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# GROUNDWATER RESOURCES OF THE CHYULU HILLS: PROGRESS REPORT, September 1982.

Dr E P Wright

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## 1. INTRODUCTION

1.1 A preliminary report was submitted in June 1982. This first Progress Report discusses the results of the analytical measurements carried out to date. A further short visit is planned in September-October 1982 in order to collect samples and make flow measurements of the springs under dry season conditions. The main area of interest is shown in the accompanying map, Figure 1.

## 2. PHYSIOGRAPHY AND CLIMATE

2.1 The Chyulu Hills are an elongated range extending some 80 km situated to the west of and parallel to the Mombasa-Nairobi road and railway and the Athi river. The surrounding plains are between 3000 to 4000 feet in elevation (higher elevation on the western side) with the hills rising to over 6000 feet. The Chyulu Volcanic mass has been extruded athwart pre-existing drainage towards the Athi which has caused significant diversions, notably for example, the Lolturesh river.

2.2 Measured annual rainfalls are commonly in the range of 500 to 1000 mm but probably exceed these amounts on the hills. The distribution is bimodal with rainy seasons from March to mid-May and October to December.

2.3 The soils on the lavas are thin to non-existent and when present are dark coloured with a gravelly, silty-clay texture. The soils of the basement plains are thick, red coloured sandy clays to clays. The vegetation includes grassland and bush and often appears more luxuriant on the volcanic soils. Vegetational changes are commonly apparent across the contact between basement and Chyulu volcanics. Changes are less obvious at the contact of the Chyulu and the older Kilimanjaro volcanics.

## 3. GEOLOGY

3.1 The Chyulu Hills north of latitude 2°30'S are included in the 1:125,000 geological map by Saggerson (ref. 1). The two 50,000 sheets, Mzima Springs and Kibwezi, which form the south-east corner of Figure 1 are included in the Geological Survey of the Taita Hills Region by Austro Minerale (ref. 2).

3.2 The Chyulu Hills are composed of basaltic lavas and pyroclastics of recent age and indications are that the age decreases to the south. Saggerson refers to a sample of carbon beneath a lava at Umani Springs in north-east Chyulu dated at 480±200 years. The Shaitani flow close to Mzima Springs is historical with an age in the range 70-170 years.

3.3 The Chyulu lavas were built up by eruptions from hundreds of vents distributed along a major north-west to south-east fracture zone and also in association with a subsidiary north-south trend which parallels the main trend in the adjacent basement rocks. The trend of the Chyulu eruptives thus lies transverse to the main basement trend but conforms with one of the two principal structural trends of the Kilimanjaro vulcanism.

3.4 Plate I shows seasonal satellite MSS images of the Chyulu region. The axial core belt of the Chyulu Hills is clearly visible and a differentiation of lava flows is also apparent. Plate II is a photograph of the most recent Shaitani flow close to Mzima and its dark unvegetated surface also appears black on the satellite image. The dark, less vegetated flows appear more common on the western side of the Chyulu Hills. Saggerson refers to 70 lava flows being distinguished in the northern Chyulu with a sequence of 14 groups identified in two areas and 8 in a third.

3.5 The Chyulu volcanics overlie the sub-Miocene peneplain and drainage lines on this surface have in places clearly influenced the trends of lava flows, notably in the Kiboko, Makindu, Kibwezi and other areas. The lavas are likely to be thicker along existing valley forms and locally perhaps to overlie older alluvial deposits. Pre-existing drainage below the lavas are masked and virtually no runoff occurs on the lava outcrops but the older trends are likely to have persisted in the adjacent foot hills. Carbonate rocks occur quite commonly in the valley of streams leading from the lavas and are assumed to be derived by the leaching of carbonates from the volcanics and subsequent deposition in the stream valleys and swamp deposits.

3.6 To the south-west of the Chyulu Hills, the recent lavas abut against more massive Pleistocene volcanics of the Kilimanjaro sequence. Elsewhere basement rocks composed of schists, gneisses and metamorphosed carbonate rocks underlie adjacent areas and the dominant north-south structural trends are clearly apparent in the satellite photographs. The area south of latitude 2°30'S has yet to be mapped in detail and the 1:2,000,000 geological map of East Africa is clearly in error in certain respects.

3.7 The elevation of the floor of the Chyulu Volcanic mass is not known with any certainty. The elevations of the various basement inliers in the peripheral Chyulu Hills, and the depth to basement in the one well located in the main lava outcrop (C2476, Table 9; B5 in Table 8 and Figures 1 and 2) suggest a general conformance with that of the surrounding plains at some 3000 feet which would imply a regional slope eastwards towards the Athi River. The Bouger anomaly map of Kenya, part of which is reproduced in Figure 3, shows no anomaly across the Chyulu Hills and with gradients suggestive of a stable basement block. No measurements have been taken in the higher hill region and a local gravity survey across the hills could provide more precise data on the thicknesses of the lava pile. The discharge characteristics of the Mzima Springs suggest a much larger subsurface catchment than would be indicated by a western extrapolation of the main drainage trends east of the Chyulu. This could imply a collapse of the basement floor along a narrow zone of the main cone belt as indicated in Figure 2 and the feature could have an important hydrogeological significance.

# 4. HYDROLOGY AND WATER RESOURCES

## 4.1 General.

No significant runoff occurs on the Chyulu Hills and rainfall which infiltrates reappears as springs or discharges into marginal rocks. The marginal rocks are mainly basement complex rocks which even when weathered have low permeability. This outflow must be minor but is of local importance.

## 4.2 Water Resources.

The Mzima Springs provide 0.43 $m^3/s$ by pipeline to Mombasa. The various springs of the Kibwezi valley (Umani, Chai, Manoni) are utilised for agriculture, domestic supply and the requirements of the railway. One of the Makindu springs has a piped offtake to Makindu Railway Station. The upper Kiboko springs provide water for the Hunter's Lodge Hotel. A number of boreholes have been drilled in the eastern Chyulu foothills. Most are completed in basement rocks with several penetrating a thin lava sequence before entering basement. Several are fairly good producers in comparison with boreholes in basement rocks generally and have yields of between 2/4 litres/sec. That such yields can be maintained may be due to some recharge from the groundwater reservoir in the lava. A few boreholes have also been drilled in the narrow carbonate outcrops downstream of the snouts of lava flows and these also are fairly productive with comparable yields.

## 4.3 Development Options.

The water resources are of importance in relation to their potential for piped supply to distant areas as in the case of the Mzima and Lolturesh springs. Water resources also have local importance for agriculture, cattle use and domestic supply and additional development is feasible in connection with all three. Water resources are probably the main limitation to development and the optimum use of the available resources will require careful planning with detailed consideration of priorities for various alternative options. Piped external supply is likely to be limited to the Mzima and Lolturesh springs which have large and (relatively) consistent discharges. Problems of further development relate to the long term reliability of discharge rates which will include possible effects of development of the Chyulu groundwater, the vulnerability to pollution at source, i.e. on the Chyulu Hills, and the need to maintain base flow in the associated rivers (Tsavo and Lolturesh). Other than for baseflow in the Tsavo and piped external supply, there would appear to be no significant local requirement in the National Park area. More controlled development excluding surface storage would require groundwater abstraction in the Chyulu Hills upgradient of the springs and could be costly. The Lolturesh does have flow which is now being lost by evaporation in riverine swamps and piped supplies for external use or local cattle ranching would seem to offer the best alternatives for use. The smaller dispersed springs of the eastern Chyulu have almost certainly more localised controls and are likely to react more rapidly to rainfall variations. Utilisation of the springs' discharge will need to take account of such variability and without the feasibility of storage, full development at source will not be warranted. Abstraction of groundwater by wells upstream of the discharge may allow greater flexibility and fuller development but significant studies would be needed to determine feasibility and cost. Small but significant additional development by boreholes in the marginal basement rocks could prove of real value for domestic supply and the significance of the hydrogeological controls to boreholes in such locations needs to be ascertained. The comparative value of water in terms of agriculture (irrigation), cattle and domestic supply needs to be ascertained. The planned development of the west bank of the Athi by irrigation from a proposed dam upstream of the Chyulu could prove very relevant in this connection.

4.4 Planning and Investigations.

A full investigation of the groundwater resources of the Chyulu Hills would be a fairly extended and quite costly programme but at the least some phased limited studies seem warranted. Preliminary consideration of the various development options outlined above is also warranted. Information on probable priorities for development would assist decisions on the justification to undertake the more detailed investigations. To assess the groundwater resources and potential for development, information is needed on recharge and the aquifer characteristics, permeability, specific yield and overall geometry. The latter information can only be obtained definitively by drilling. The present limited studies are aimed mainly at recharge evaluation. The principal techniques under consideration include (i) rainfall and evapotranspiration with assumptions of nil runoff; and (ii) a chloride balance of rainfall and groundwater. The following discussion summarises the results to date.

