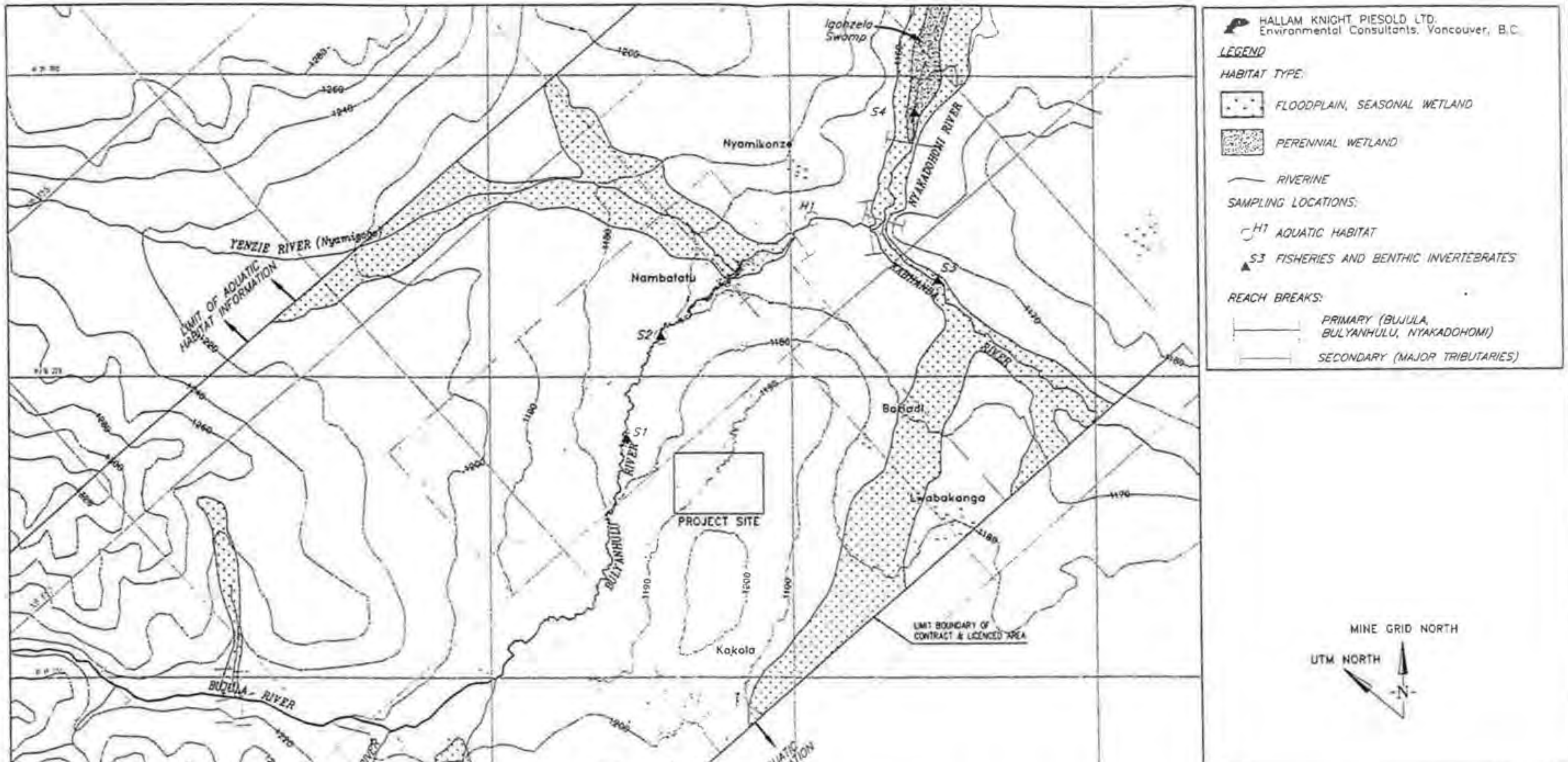
SCALE: 1:100 000
metres
0 1000 2000 3000 4000 5000

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-22

NORECOL DAMES & MOORE



BULYANHULU PROJECT
FISHERIES SAMPLING LOCATIONS AND THE DISTRIBUTION OF AQUATIC HABITAT

TANZANIA, AFRICA

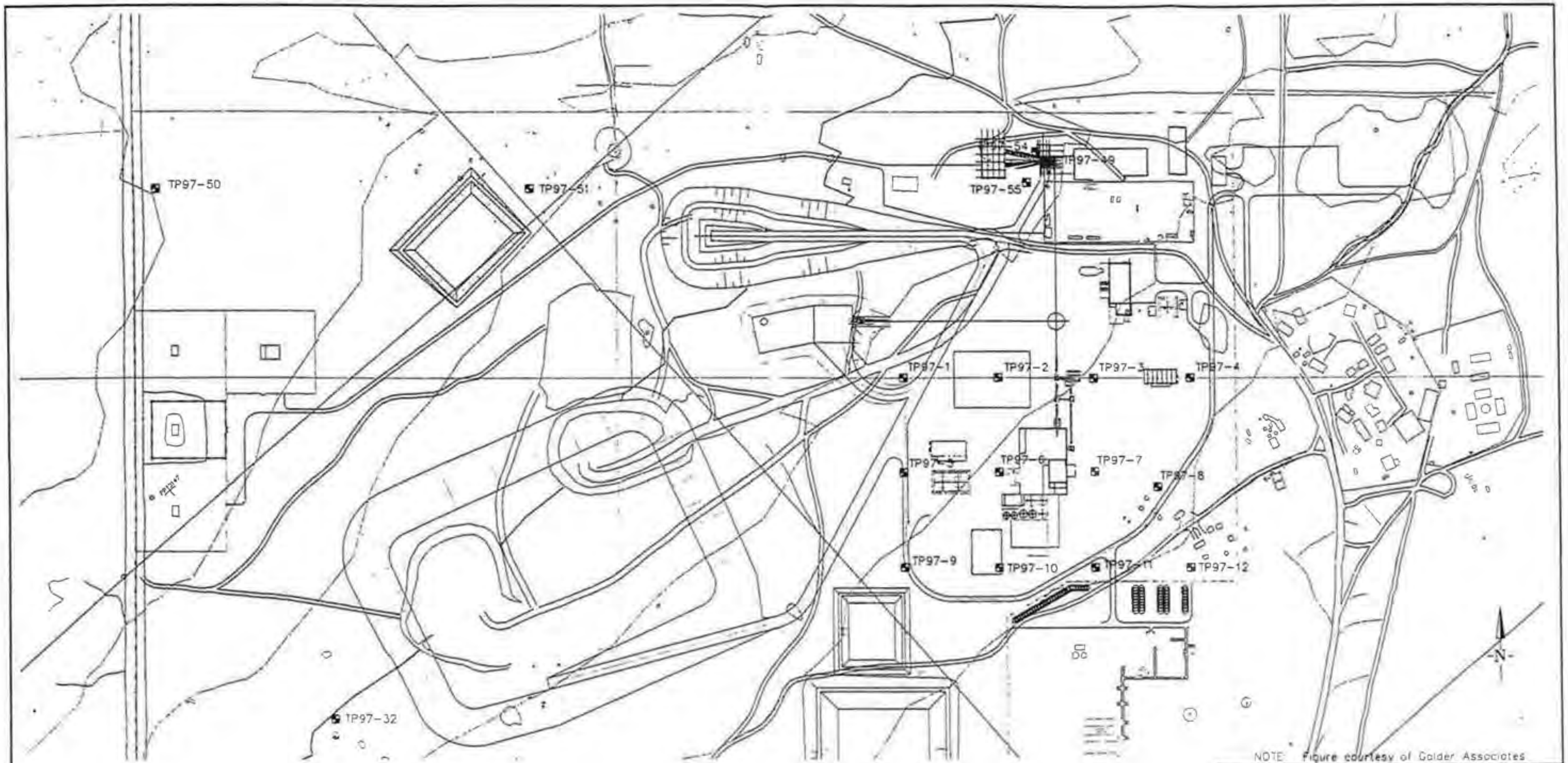
KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-24

NORECOL DAMES & MOORE

A DAMES & MOORE SUBSIDIARY

35367-001-dwg-ndm-14_24



NOTE: Figure courtesy of Golder Associates

SCALE: 1:4000
metres
0 40 80 120 160 200

LOCATION OF TEST PITS

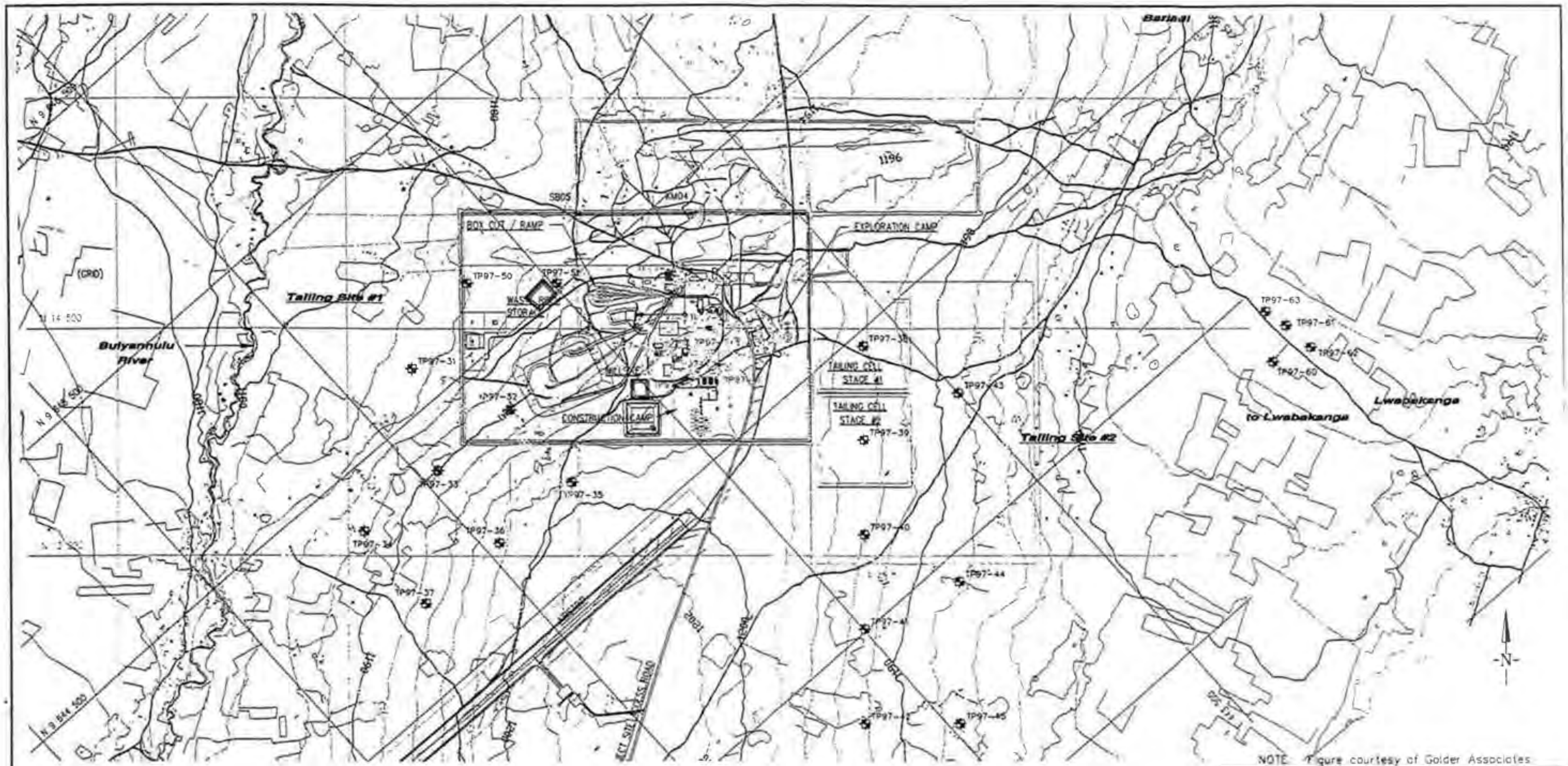
BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-25