## 5. SURFACE HYDROLOGY

5.1 The main rivers include the Kiboko and the Lolturesh-Tsavo and several smaller rivers from the east Chyulu Hills directed towards the Athi (Figure 1). The regional slope of the pre-Chyulu ground surface was eastward and the lava pile has clearly intersected and in places diverted older drainage channels. The Kiboko and the Lolturesh have been directed to the north and south respectively and in between a central swamp region abuts against the western Chyulu. Indications are that the swamps are seasonal and derived from surface runoff from the west. The Kiboko (or Oldukai) also flows seasonally but the lesser Kiboko which originates in the Kiboko springs (1 in Figure 1) has perennial flow. The Lolturesh river receives a major contribution from the Lolturesh springs (13) discharging in the foothills of Kilimanjaro. A significant flow was observed in May 1982 at the road crossing near to Oloitokitok (R2). Downstream and to the east where the road to Mtito Andei crosses the Lolturesh again, no flow was observed despite recent rainfall. It seems likely that flow in the middle Lolturesh occurs only at limited periods following heavy rain. Further downstream, surface water was again observed in the Lolturesh channel being derived presumably from two groups of springs in the south-west Chyulu (11, 12). The flow observed near Oloitokitok must be lost by evaporation in the intervening swamps close to the West Chyulu Hills and clearly apparent in the satellite photographs. The occurrence of some groundwater inflow to the swamps from the Chyulu Hills could also be considered a possibility and will be very easy to check since the stable isotope compositions of the Lolturesh springs have been shown to be significantly different to the Chyulu groundwater and correlate with a higher elevation of precipitation. The swamps in the west Chyulu have yet to be visited.

5.2 The streams draining the east Chyulu have base flows derived from springs with some additional runoff during the rainy seasons. The principal streams and the springs are associated with tongues of lava extending from the main lava pile which clearly have followed old drainage channels. The majority of the streams now skirt the lava tongues and have presumably been displaced laterally in consequence of the damming effect of the lava flows. The Kibwezi river which has a channel partly on the lava outcrop shows intermittent occurrence of surface water which periodically disappears and emerges as springs further downstream.

## 6. SPRINGS

6.1 Springs discharge from the Chyulu Volcanics at various locations on the east, south and south-west foothills. All except one (referred to by Temperley, ref. 3) occur at low elevations close to or at the margin between the volcanics and adjacent older rocks (mainly basement). During the recent survey, all the main springs were visited and wherever possible the spring outflow was sampled and discharge rate measured. The measurement technique used was by float and stopwatch and is unlikely to be more accurate than ±15%. The full details of springs are shown in Table 6 but a summary of discharge rates and spring elevations are shown below. Current total flow is c. 5.5m$^3$/s.

6.2 The Mzima springs occur at the southern end of the Chyulu Hills and have the lowest elevation and maximum discharge of all the springs. Temperley's statement that the Mzima springs represent 90% of The Chyulu Hills outflow appears a slight overestimate. The remaining spring discharges total about 0.92 m$^3$/sec and are likely to be an underestimate although some 'double accounting' must be included in the Kibwezi group (4, 5, 7). The Kamba ya Simba discharge also disappears underground shortly after its initial emergency and may reappear at Kitane. However there are more likely to be underestimates in the flow rates and a better indication of gross discharge may be feasible in the dry season by measurements of base flow in the springs and stream channels. The lower Lolturesh, for example, is likely to be wholly derived from spring discharge, as indeed also the Mtito Andei and Kambu rivers. Two permanent water holes on the lava surface are also known, Lake Embu, west of Mtito Andei and Changondu, west of Makindu.

| Map Ref. | Spring | Rate ($m^3/s$)[1] | Altitude (ft asl)[2] |
|---|---|---|---|
| 1 | Kiboko Upper Springs<br>Kiboko Upper Springs | {0.042[3]<br>{0.015[4] | 3046 |
| - | Kiboko Lower Springs | 0.099[5] | not visited |
| 2 | Makindu Railway | 0.055[6] | 3278 |
| 3 | Makindu Ranch<br>Makindu Ranch? | {0.008<br>{0.003[7] | 3323 |
| 4 | Manoni | 0.047 | 2494 |
| 5 | Chai<br>Chai + Kikoo | {0.16<br>{0.20[8] | 2838 |
| 6 | Kibwezi Railway Station | negligible | |
| 7 | Umani<br>Umani | {0.06<br>{0.09[9] | 3222 |
| 8 | Kisimani | 0.09 | 2895 |
| 9 | Mangolete | 0.155 | 2708 |
| 10 | Mzima | 4.53[10] | 2231 |
| 11 | Kamba ya Simba | 0.077 | 2629 |
| 12 | Mailu | not measurable | 2716 |
| 14 | Kitane | 0.127 | 2396 |
| | Approximate Current Total | 5.45 $m^3/s$ | |

1 Measured in May 1982 unless otherwise stated

2 By corrected altimetric traverses with single base altimeter

3 Discharge measured at outlet of Hunters Lodge reservoir

4 Quoted by Saggerson, 1956 measurement

5 Saggerson, by difference, measurement below railway bridge

6 Measurement by Saggerson 1956; unable to measure on current visit due to outlet obscured by swamp

7 Cattle spring of Saggerson, probably same

8 Saggerson

9 Saggerson

10 Mean of 1981 flows

6.3 The general absence of high level springs, the apparent absence of springs in the western Chyulu and the occurrence of known springs close to the volcanic contact with adjacent rocks and in particular in association with tongues of lava probably following older drainage channels strongly suggests that the saturated section occurs near base of the volcanic pile and is generally of little thickness. Hydraulic heads and discharge locations will tend to be closely controlled by the topography of the basement floor. It may also be significant that the main protruding lava tongues are composed of the more permeable Pahoehoe lavas as compared with the Aa type. The lavas all have high infiltration capacities. The absence of springs on the western Chyulu seems indicative of the easterly slope of the basement floor. Some confirmatory evidence is provided by the records of the one well (C2476 = B7 in Figure 1) drilled into the main lava field west of Mtito Andei. The static water level at the time of drilling was recorded at 390 feet below ground level which is 30 feet above the weathered basement surface (Figure 2).

6.4 The easterly slope of the sub-Chyulu basement floor and the presence of the various springs near the protruding lava tongues is suggestive of the hydraulic control of the basement floor configuration, with the main lavas following the trend of older valley forms. The explanation seems satisfactory with the exception of the occurrence of the Mzima Springs. The Mzima valley occupies an older pre-lava valley draining towards the Tsavo but the magnitude of the spring flow and the lack of seasonal variation indicates a large catchment which is unlikely to correspond with that of the original pre-lava valley. The explanation proposed by Temperley (ref. 3) whereby sagging of the basement floor below the axial cone belt has resulted in a channelling of the subsurface flow over a large catchment towards the Mzima springs is feasible although on the assumption of a thin aquifer located just above the contact, sinking of the floor would need to be considerable. A channelling southwards of perched aquifers above the basement floor and within the lava pile is also a possibility but the absence of high level springs does not assist the explanation. A southerly diversion by more massive dyke like bodies within the cone belt would provide an adequate explanation but there is no surface evidence of the existence of such diversionary bodies. The geometry and position of the aquifer body below the central Chyulu could have important implications if groundwater development by boreholes is to be considered.

6.5 Spring Discharge with Time.

Daily measurements of flow are made of the Mzima springs and the Kibwezi River. The gauging station at Mzima is approximately two miles downstream of the source. The Kibwezi gauging station is on the Kibwezi river downstream of the Manoni spring. Records at Mzima extend back to 1950 and at Kibwezi to 1973. A number of studies of the Mzima springs discharge have been made, notably by Scott Wilson Kirkpatrick & Partners (ref. 4) and TAMS (ref. 5). The large flows at Mzima show negligible short term/seasonal variations but longer term changes do occur (see Figure 2.3 in the Scott Wilson Kirkpatrick Report). The TAMS study demonstrated that the best correlation is apparent between the mean annual flows and the average of three consecutive years rainfall (as recorded at the Mzima rain gauge) and a two year lag. Figure 4 prepared by D K Mbogori of the MOWD shows monthly runoff data for the Kibwezi river and monthly rainfall recorded at the Dwa Plantation which occurs in the same area. The considerable variations in the discharge contrasts markedly with the constant discharge of the Mzima river. How much direct runoff contributes to the overall discharge of the Kibwezi is not known and it would be valuable if records could be obtained on one or two of the actual springs. The Umani springs are fitted with a rectangular weir but regular readings are not apparently kept. The response to rainfall appears almost instantaneous and indicative either of direct runoff contribution or very rapid throughflow in the immediate aquifer and a fairly limited catchment.

## 7. RECHARGE ESTIMATES

Recharge estimates have been made using two techniques, (i) rainfall minus evapotranspiration and (ii) a chloride balance of rainfall and groundwater. Discussion of the basic parameters follows:

### 7.1 Rainfall.

Areal rainfall estimates are required for both calculations. A number of daily raingauges with long term records are installed at locations in the eastern and southern Chyulu foothills, at elevations around 3000 feet (Table 1 and Figure 1). At varying times and for short periods, storage gauges have been installed in the Chyulu Hills (Table 2 and Figure 1). The periods of record are short and intermittent. Interference of the unattended gauges is frequent, by Masai herdsmen, poachers or wild animals. Preliminary estimates of areal rainfall have been made but the values must be regarded as very provisional.

7.1.1 Temperley (ref. 3) following an examination of records of Makindu, Dwa, Masongaleni and Mtito Andei station, concluded that there was no similarity in the long term incidence of rainfall which could be deduced from the data. The lack of correlation is attributed to rainfall occurrence in highly localised storms. However a consistent pattern has been obtained in plots of a three year running mean (Figure 5) for the stations at Mzima, Makindu, Dwa and Kamboyo, particularly for the period 1968-1982. Listed in Table 3 and plotted in Figure 4 are mean annual and mean monthly data for 1972-80 for these and other stations in the east Chyulu foothills and extending from south to north of the hill range. The mean annual rainfalls show a close to normal distribution decreasing to north and south from the central Chyulu latitude at Dwa. The Makindu data correspond quite closely with the mean of the 6 stations

7.1.2 Data from the storage gauges in the Hills are shown in Table 5 with equivalent data for the long term gauges in the eastern foothills. Monthly data for 3 years, 1975, 1977 and 1979 is shown in Table 4. No consistent correlations can be deduced in either monthly or annual records, for the hill areas in comparison with the foothills. Considering annual data only, the hill gauges in the late fifties showed significant increases over those in the foothills, commonly around 100% or more. Between 1970-80, the hill gauges gave mean values generally only slightly above the mean of the foothills, mainly in the range 15-41%.

## 7.2 Evaporation.

Long term records have been maintained at Makindu since 1904. Evaporation measurements by a Class A pan are available from 1958 and Woodhead (ref. 6) has made a Penman calculation of potential evapotranspiration using cloud cover in oktas for the radiation term. A summary of the monthly pan figures for 1958-1970 and $E_O$ by Penman calculation for 1938-1962 is listed below.

| | Mean Rainfall (1904-1970) mm | Pan Evaporation (1958-1970) mm | $E_O$-Penman mm |
|---|---|---|---|
| January | 40 | 171 | 175 |
| February | 31 | 181 | 179 |
| March | 81 | 198 | 182 |
| April | 113 | 169 | 160 |
| May | 29 | 154 | 151 |
| June | 2 | 150 | 139 |
| July | 1 | 145 | 139 |
| August | 1 | 164 | 153 |
| September | 2 | 193 | 179 |
| October | 28 | 210 | 191 |
| November | 174 | 173 | 154 |
| December | 119 | 152 | 149 |
| Total | 621 | 2060 | 1951 |

The present equipment at Makindu now includes sunshine recorders and soil temperature measurements and the data will allow a more precise Penman calculation to be made. For the present preliminary calculations the Pan readings have been utilised and an assumption made that they are equivalent to the Penman $E_O$. A pan factor of perhaps 0.7 would normally have been expected but the Penman calculations seem to indicate little difference with the pan values although admittedly the periods used for the summary of the means differ. For future calculations, it is hoped to obtain Penman $E_O$ calculations for individual years.

7.3 Recharge Calculations by Rainfall-Evapotranspiration.

For basin water balance studies, rainfall and actual evapotranspiration need to be calculated with assumptions made of a root constant and a maximum soil moisture deficit. Potential evapotranspiration is converted to actual evapotranspiration in accordance with the selected root constant and following the Penman (ref. 7) correlation between actual soil moisture deficit and potential deficit. A number of very significant uncertainties exist in this calculation.

(i) The validity of using uncorrected pan data for $E_o$. ($E_o$ is subsequently converted to ET (potential evapotranspiration) by multiplying by a factor of 0.7 for a short grass crop). Improved calculations of $E_o$ can be determined with the present day records as noted above.

(ii) The extrapolation of the Makindu data to the main Chyulu Hills. A decrease in temperature with altitude is to be expected and the Hills rise to over 6000 feet as compared with the altitude of Makindu at c. 3000 feet. An increase in cloud cover is also to be expected which will reduce the solar radiation and is likely to have a greater effect on evaporation than the temperature changes resulting from the altitude effect. A further significant factor would be a change in the vapour pressure deficit. No simple technique to assist extrapolation of the Makindu data to the Chyulu Hills is apparent. The altitude regression determined by Woodhead (ref. 6) from regional data is not applicable to these more pronounced localised phenomena. For the preliminary calculations in this report, the Makindu data are used but consideration will need to be given to modifying this data to achieve more representative results. Cloud cover from satellite imagery may be one possible approach.

An assessment of the effects on potential evaporation ($E_p$) of rapid changes in altitude has been made by an examination of data from the Mount Kulal area of north Kenya where both high level (Mount Kulal, 5906 ft elevation) and low level (Belesa Kulal, 1969 ft) meteorological stations exist (Fig 7). Belesa Kulal is some 20 km from Mount Kulal and thus distance, gradient and location in respect to prevailing winds is comparable to the Makindu-Chyulu Hills situation although the mean annual rainfall of the latter area is somewhat higher. A limited amount of concurrent data for the two stations for two 10-day periods in 1979 have been assembled and analysed by courtesy of Dr Stewart of the Institute of Hydrology and the results are listed below. Original records are of daily data.

7.3.2 In Figure 8 and Table 12 are shown correlations of discharge-recharge. Two cases of discharge estimates are used; case (a) in which the Mzima flow (corrected for abstraction) is regarded as 70% of the total Chyulu discharge and case (b) when it is 80%. As measured on the various springs, the Mzima flow is about 85% of the total but this does not account for dispersed underflow into the basement, loss from the two lakes etc. The mean annual total discharge is recalculated as an equivalent height over the total catchment.

7.3.3 In accordance with the calculations in Table 11, recharge mainly occurs in November/December and less commonly April. It is also restricted to certain years and there are gaps of varying duration up to several years in which the calculated recharge is nil. The percentage recharge of precipitation in those years in which it does occur is also variable; for the 75 mm root constant, it can vary from c. 4 to 40%.

7.3.4 Figure 4 suggests that the conceptual approach is correct and also that a lag exists between the mean annual recharge and discharge at the Mzima springs. Maximum discharge was not attained until 1970 with the previous recharge occurring in 1968. The long regression from 1970-8 correlates with the absence of recharge during this period.

7.3.5 The period 1961-77 has been used to correlate estimated discharge-recharge. Allowing for the two year lag, 1963 to 1977 at which times the discharge rates were closely comparable and hence reflected comparable hydraulic heads in the aquifer are correlated with the period 1961-1975. Recharge occurred in 1961 following several years of nil recharge and 1975 occurs within a period of regression. A close correlation of the recharge (1414 mm) using a 75 mm Root Constant and the total Chyulu Discharge (1433, case a) is obtained.

7.3.6 These correlations are indicative that the conceptual approach is correct and improvements should help to refine the analyses. The use of a simple statistical correlation of rainfall with discharge is seen to have a very dubious meaning. Depending on the validity of predicting monthly rainfalls at the critical times and the evaporation rates which will be easier, predictions of discharge can be made.

## 7.4 Hydrochemistry.

### 7.4.1 General chemical composition.

A number of main mineral analyses are shown in Tables 13 and 14. The spring waters are fresh to very fresh and in general the quality is obviously adequate whether for domestic supply or irrigation. The Manone spring has probably increased its mineral content either by evaporation of upstream surface flow or in consequence of the contribution of recycled irrigation water from the Dwa plantation. The Kiboko spring is also somewhat anomalous in its significant sulphate component as well as the fairly high chloride value, and no obvious explanation occurs. The Mzima springs show a general consistency of composition with time (Table 14). Boron contents are not known and in the irrigation context this information would be desirable. A slight question mark exists against the fluoride (F) content. The IGS analyses shown in Table 15 are in most cases higher than the MOWD equivalent results and one/two of the (IGS) values are greater than 2 ppm which would be regarded as somewhat excessive. In particular the Mzima springs composition needs to be carefully checked in this respect since it is used for the Mombasa supply.

7.4.2 Chloride balance : recharge estimation.

The method assumes that all chloride enhancement of the rainfall (less runoff) relates to evapotranspiration (or can be corrected) and the rainfall component which infiltrates to groundwater can therefore be calculated. No addition of chloride within the rock or soil formations, saturated or unsaturated zone, is assumed and the assumption is reasonable in the present instance. The difficulty in applying the technique in the Chyulu area lies in the variable occurrence of recharge and the lag in response of the discharge. Spring discharge will increase in relation to hydraulic head changes even before the arrival of the particular recharge water. It must furthermore be assumed that any Cl which accumulated in the soil during periods of nil recharge would be flushed through in the subsequent recharge period. Chloride contents would be expected to vary therefore in relation to the durations of the previous nil recharge period, and the degree of subsequent recharge in relation to concurrent infiltration. The initial flushing would contain higher chloride content and the feature would eventually reflect in the variable quality of the springs discharge. Insufficient data are available on the variations in chloride content for satisfactory evaluation of either individual recharge events or for mean long term recharge calculations but some preliminary consideration of the available data is provided. The accuracy of the chloride determination is critical since the calculation of recharge is based on a direct ratio of the chloride content of the recharge (represented by the groundwater) and that of rain.