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY

35367-001-ndm-149_1



NOTE: Figure courtesy of Golder Associates

SCALE: 1:15 000
metres
0 150 300 450 600 750

NORECOL DAMES & MOORE

35367-001-ndm-f49_3

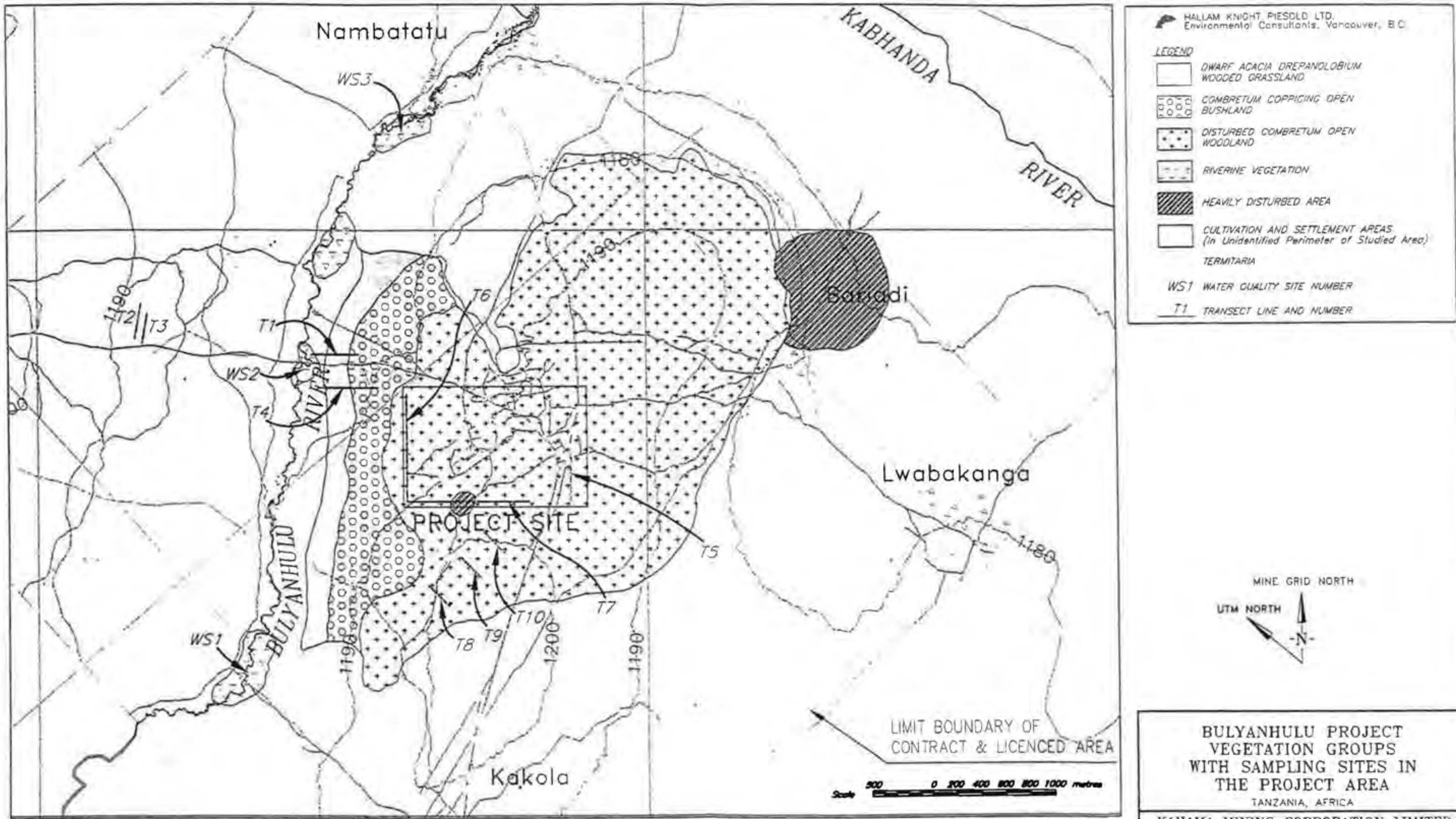
LOCATION OF TEST PITS

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998

FIGURE 4-26



BULYANHULU PROJECT
VEGETATION GROUPS
WITH SAMPLING SITES IN
THE PROJECT AREA
TANZANIA, AFRICA

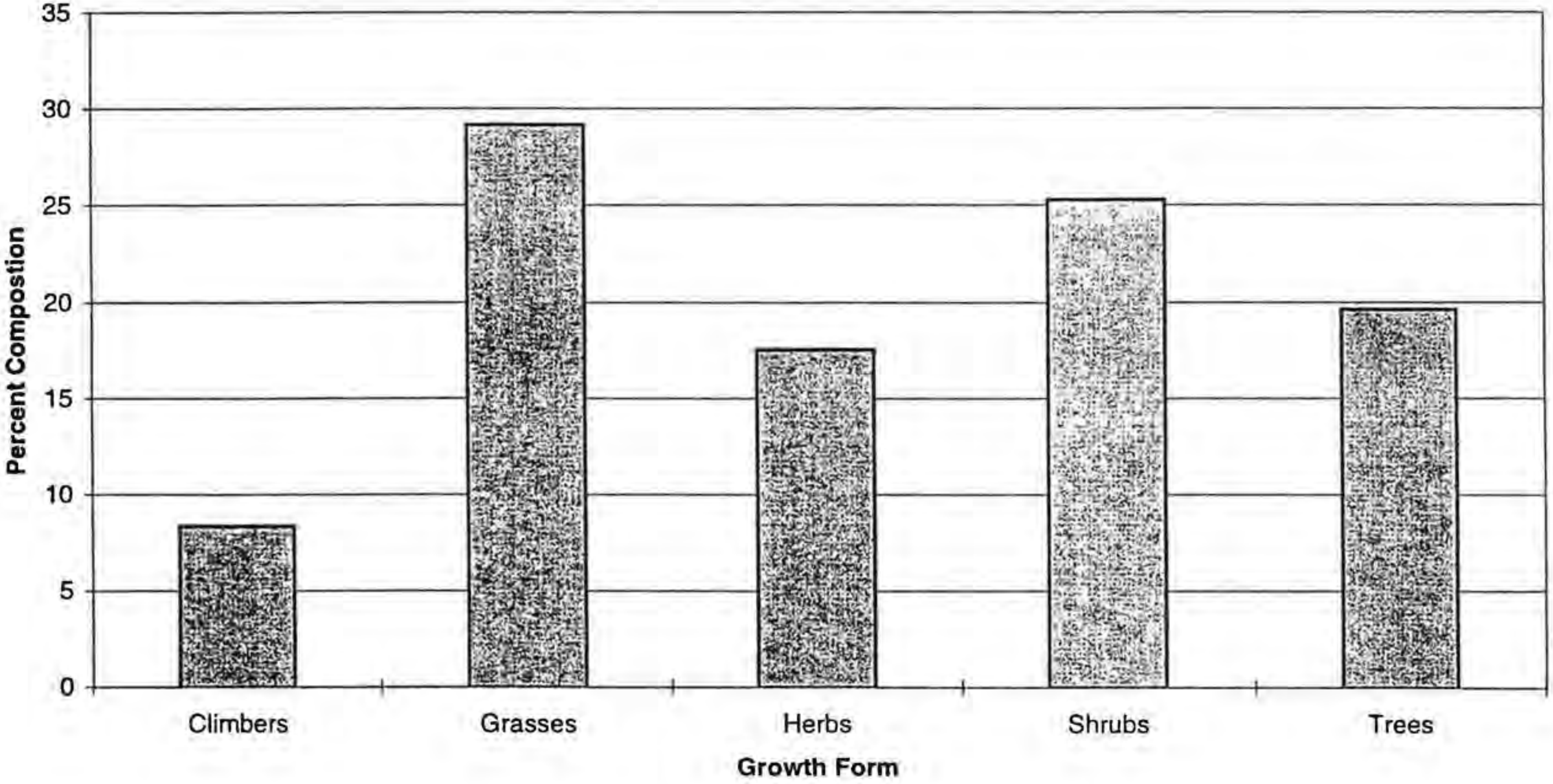
KAHAMA MINING CORPORATION LIMITED

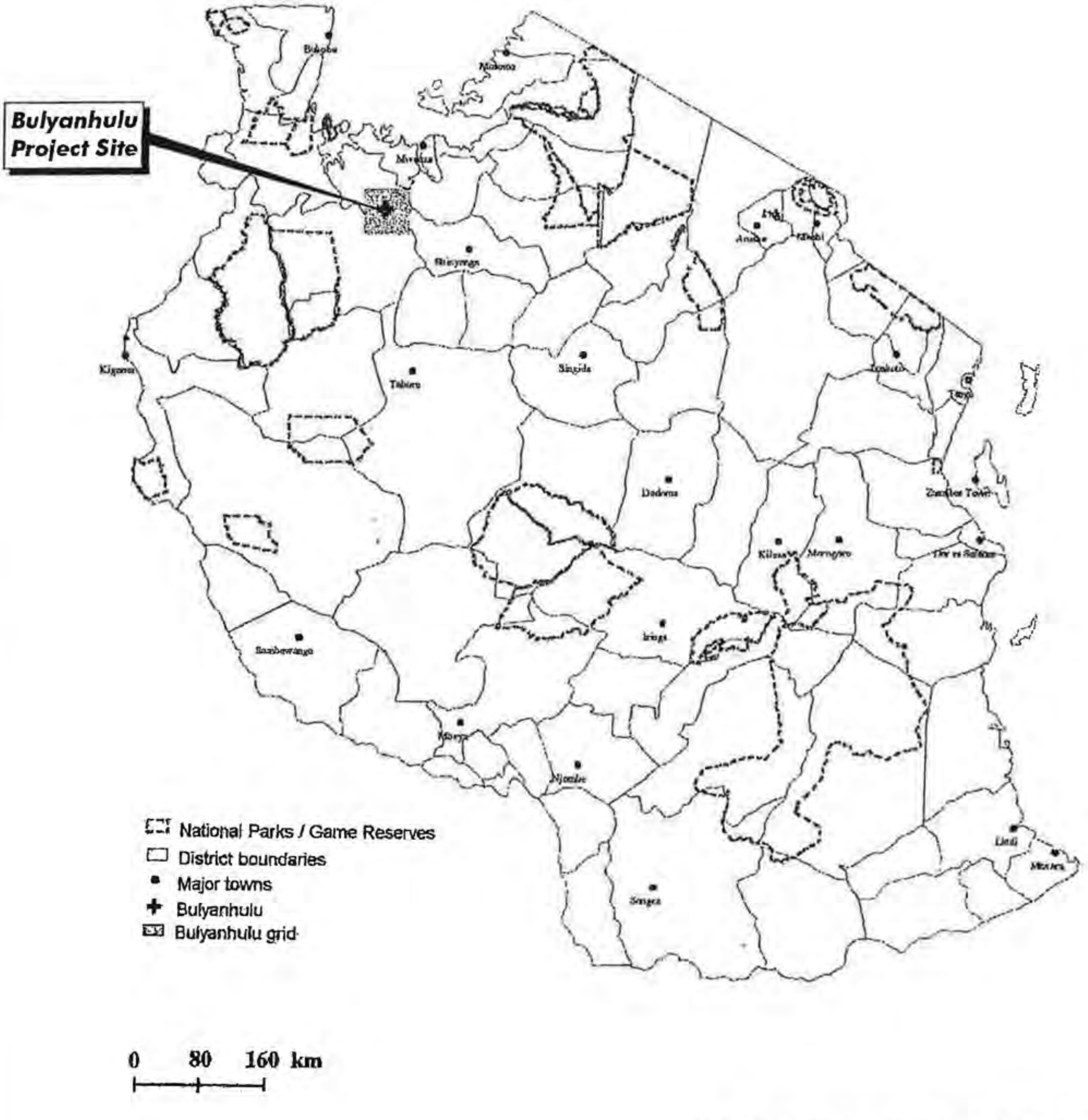
MAY 1998 | FIGURE 4-27

NORECOL DAMES & MOORE

35367-001-dwg-ndm-f4_27

FIGURE 4-28
PERCENT COMPOSITION OF GROWTH FORMS BY SPECIES NUMBER
FOUND IN THE BULYANHULU PROJECT AREA