7.4.2.1 The chloride content of 8 samples of rainfall collected during the recent visit is shown in Table 15. The mean value is 3.95 with a range between 1.3 and 7.8. The chloride content on the Mzima springs sampled on various occasions between 1965-1980 shows a range of 8-16 and a mean of 10 mg/1 (Table 13). If this low value of groundwater chloride content could be regarded as a long term mean, it would imply that recharge was some 40% of rainfall which is manifestly improbable. The distribution of the chloride determinations in Table 13 show that the last five determinations occurred during a period of virtually nil recharge as also were the previous 3 years during which no analyses are available. If it can be assumed that the chloride accumulated during the short previous period of nil recharge (1965-66) had been leached out in the first flushing with the later recharge having a chloride content consonant with the appropriate balance of rainfall and evapotranspiration, the recharge can be computed from these chloride ratios and the rainfall occurring between November 1967 and December 1968. Total rainfall during this period was 1519 mm and computed recharge would be 607 mm. This compares fairly closely with the recharge of c. 500 mm computed from rainfall - evapotranspiration relations (Table 11).

7.4.2.2 Chloride contents of samples of the major springs in the Chyulu region are shown in Table 15. Samples were collected in May 1982. The chloride content of the Mzima springs averaged 25 mg/l (analysed by IGS) which is apparently higher than that shown in the previous set of samples (1965-1980). The mean of the other main springs excluding those samples whose compositions are likely to have been locally enhanced by evaporation have a comparable mean value of 26 mg/l. The higher chloride values could represent flushing of accumulated chlorides by the recharge events of 1978-79 and it would be of value to observe any subsequent regression in chloride content.

7.4.3 Environmental isotopes.

Samples of rainfall, surface and groundwaters were obtained for analysis of the radioactive isotope tritium and stable isotopes of deuterium and oxygen-18. The tritium results have yet to be obtained and the discussion below is a preliminary interpretation of the stable isotope data. Further samples are to be collected in the forthcoming visit.

7.4.3.1 The main objectives of the sampling programme were as follows:

(i) To characterise groundwaters from different sources and to relate then to time and place of discharge.

(ii) To calculate the residence times of the groundwater reservoir in order to correlate with recharge-discharge analyses.

In particular, it was hoped to differentiate inputs from the Chyulu Hills and Kilimanjaro, and to obtain an indication of the areal extent of the Mzima sub-catchment as compared with those of the smaller springs of the eastern Chyulu. It had been suggested that the springs in the SW Chyulu Hills originated in Kilimanjaro. A related problem is the origin of waters occurring in swamps to the west of Chyulu. These swamps have yet to be visited.

7.4.3.2 A general discussion on environmental isotopes will be deferred until a later report by which time the tritium results should be available. The stable isotope results are listed in Table 16 and plotted in Figure 9. Considering firstly the rainfall, the plots all fall on or close to the world meteoric regression line. The storage gauges, Chyulu I and II, plot fairly close together with the former at a somewhat higher altitude being more depleted as is to be expected although the differences are not great. The plots of the two single events are widely spaced at opposite ends of the regression line with the two weeks accumulation occurring in intermediate positions. The groundwaters/surface waters also plot close to the regression line but with the Lolturesh spring and river markedly separate from the Chyulu springs. The positions close to the regression line indicate the absence of fractionation which would have resulted from evaporation (evapotranspiration has no fractionation effects). The lighter waters of the Lolturesh springs are consistent with an origin on the higher altitudes of Kilimanjaro and indicate that none of the Chyulu springs are derived from Kilimanjaro. It should also be feasible to identify the source of the water in swamps on the western edge of the Chyulu.

The Chyulu groundwaters all plot fairly close together and in the general vicinity of Chyulu I and III rainfall which suggests that the single or short term accumulations are atypical or not closely representative of the mean rainfall compositions on the hill areas. The Mzima springs do not differ in any degree from the other spring waters and no relation to catchment size or altitude is therefore apparent. Tritium results are likely to be more indicative since they will relate to residence times.

## 8. SUMMARY OF CONCLUSIONS

(i) The Mzima springs discharge is probably some 70% of total groundwater discharge from the Chyulu.

(ii) Recharge seems likely to have occurred at variable intervals with gaps of up to several years with no recharge occurring.

(iii) Precipitation in the eastern foothills shows a decreasing trend to both north and south from a central maximum. The Makindu values can provisionally be used as representative regional precipitation for the eastern foothills.

(iv) Precipitation increases at higher altitudes but the degree is uncertain. In some years it appears to be some 10-40% higher than the mean (Makindu) precipitation; in others it may exceed by 100% or more.

(v) The western Chyulu may be in a slight rain shadow with lower precipitation but this is as yet surmise.

(vi) Recharge has been calculated by analysing rainfall-evapotranspiration data and chloride ratios in rainfall and groundwater and a general correlation has been established either with recharge computation or withdrawals from storage over comparable hydraulic head changes. The correlation gives some confidence in the conceptual value of the proposed process. The lag of discharge on recharge and information on storage columes can be deduced. Further studies to improve the accuracy of the basic parameters - evapotranspiration, areal precipitation, soil moisture deficits will assist the accuracy of the correlations. Statistical studies on rainfall are needed in particular in relation to the critical assessment of maximum rainfall rates in November/December and April to assist reliable predictions of future discharge. In this connection also, the tritium results may eventually throw more light on the residence time in the aquifer and hence recharge-discharge relations.

(vii) The MSS imagery has yet to be obtained but will be used for the following derivations:-

- soil and vegetation cover mapping to assist in estimates of evapotranspiration, soil moisture deficits etc.

- structural and geological interpretation; in particular the possibility of a central graben parallel to the principal Chyulu trend.

- cloud distribution with time (NOAA satellite data) to assist regional precipitation measurements and radiation evaluation.

- location of spring discharges.

(viii) Development options should be given early consideration. The use of groundwater by drilling/increased abstraction from springs can be considered in the context of probable recharge and storage volumes but the technicalities of abstraction by drilling are uncertain. Preliminary evidence is unfavourable since it indicates a thin extensive aquifer located at the base of the lava succession. A thicker section may occur in the Mzima springs sub-catchment but this is more likely to occur below the higher Chyulu Hills and drilling costs would be prohibitively high. Some test drilling/geophysical survey is needed to evaluate these aspects.