NOTE: Figure drafted by K.M. Howell, University of Dar es Salaam

LOCATION OF BULYANHULU PROJECT SITE AND NATIONAL PARKS/ GAME RESERVES

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

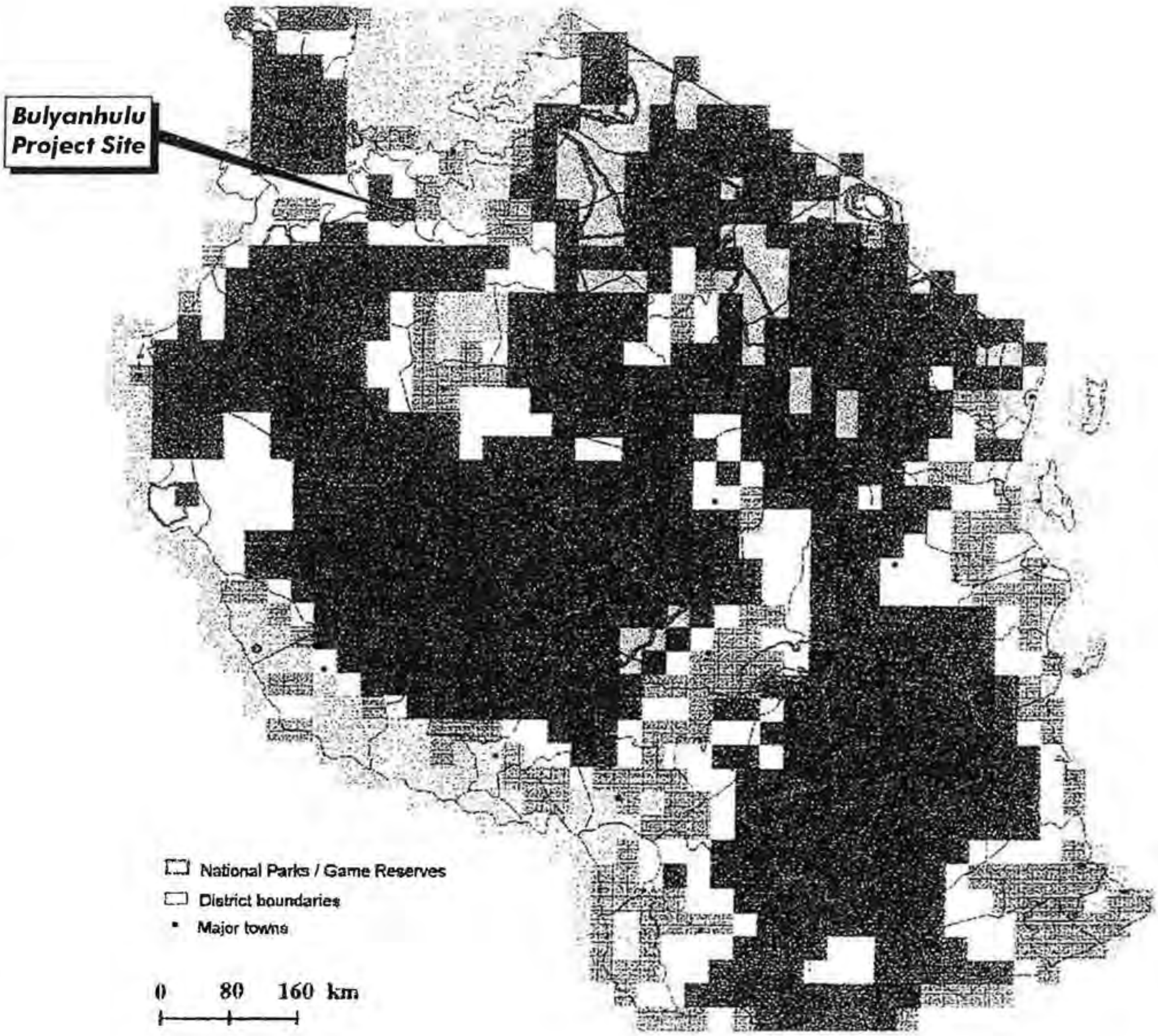
KAHAMA MINING CORPORATION LIMITED

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-cdr-f411_1feb98

MAY 1998

FIGURE 4-29



No. of Mammal Species
(Total 49 Species)

31 to 33	(4)
26 to 30	(56)
21 to 25	(285)
16 to 20	(428)
11 to 15	(215)
6 to 10	(159)
0 to 5	(181)

NOTE: Figure drafted by K.M. Howell, University of Dar es Salaam

DENSITY OF LARGE MAMMAL SPECIES IN TANZANIA, BASED ON A 1/4 BY 1/4 DEGREE GRID (AFTER RODGERS, 1967)

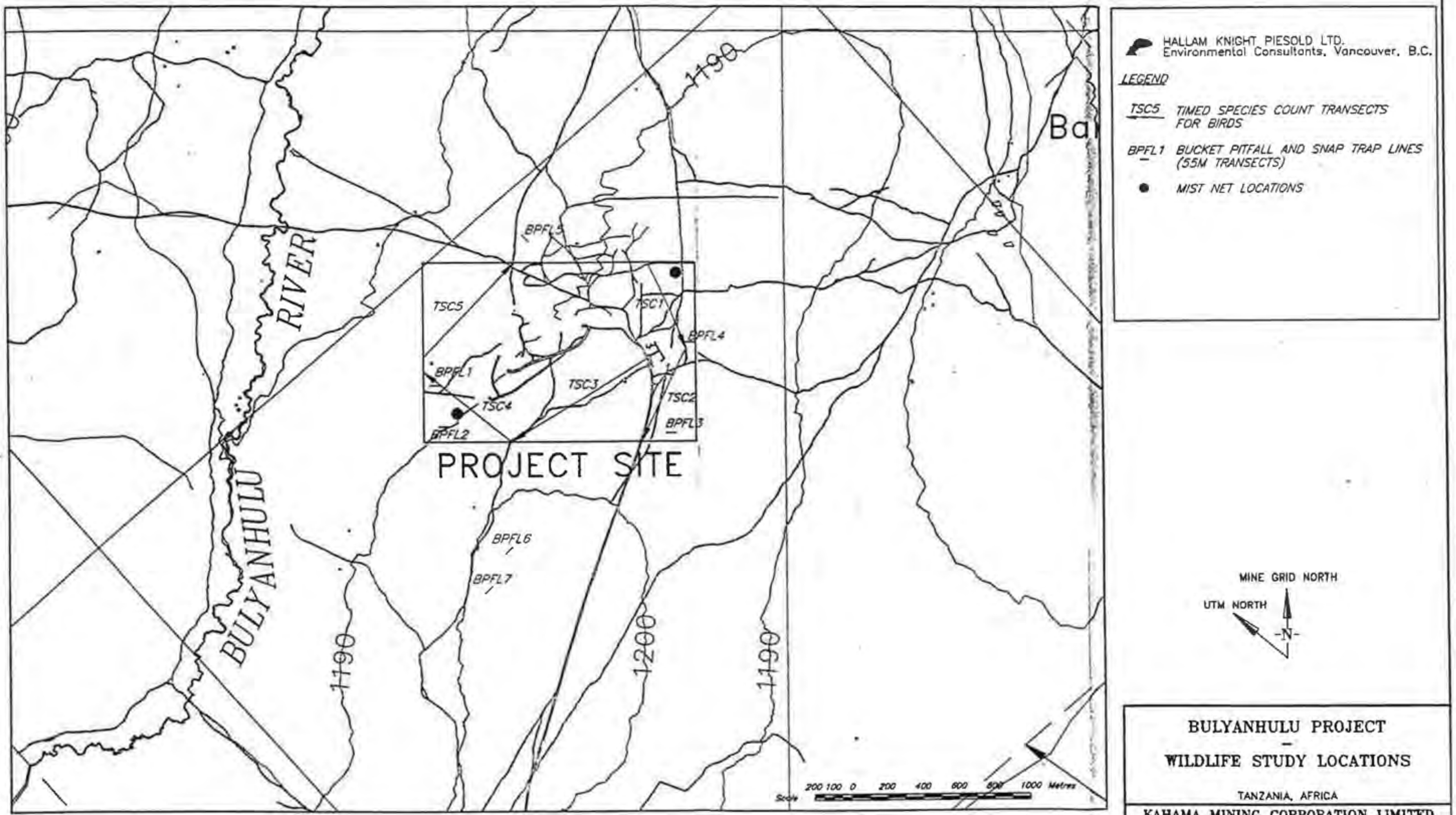
BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-cdr-f411_2feb98

MAY 1998 | FIGURE 4-30



BULYANHULU PROJECT
—
WILDLIFE STUDY LOCATIONS

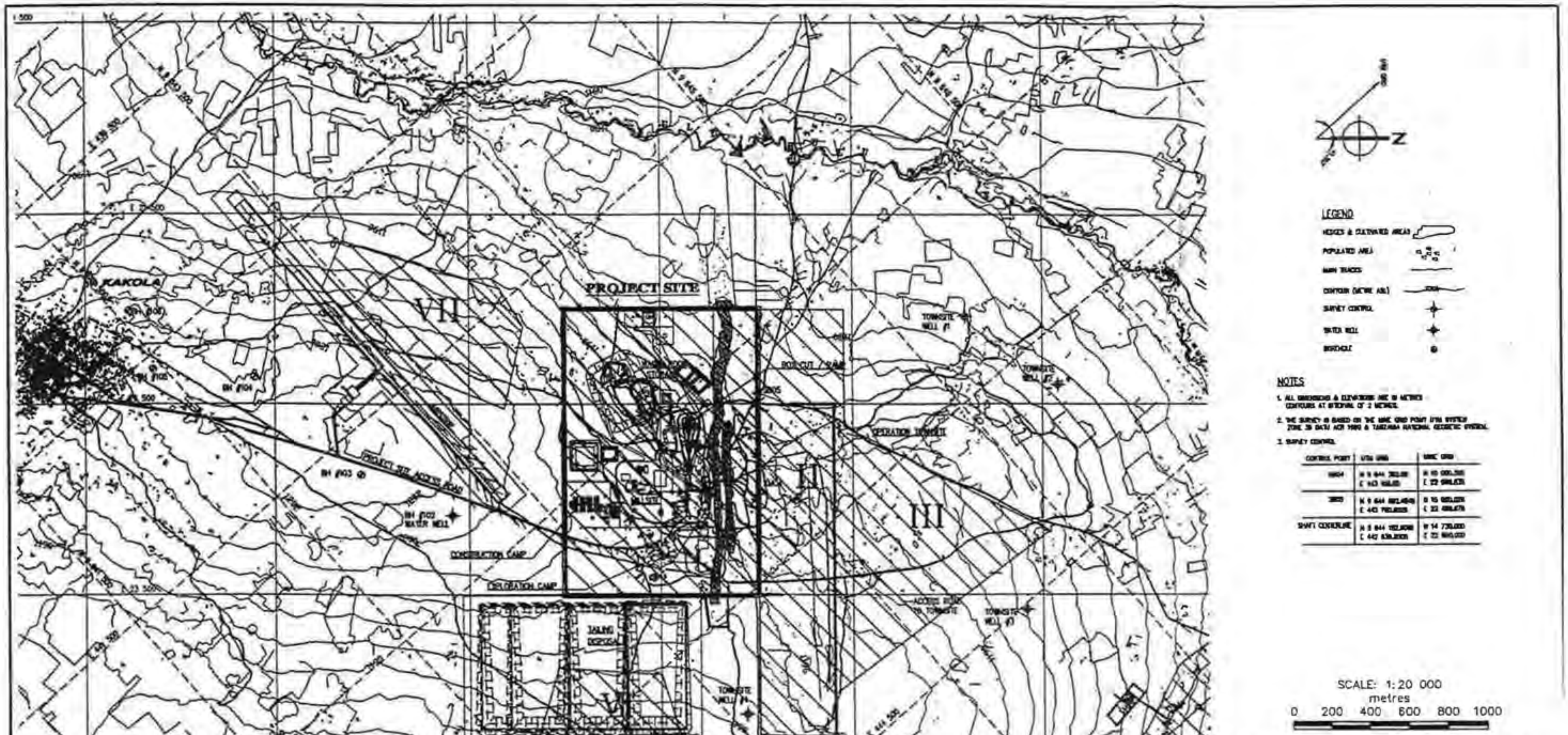
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-31

NORECOL DAMES & MOORE
A DAMES & MOORE SUBSIDIARY

35387-001-dwg-ndm-N_31



NOTE: Figure courtesy of Kilborn SNC-Lavalin

ARCHAEOLOGICAL SURVEY ZONES

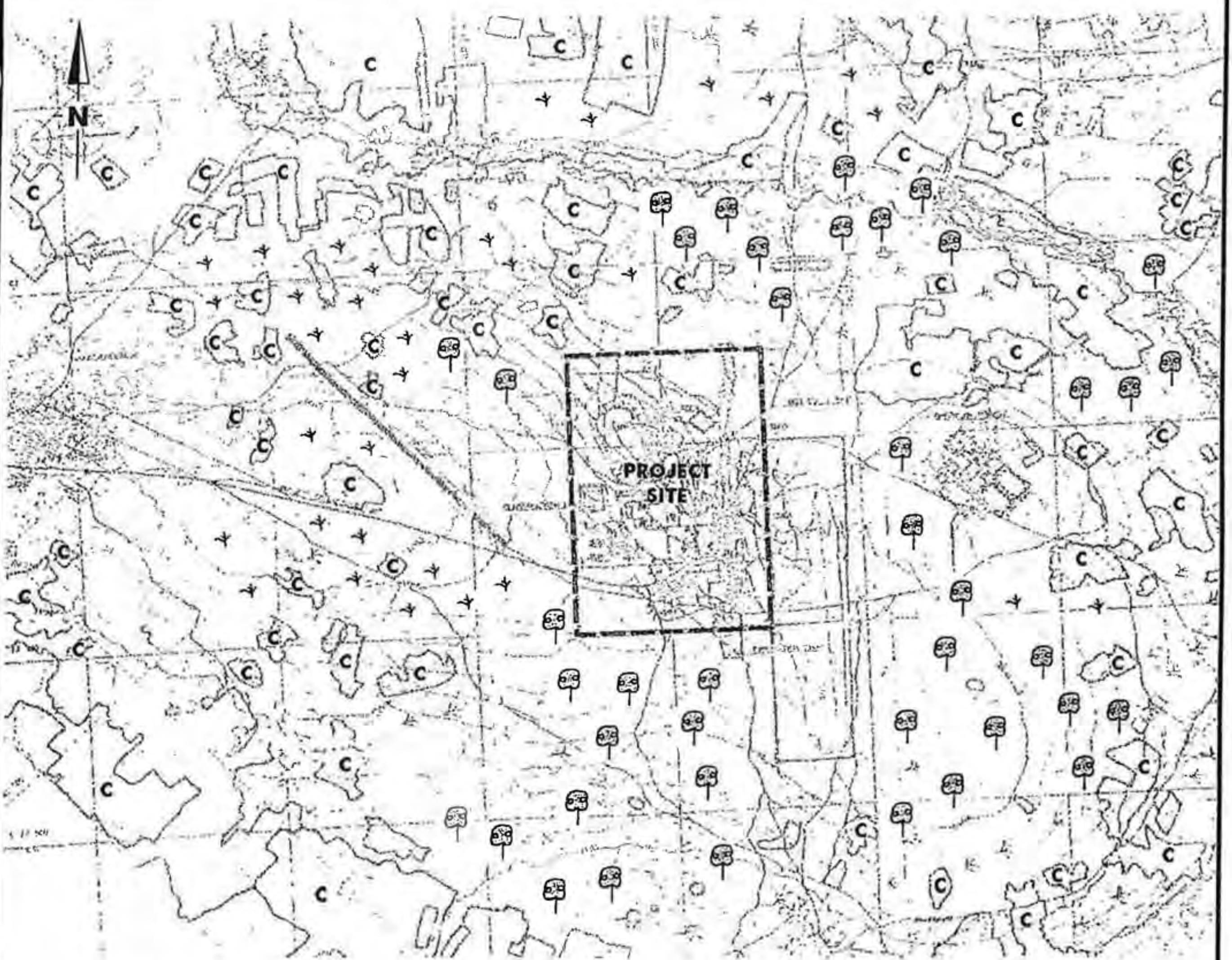
BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-32

NORECOL DAMES & MOORE

35387-001-NDM-F412_1



LEGEND

Cultivated Areas (Maize, Sorghum, Cassava, Cotton) — C

Grassland and Fallowland (Grazing)

Bushed Area

METRES
0 1000

Source: The Centre for Energy, Environment, Science and Technology Land Use Study, 1998

BULYANHULU LAND USE PATTERNS

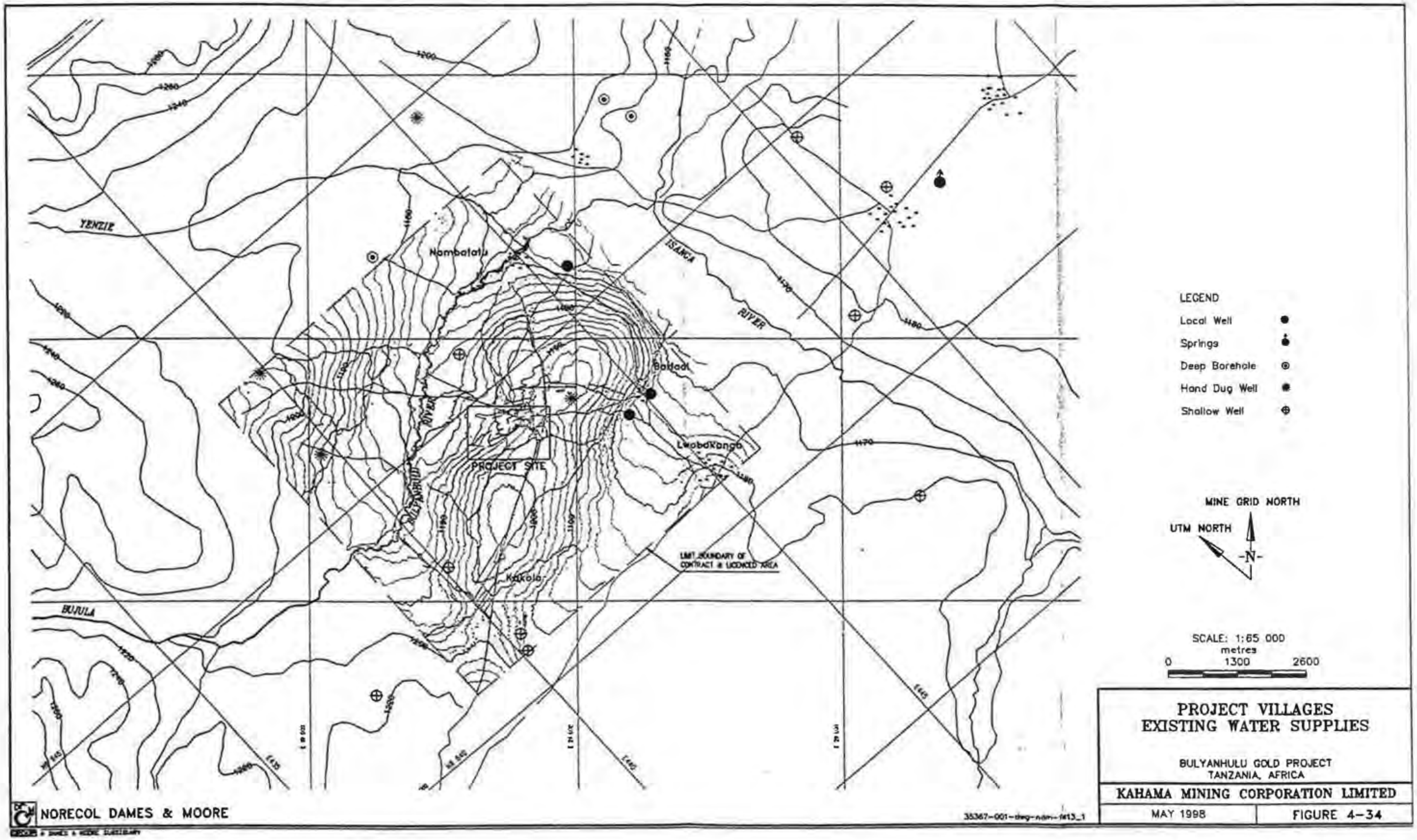
BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