E P Wright.
September 1982

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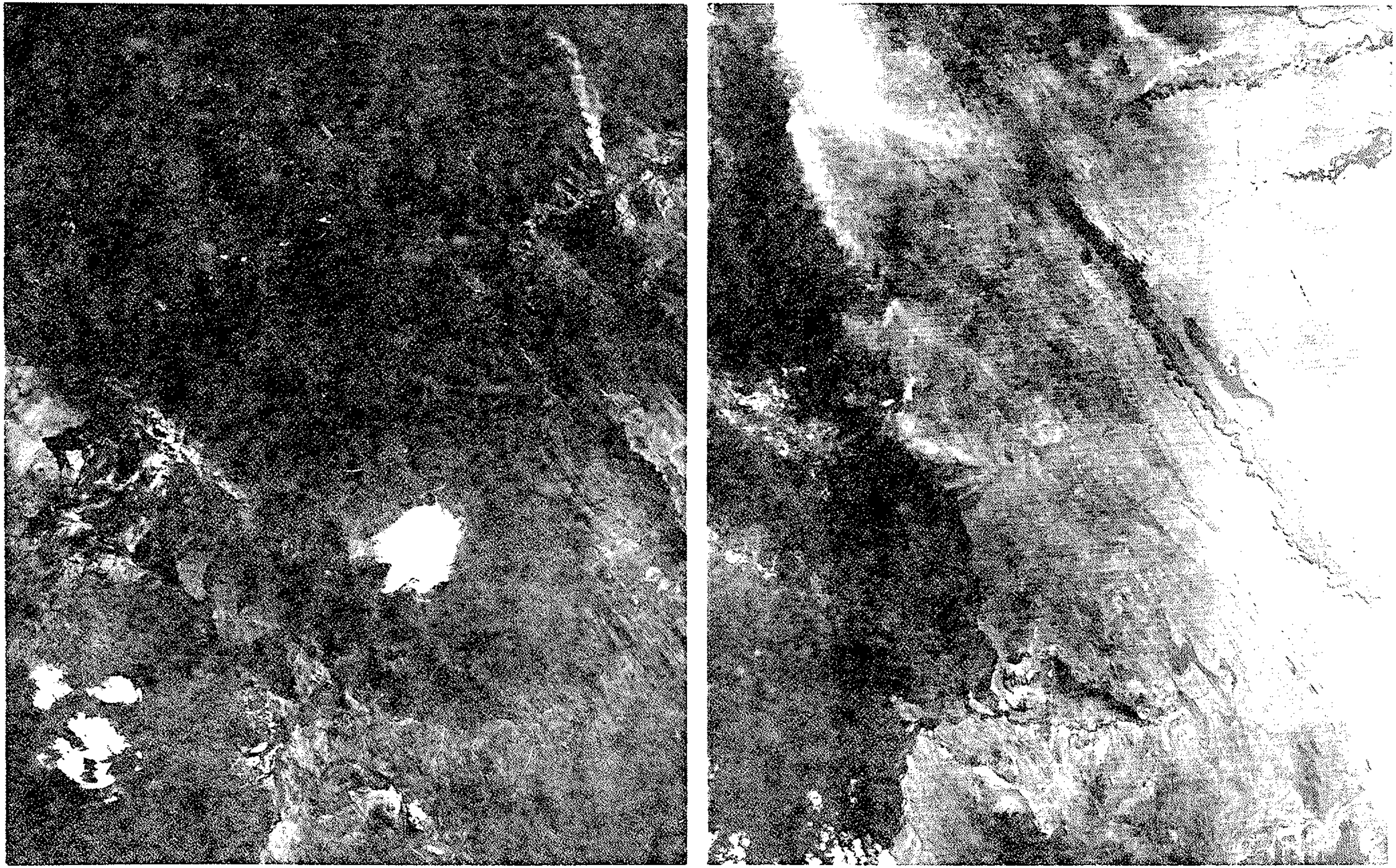
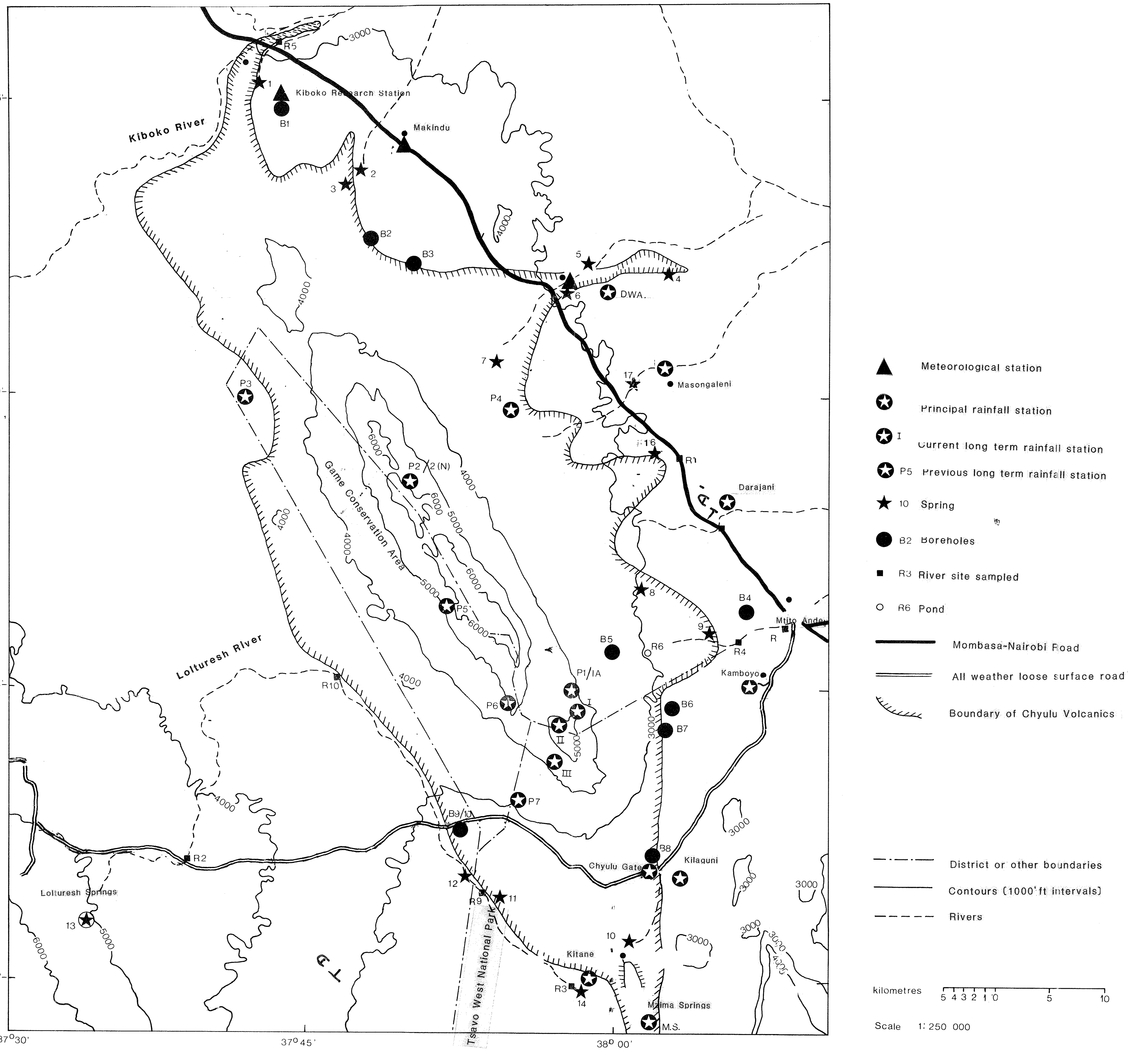


Plate 1

Plate 2

## Map of the Chyulu Range Region Figure



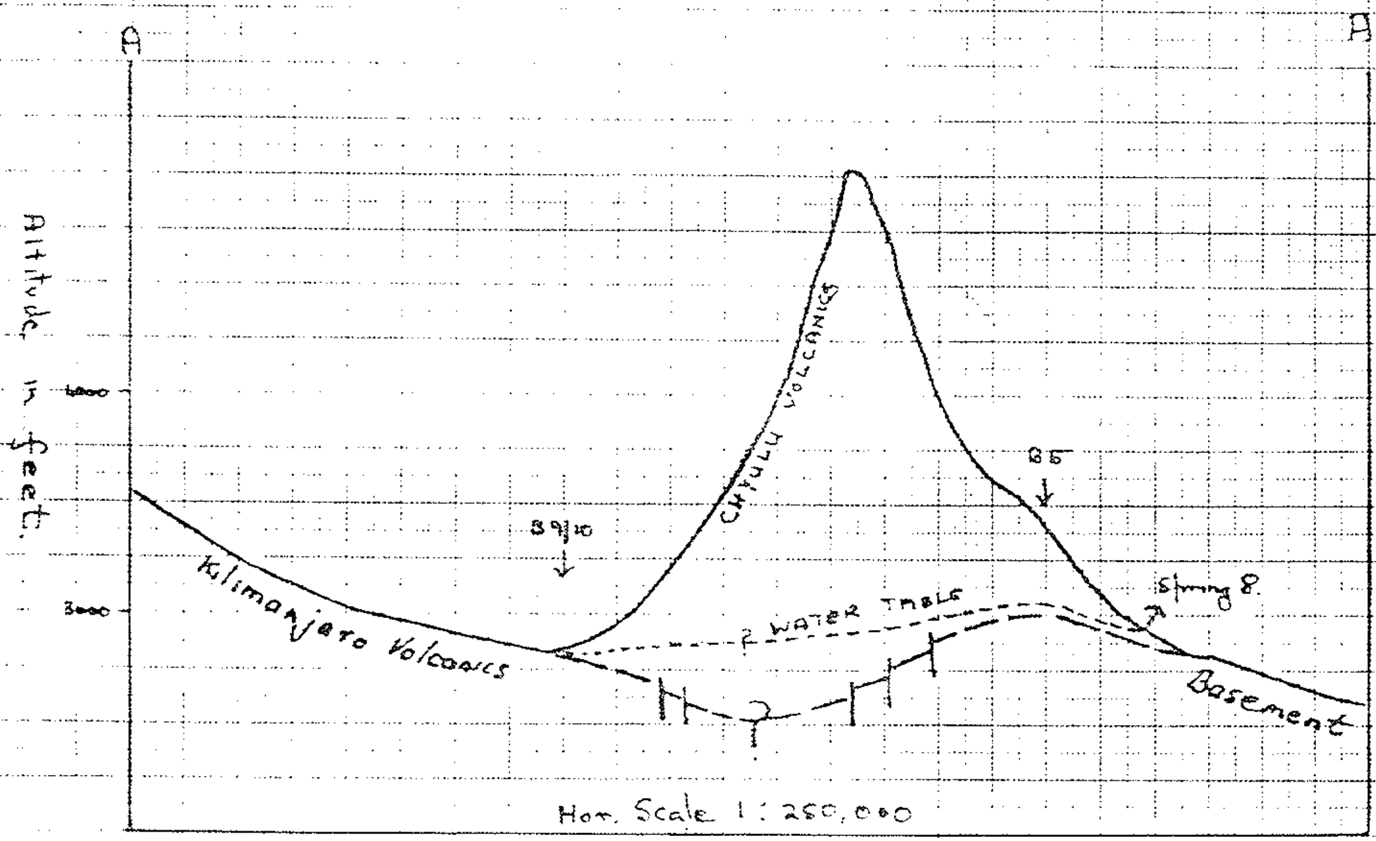



Figure 2 Schematic Cross Section across Chyulu Hills. Line on Fig. 1.

FIGURE 3. Bouger Anomaly Map of Kenya (Source: Leicester University, 1977).

Countour Interval 10 mGal
Scale 1 : 2,000,000 (approx.)

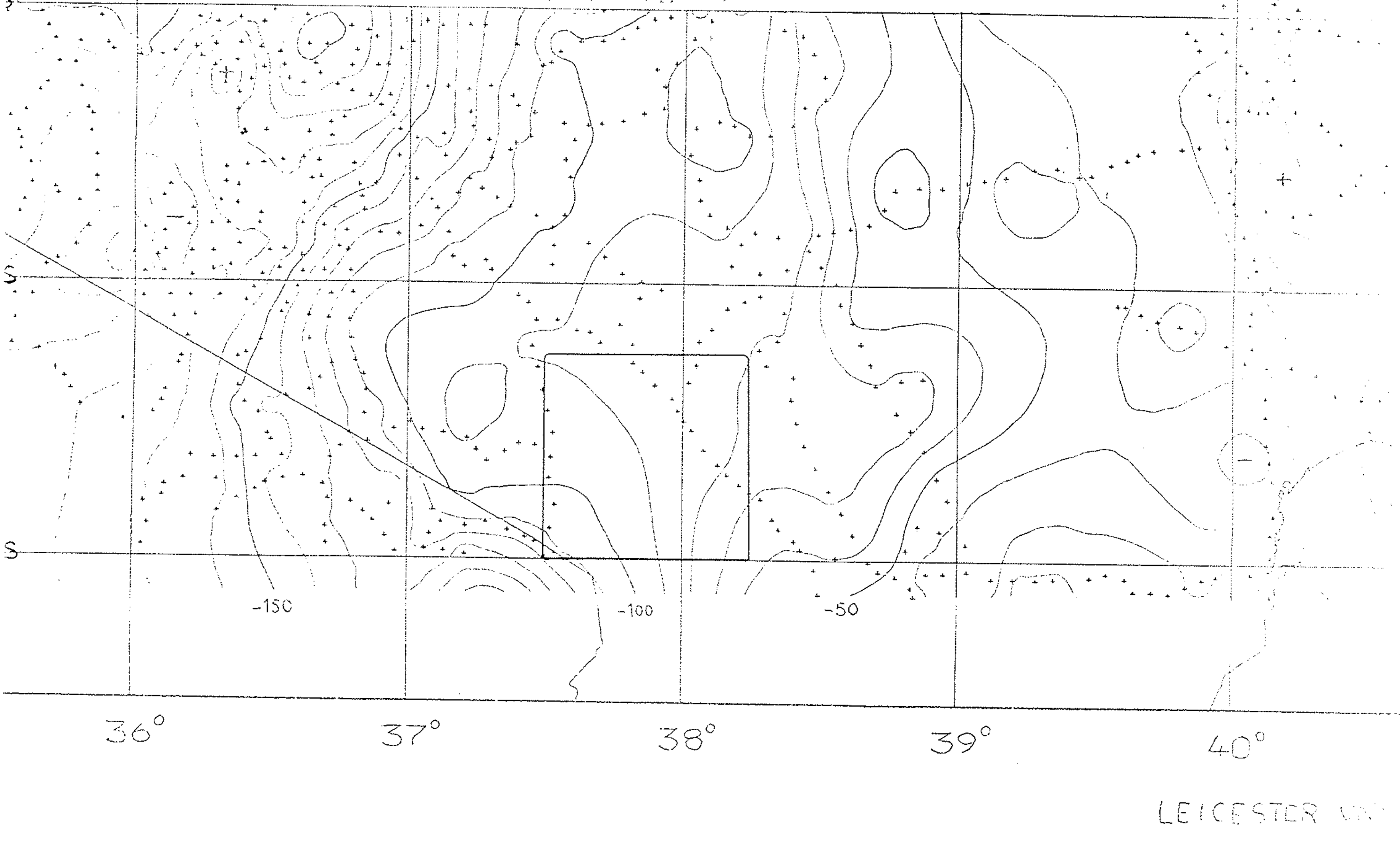


FIGURE 1. Monthly Rainfall at Kibwezi Dwa Plantation and Runoff on Kibwezi River St. No. 3F6.

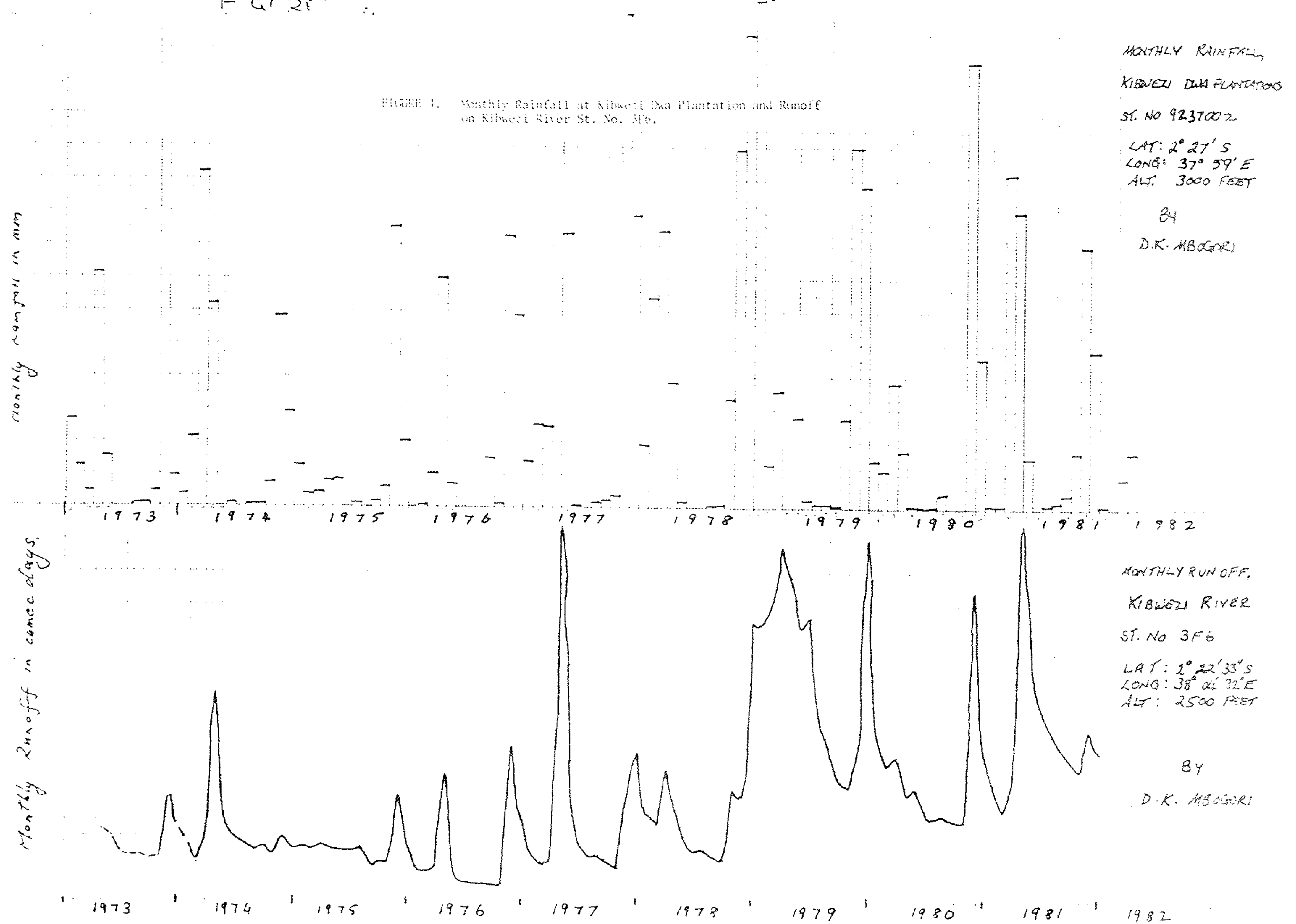


FIGURE 5. Three Year Running Mean of Annual Rainfall for Selected Rainfall Stations.