KAHAMA MINING CORPORATION LIMITED

MAY 1998 | **FIGURE 4-33**

NORECOL DAMES & MOORE
GROUP A DAMES & MOORE SUBSIDIARY

35367-001-cdr-f413_2

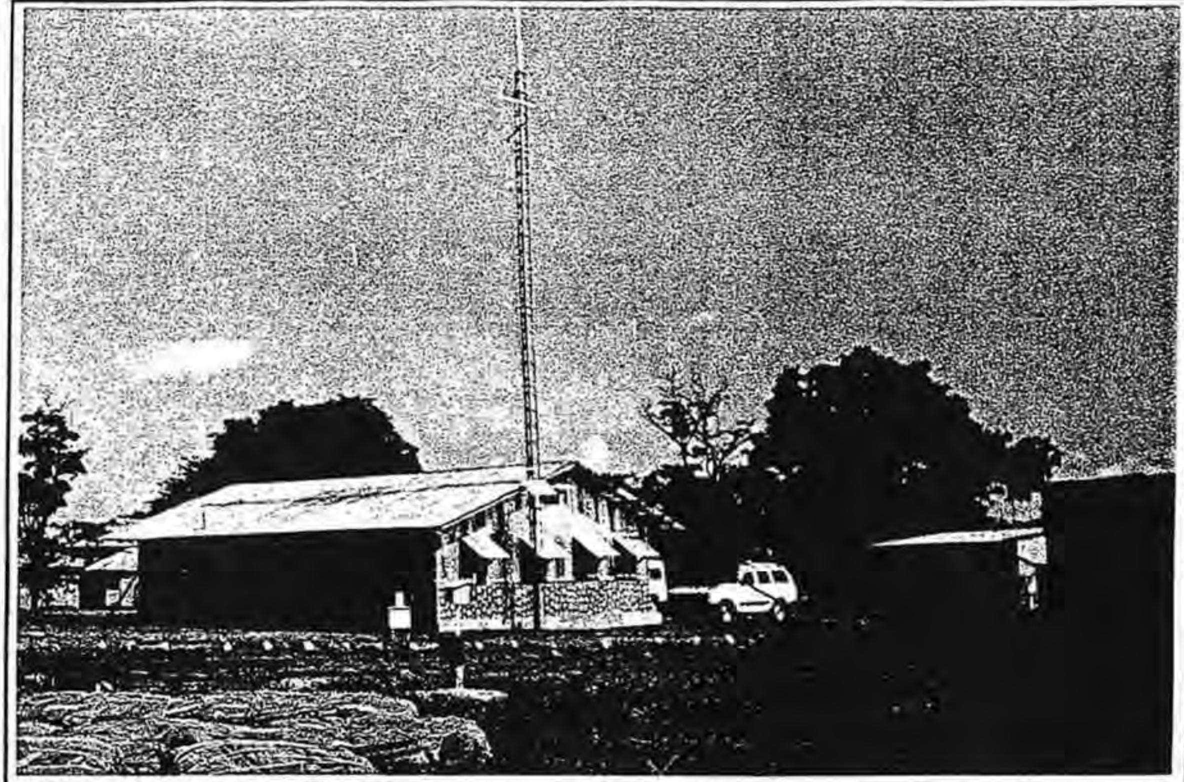


PROJECT VILLAGES
EXISTING WATER SUPPLIES

BULYANHULU GOLD PROJECT
TANZANIA, AFRICA

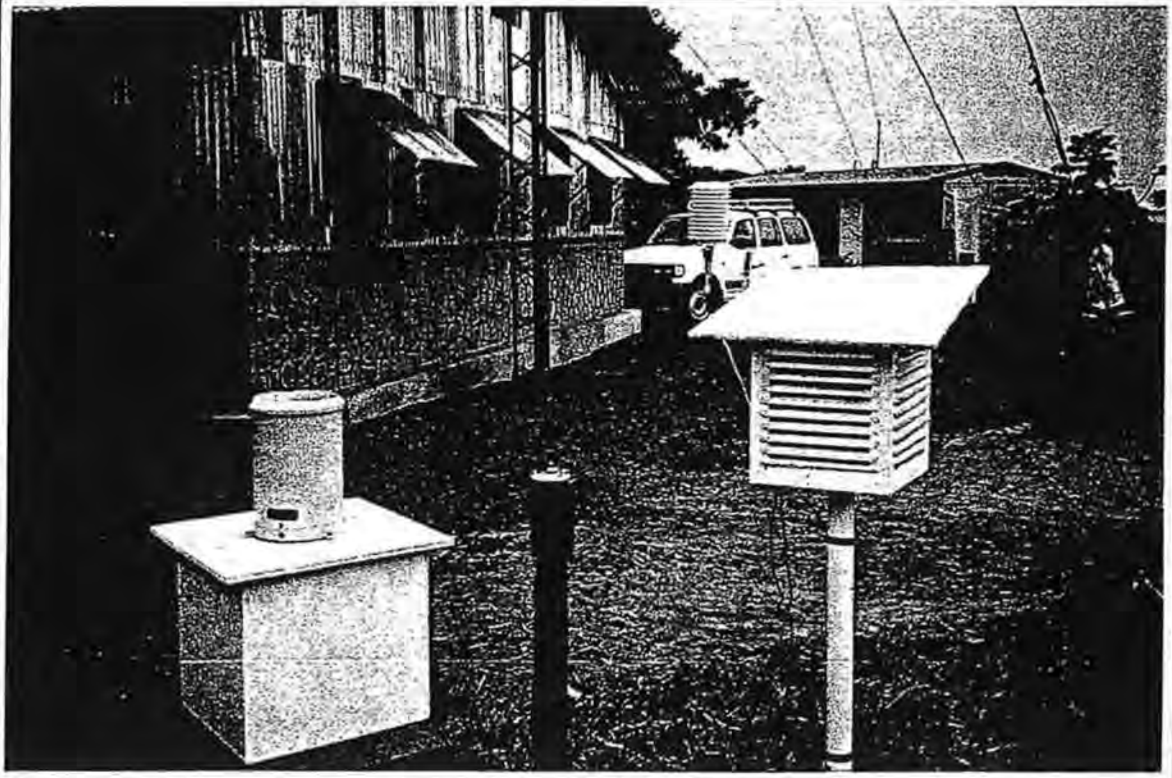
KAHAMA MINING CORPORATION LIMITED

MAY 1998 | FIGURE 4-34



Climate Station and mast at the Bulyanhulu camp.

PLATE 4-1



Climate Station at Bulyanhulu camp showing tipping bucket rain gauge, radiation sensor and temperature relative humidity sensors inside a radiation shield.

PLATE 4-2

Canister being replaced at a dust fall monitoring station.

PLATE 4-3

Gauging Station looking east, upstream, Bulyanhulu River.

PLATE 4-4

Measuring stream discharge at Gauging Station.

PLATE 4-5

Gauging Station H3.

PLATE 4-6

Water sampling the Bulyanhulu River.

PLATE 4-7

Water sample station W4, Smith Sound.

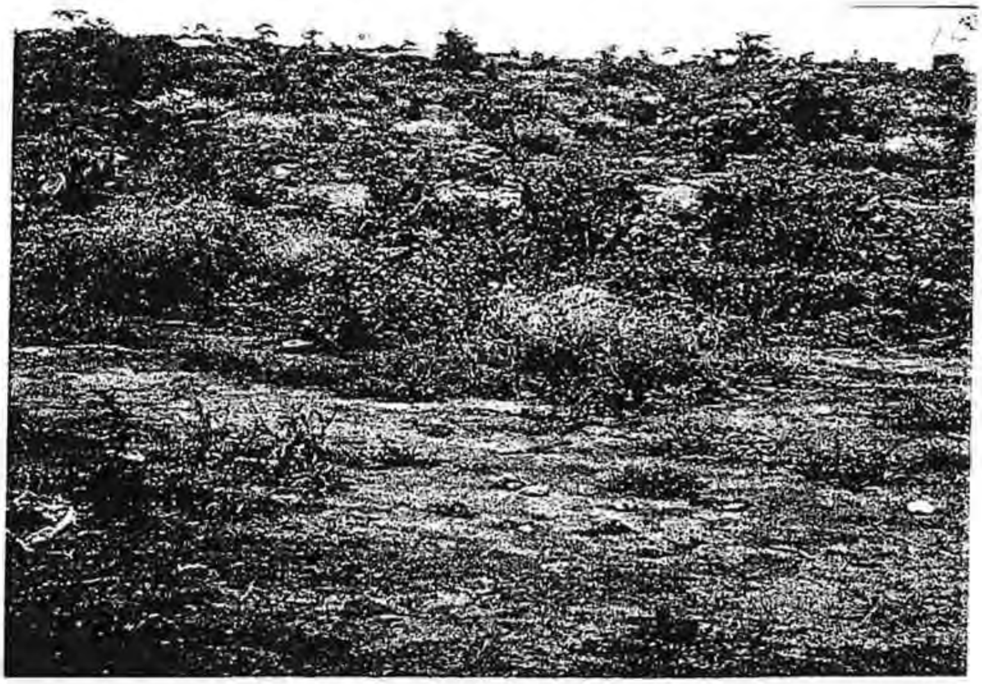
PLATE 4-8

In the foreground is *Acacia drepanolobium*, the dominant shrub along transect 4. This is an indicator of the seasonally water-logged soils.

PLATE 4-9

Along transect 4. In the left foreground is a young *Combretum zeyheri*, in the middle ground is *Hyparrhenia sp.* the dominant grass in the area. In the background are some scattered *Acacia drepanolobium*. The area is seasonally wet.

PLATE 4-10

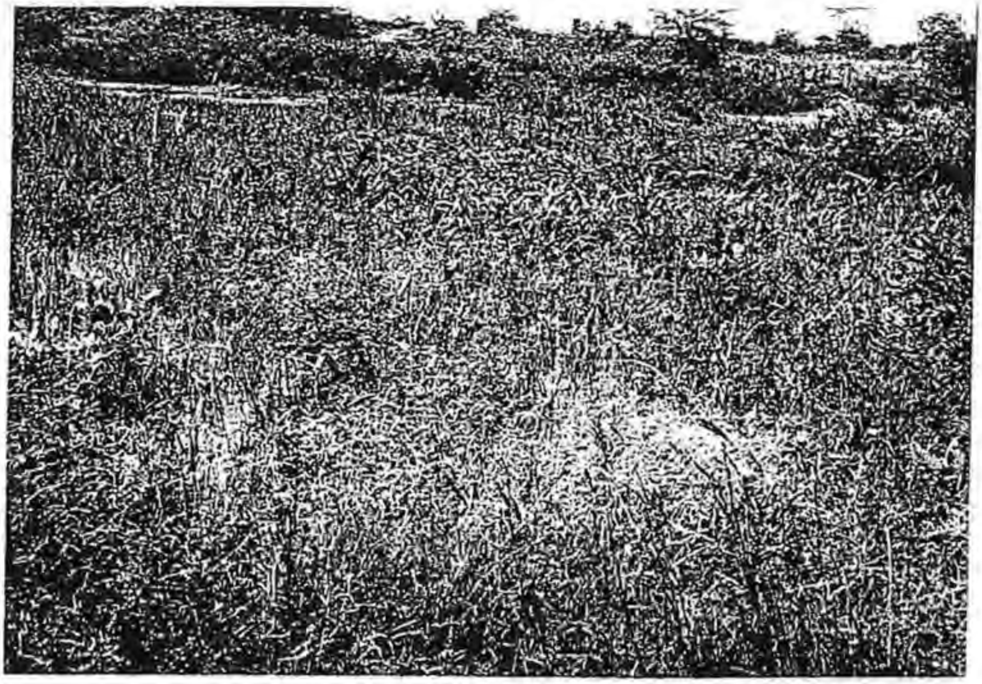


Old settlement area south of the dump site in the fenced area. 50% of the ground is covered by colonizing weeds. Only a few scattered trees are seen on site.