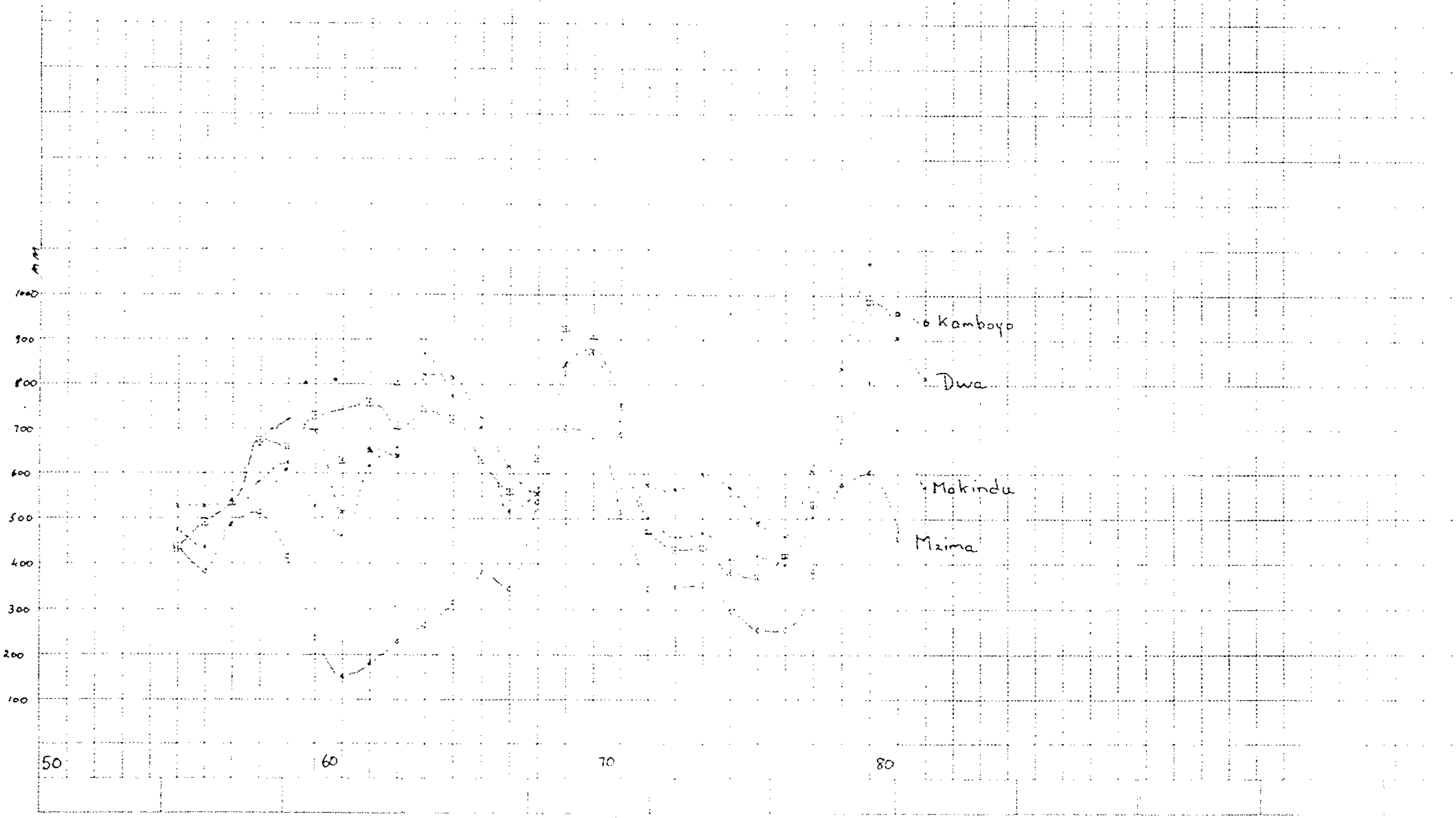


FIGURE 6a. Plot of Mean Monthly Rainfall for Chyulu Rainfall Stations for period 1972-1980.

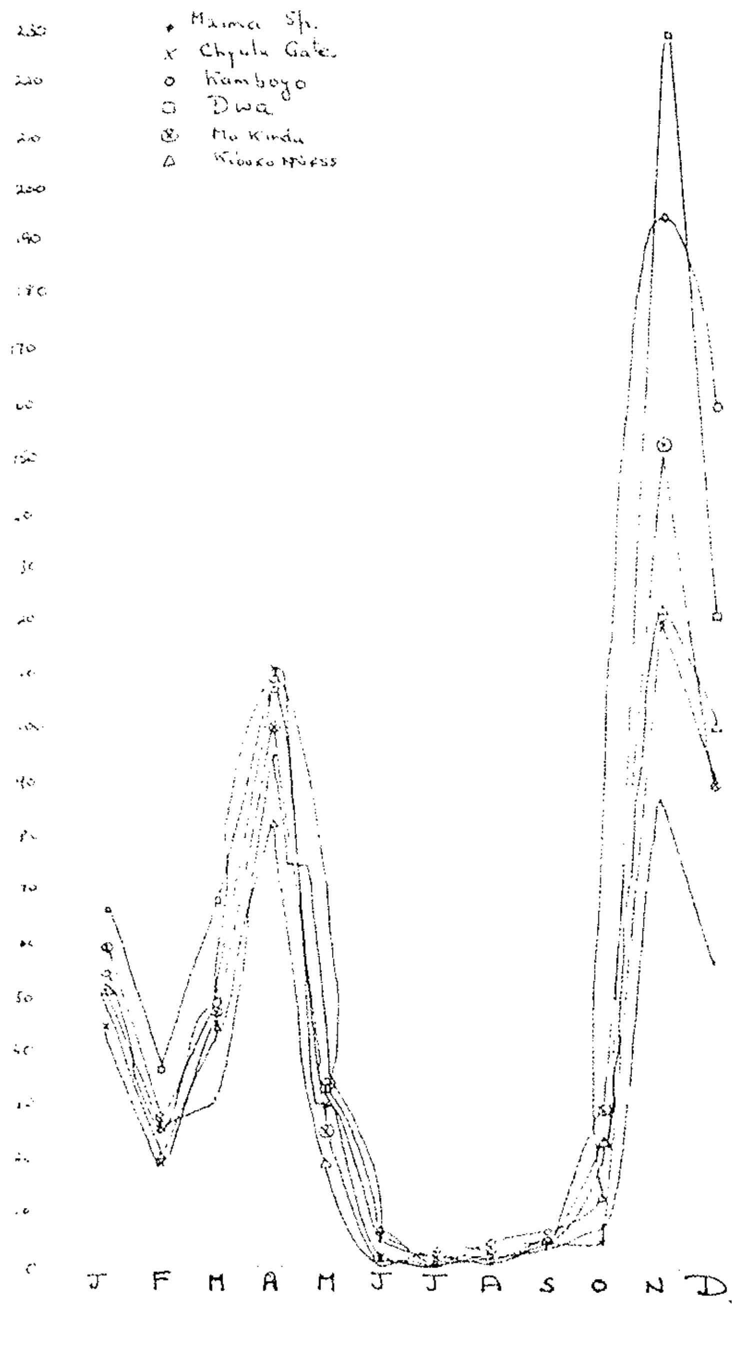



FIGURE 6b. Plots of Mean Annual Rainfall over same period (Table 5).

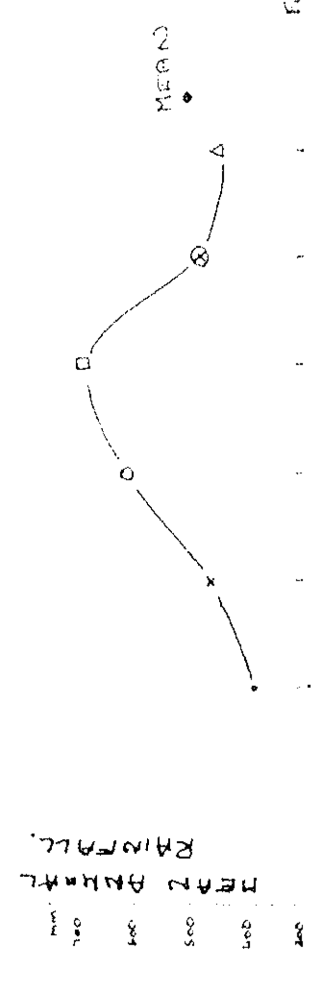



Figure 6 b.

Plate 7. Topographic Map, 1 : 250,000, showing locations of Meteorological Stations on and near Mount Kulal.