PLATE 4-11

Some of the few remaining trees in an area of former settlement along transect number 7. The tree in the left foreground is *Xerroderis angolensis, Combretum zeyheri* is in the right middle ground.

PLATE 4-12

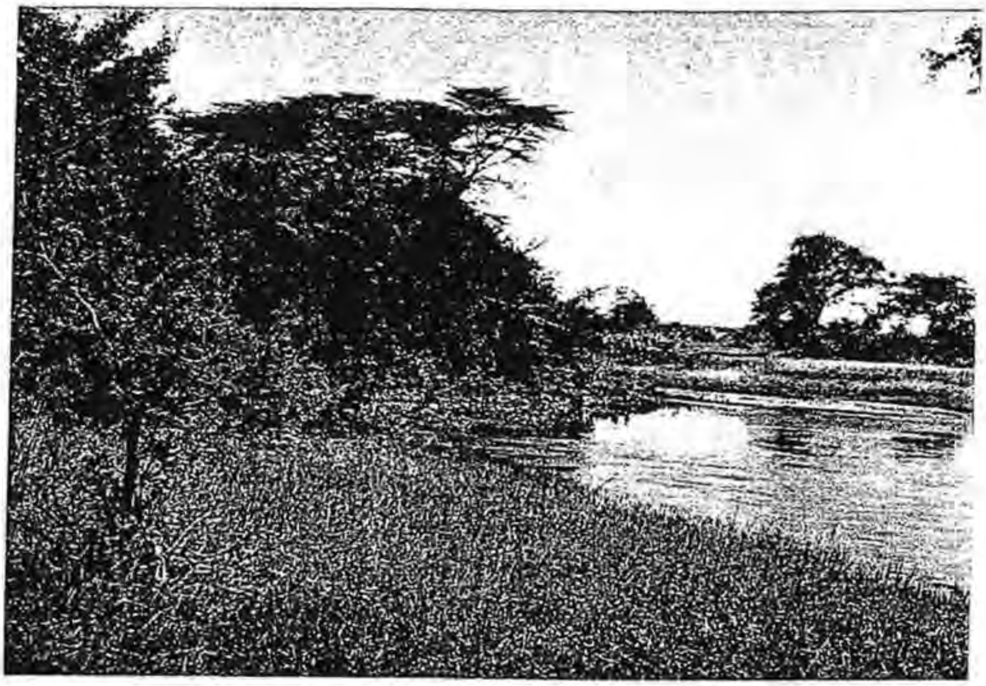


View of the Water Quality Sampling Point 1 temporarily flooded following heavy rains. The white flowering plant in the middle ground is *Polygonum setulosum* while in the extreme left background is *Mimosa pigra*. Wild Rice, *Oryza longistaminata* was collected.

PLATE 4-13

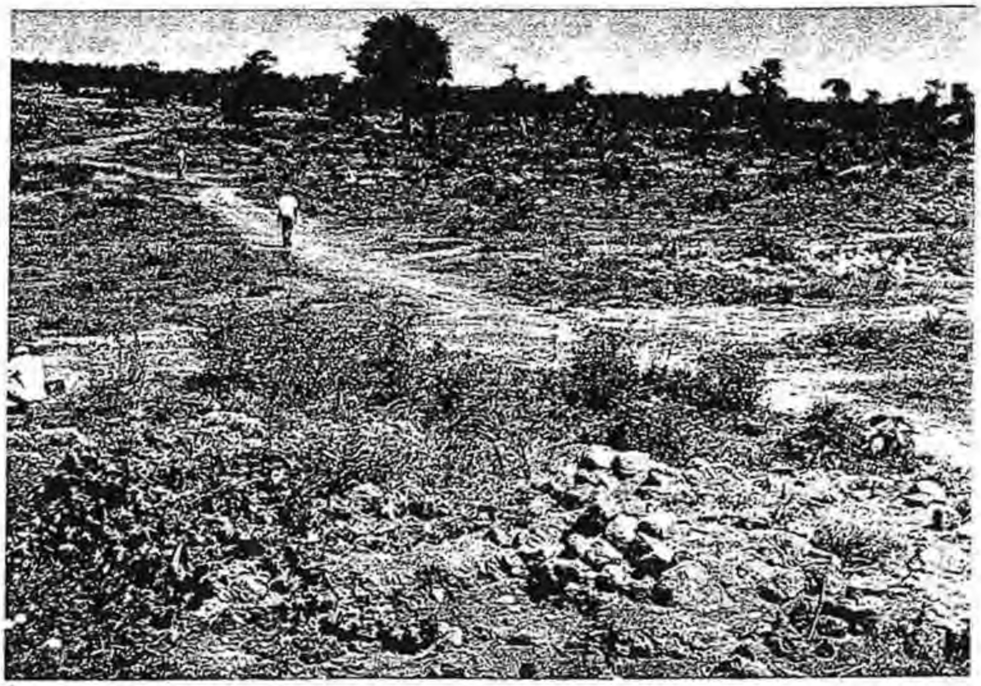
View of Water Quality Sampling Point 2 with clustered trees. In the middle ground is *Syzygium guineense*. The emergent tree is *Fiscus natalensis*.

PLATE 4-14



Water Quality Sampling Point 3, a more closed vegetation with emergent large trees of *Acacia etbaica* and *Acacia robusta* and closed thickets.

PLATE 4-15

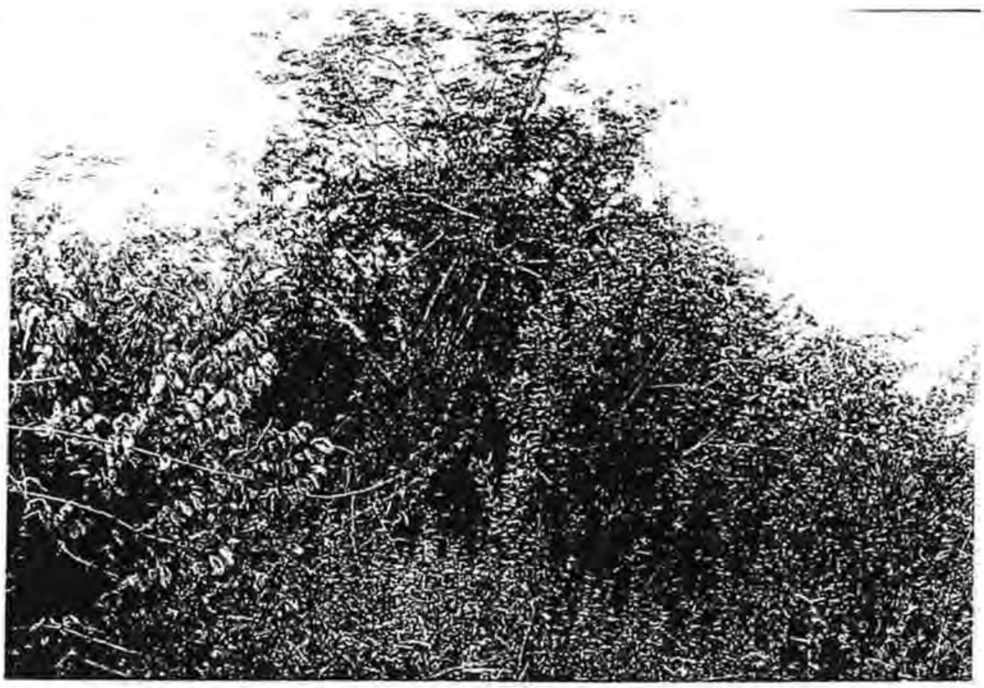


Bariadi area. In the fore and middle ground remnants of unburnt mud bricks crumbs of the demolished houses are still evident in the area. The area is dominated by colonizing weeds, with a ground cover of about 60%.

PLATE 4-16

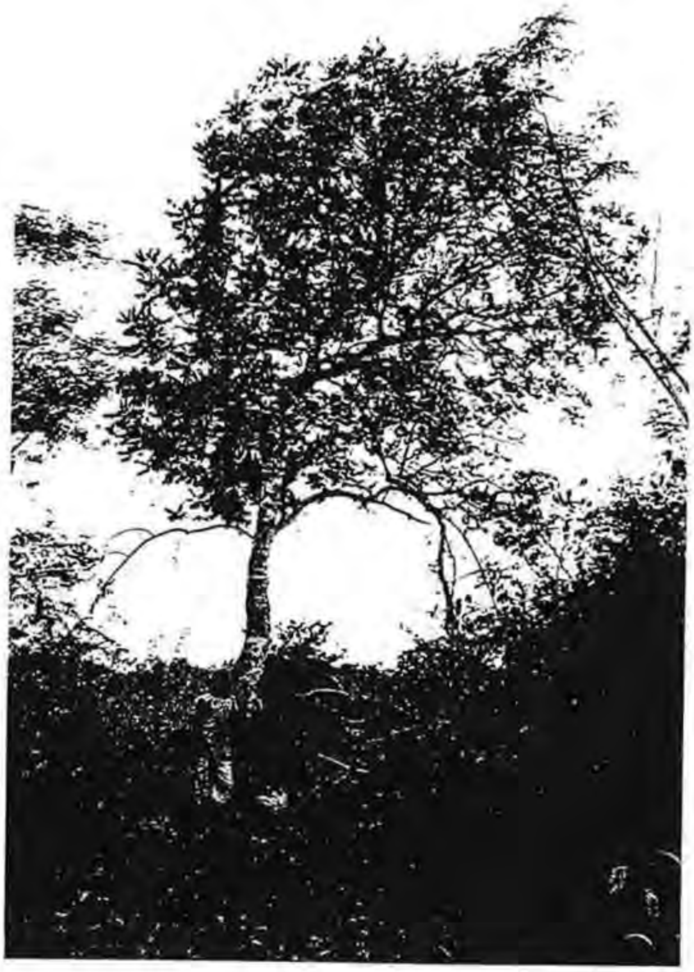
Transect 3 showing the vegetation typical of termitaria with *Acacia brevispica* dominating the middle ground. Ground cover is 100%. In the foreground is a coppicing *Combretum sp.*

PLATE 4-17



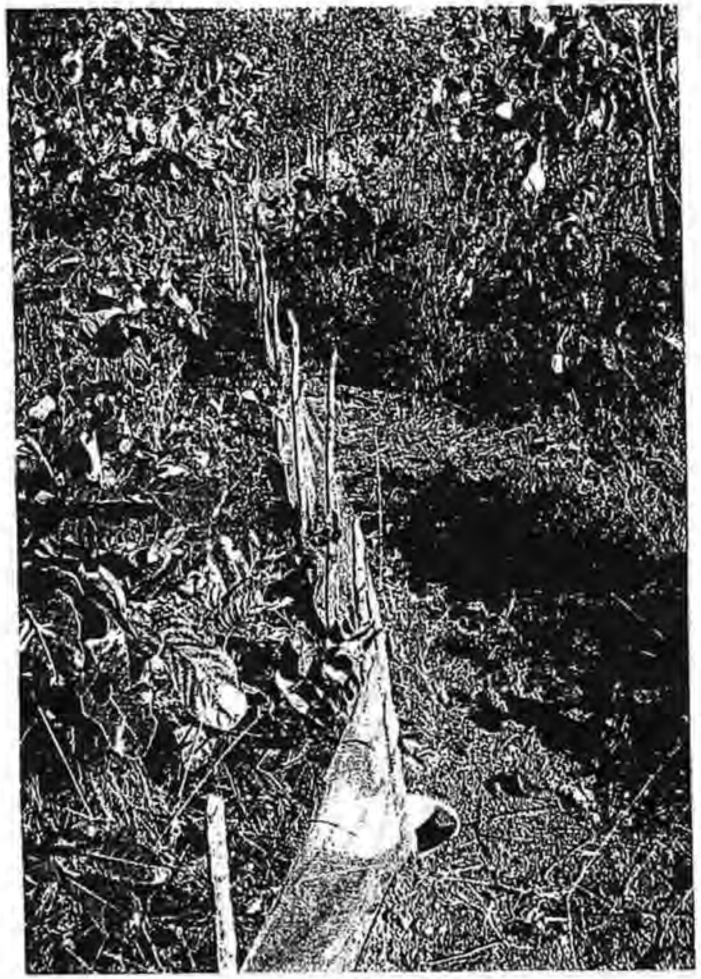
Termitaria vegetation along transect 3 in Iyenze area. The outstanding tree on the mound in the middle ground is *Albizia petersianna.* To the extreme left foreground is *Croton dichogamus.* Ground cover is 100%.

PLATE 4-18



Entandrophragma bussei recorded from transect 3 in Iyenze area. Normally this tree grows in *Commiphora* thickets according.

PLATE 4-19



May 18, 1997. Bucket Pitfall Line, west of airstrip.

PLATE 4-20

October 4, 1997. Bucket Pitfall Line #2.

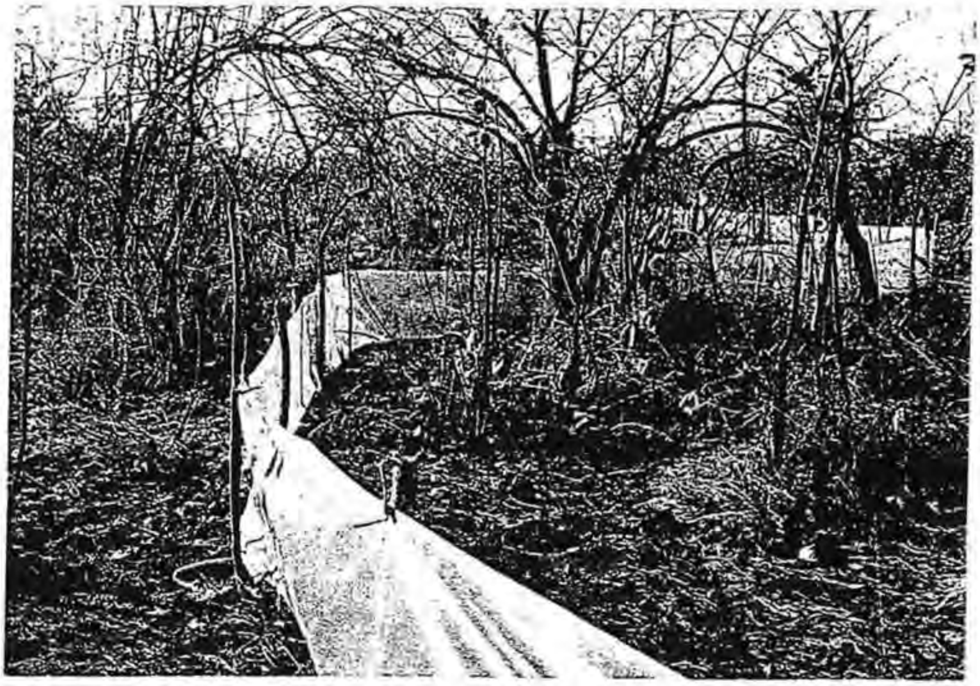
PLATE 4-21

October 4, 1997. Bucket Pitfall Line #3.

PLATE 4-22

October 4, 1997. Bucket Pitfall #6.

PLATE 4-23



October 1997. Bucket Pitfall Line #7.

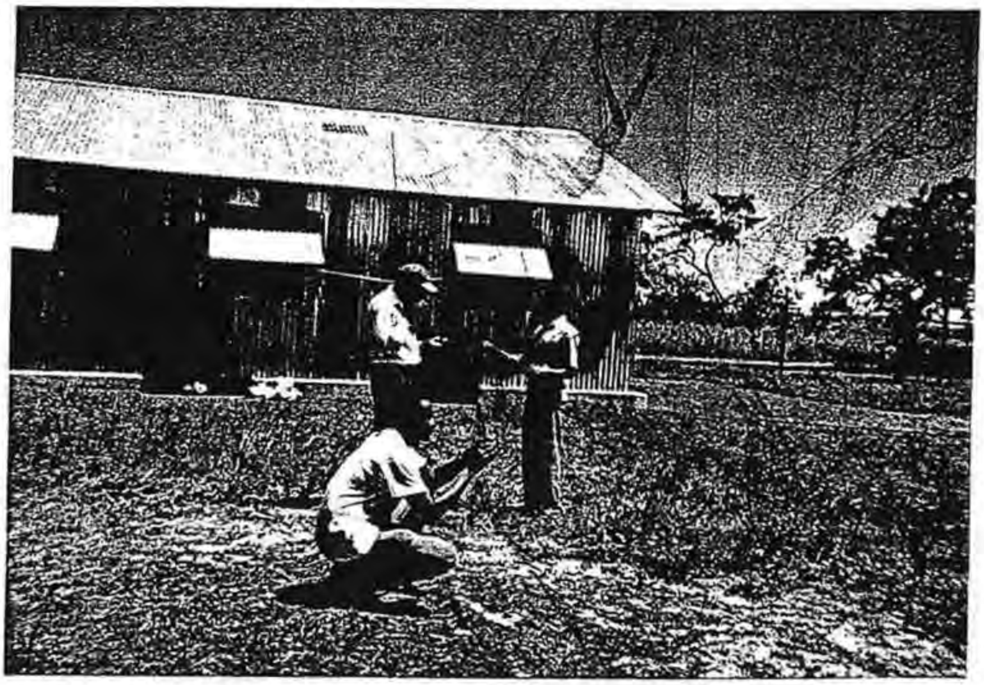
PHOTO 4-24

May 18, 1997. Snap Trap set along BPFL 3.

PHOTO 4-25

May 1997. Setting mist net for birds.

PHOTO 4-26



May, 1997. Cleaning and repairing mist net.

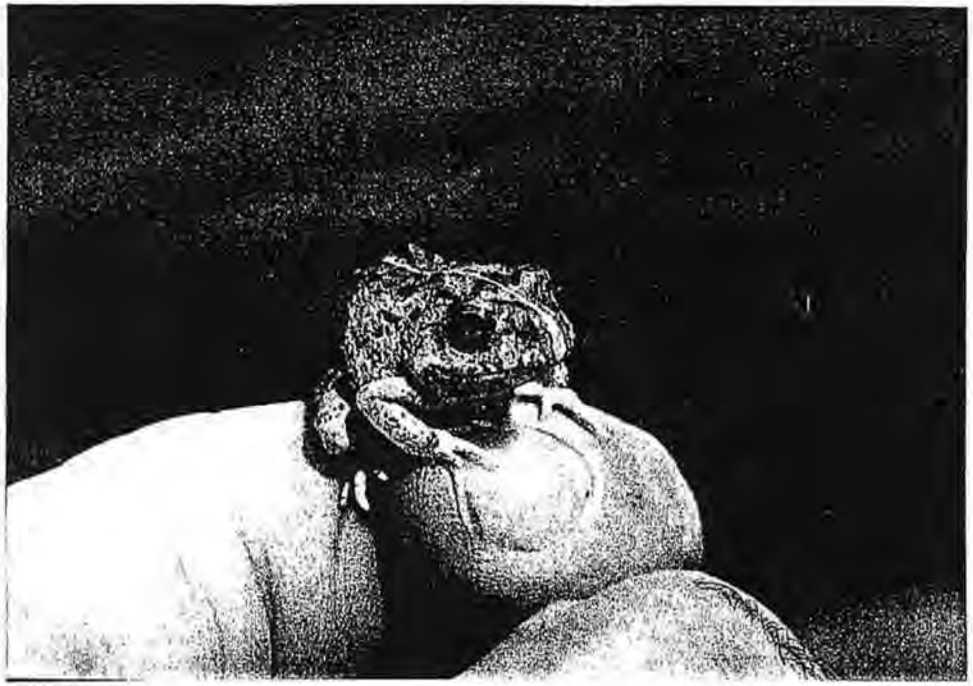
PHOTO 4-27

October, 1997. Small mammal specimens.

PLATE 4-28

October 6, 1997. Female pennant-winged nightjar *(Macrodipteryx vexillarius)* brooding two chicks.

PLATE 4-29

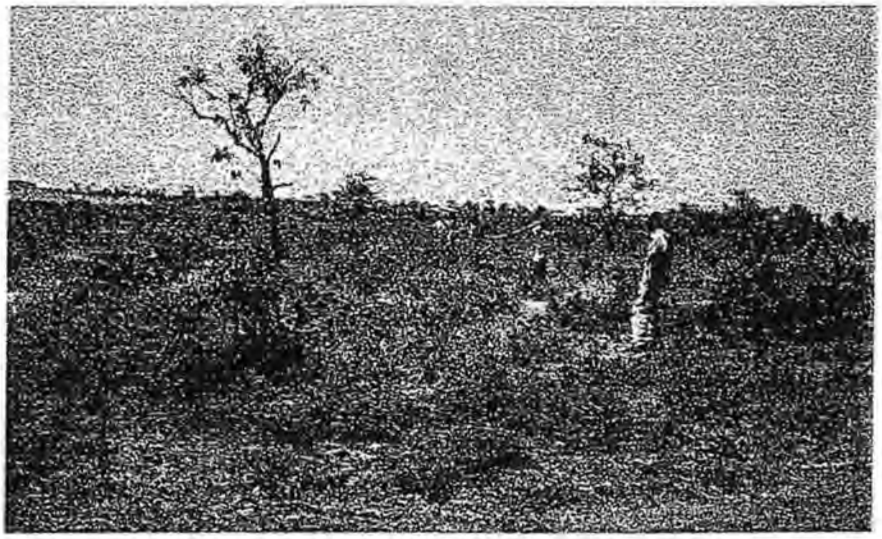


May 18, 1997. Specimen No. KMH 15013, *Tomopterna sp.*, a Sand Frog.

PLATE 4-30

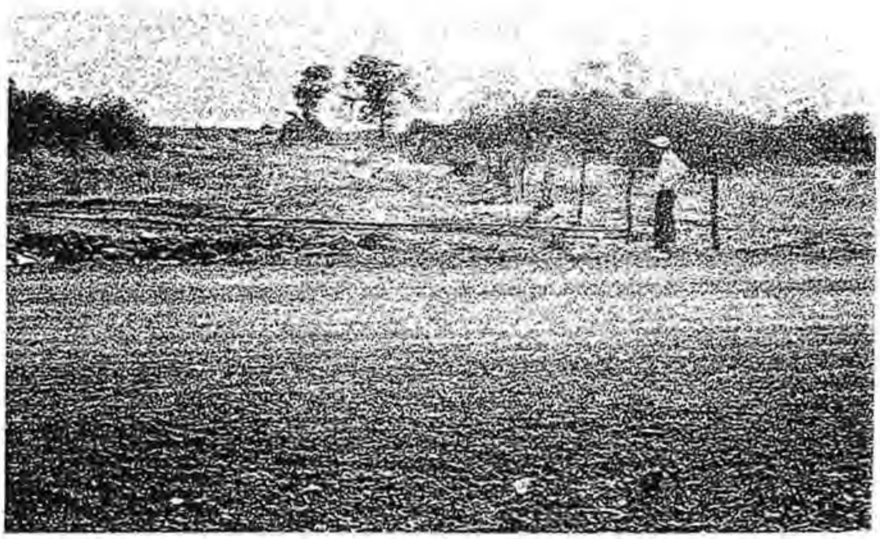
May, 1997. Black-necked Spitting-Cobra *(Naja nigricollis)*.

PLATE 4-31



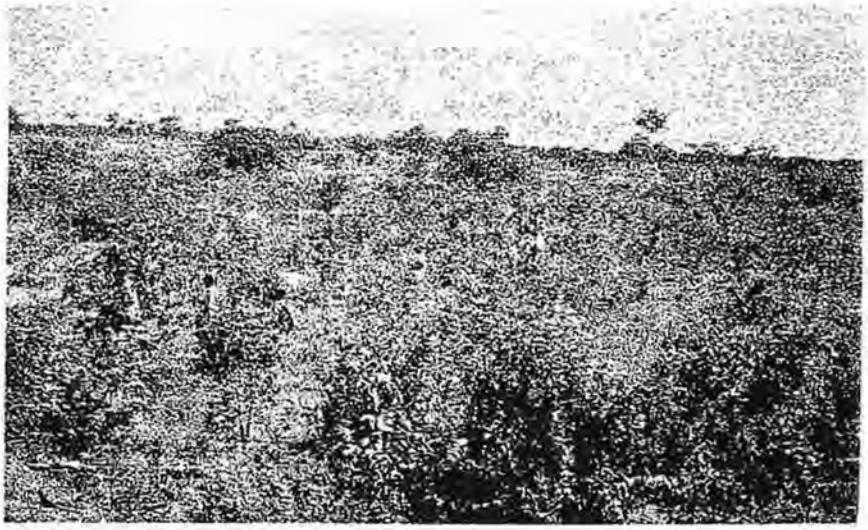
Typical soil coverage of the surveyed area.

PLATE 4-32



Survey crew aligning on a straight line, ready for walk-over.

PLATE 4-33

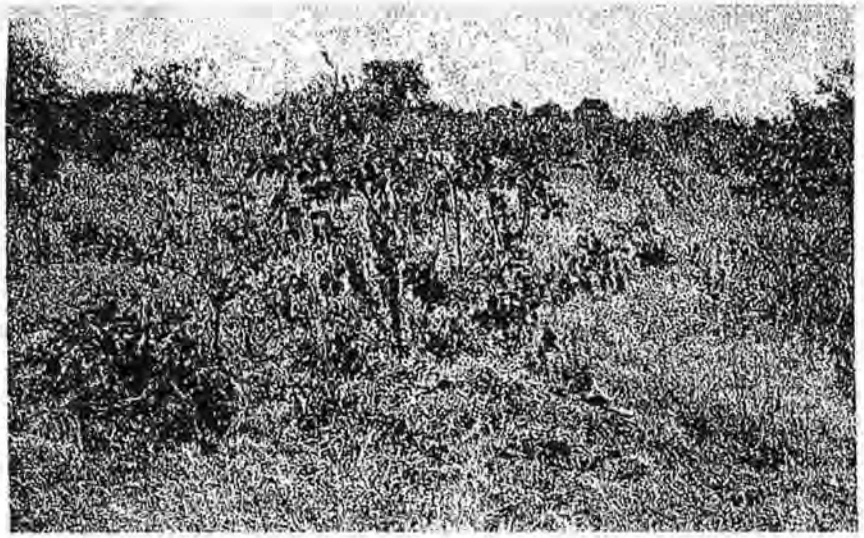


Survey crew walking along parallel transects, 10m apart.

PLATE 4-34

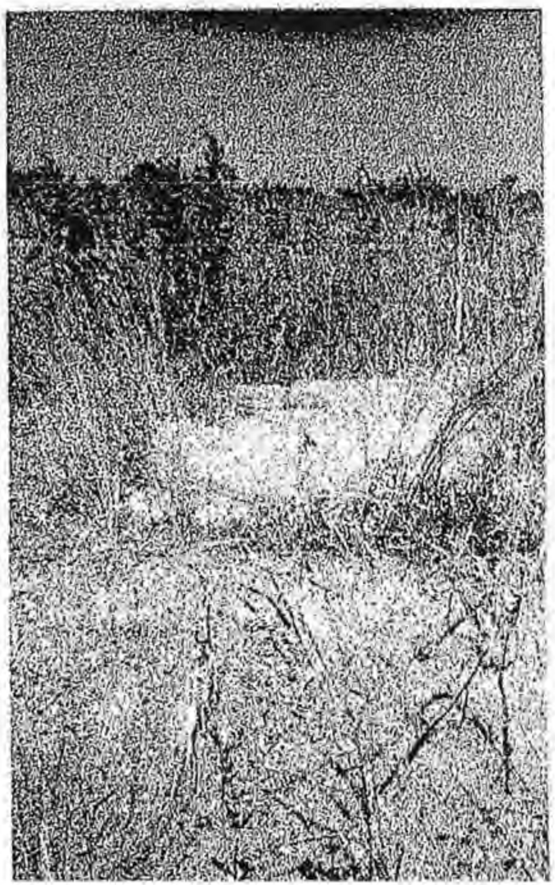
One of many pits dug by artisan miners. Most of the pits were back-filled last year by bulldozer. This is one of a few that were missed.

PLATE 4-35



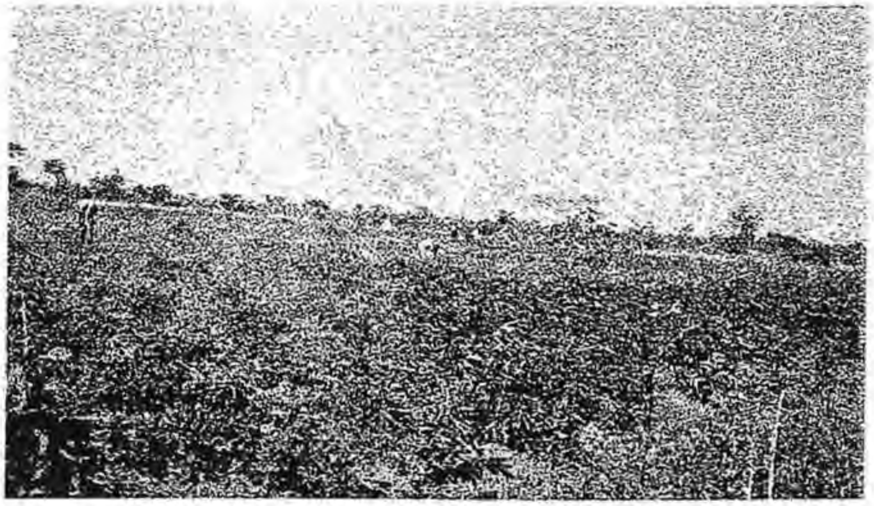
A single grave in Burial site 1, Survey Zone I.

PLATE 4-36



A concretized grave, located in Burial site 4, Survey Block II.

PLATE 4-37



Farming in Bulyanhulu and cattle grazing along Bulyanhulu River.

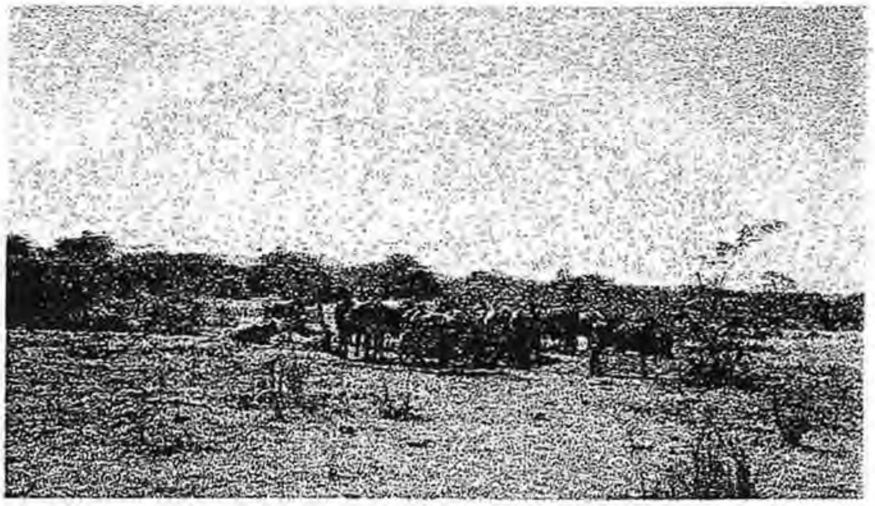
PLATE 4-38a

Farming in Bulyanhulu and cattle grazing along Bulyanhulu River.

PLATE 4-38b

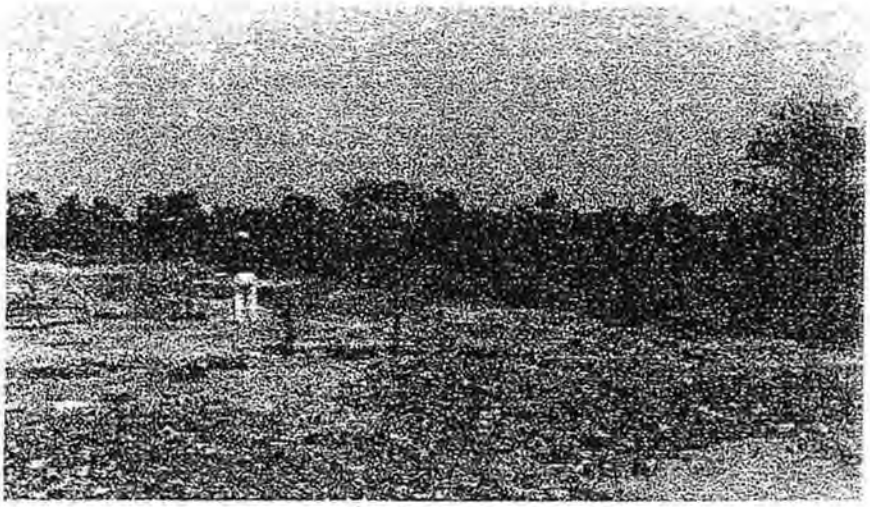
Land clearing for farming and grazing.

PLATE 4-39a



Land clearing for farming and grazing.

PLATE 4-39b



Artisanal mining damage of the landscape, Bariadi Dobboro.

PLATE 4-40a

Artisanal mining damage of the landscape, Bariadi Dobboro.

PLATE 4-40b