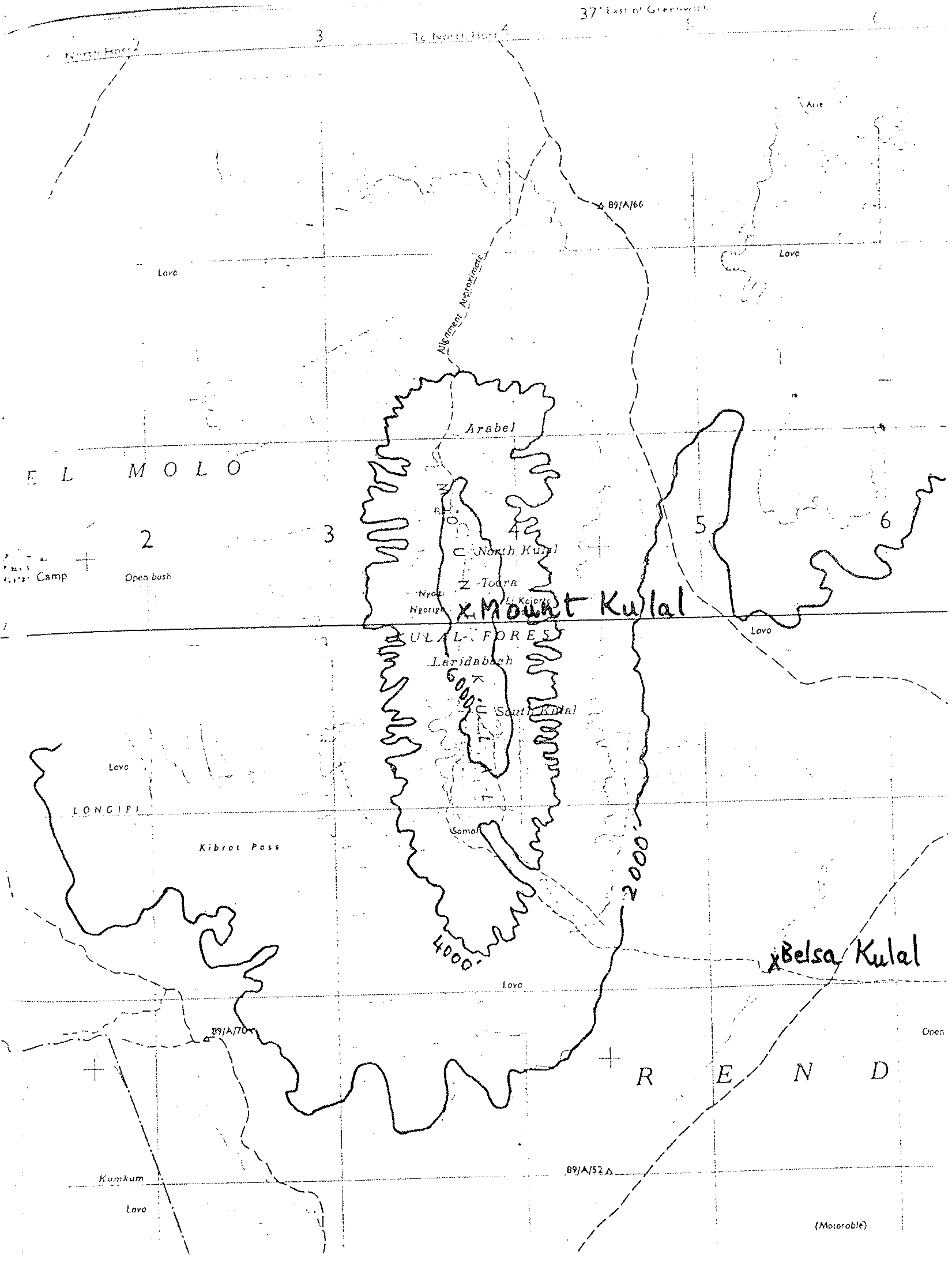
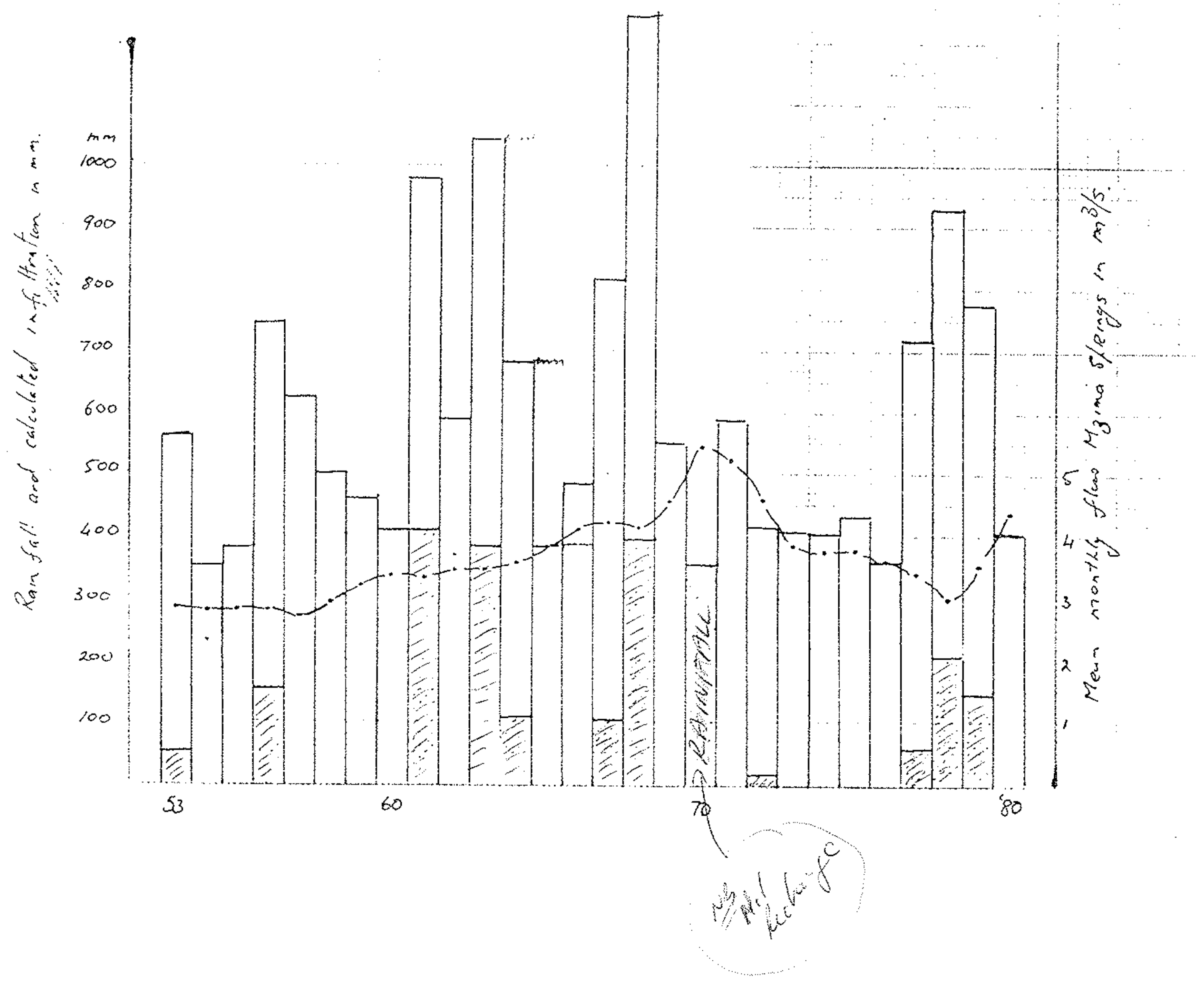


FIGURE 8. Plot of Mean Monthly Flows measured at Mzima and the Calculated Infiltration over the Chyulu Hills by Rainfall-Evapotranspiration.



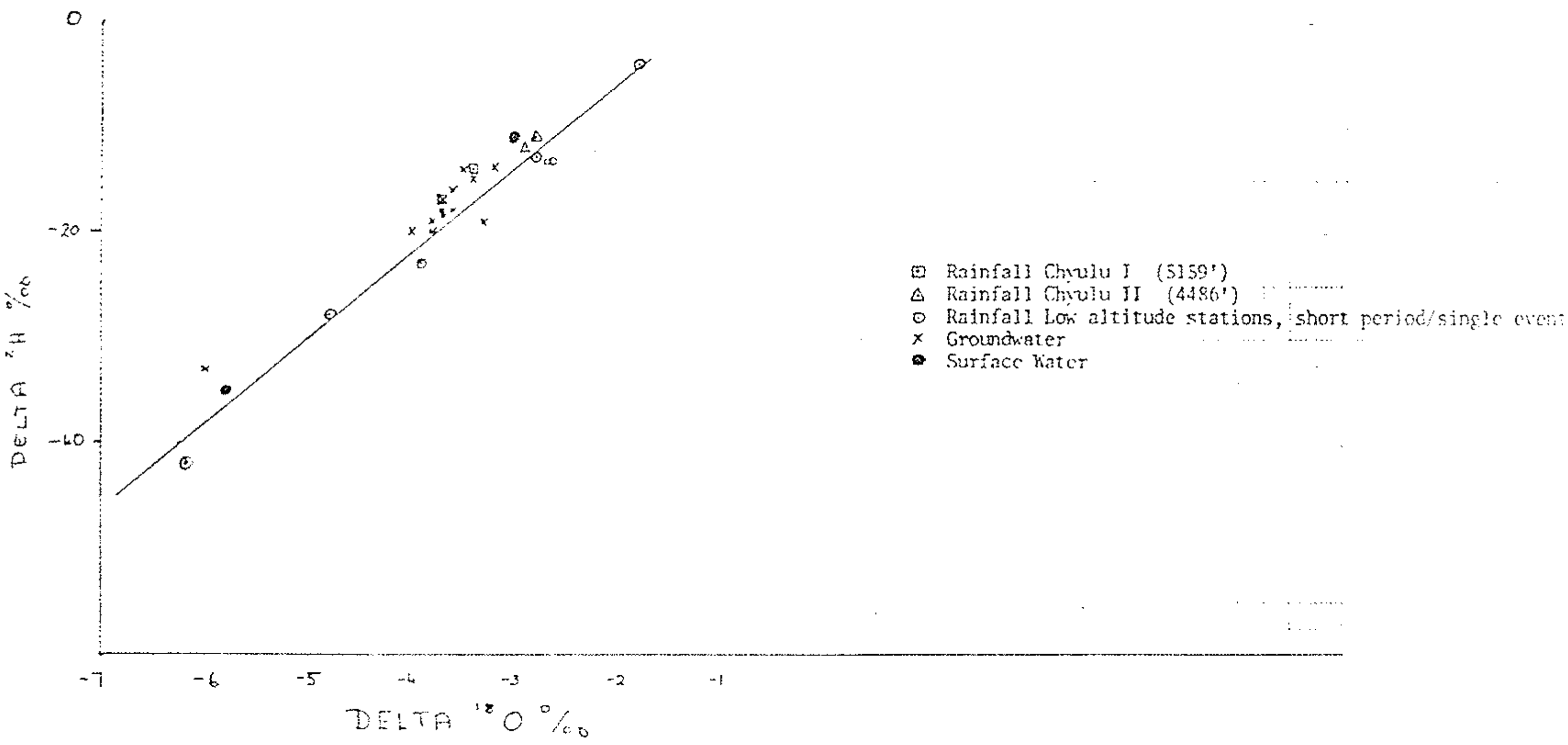

0
-20
-40
DELTA ²H ‰
-7
-6
-5
-4
-3
-2
-1
DELTA ¹⁸O ‰
Rainfall Chyulu I (5159')
Rainfall Chyulu II (4486')
Rainfall Low altitude stations, short period/single event
Groundwater
Surface Water

FIGURE 9 (Cont'd)

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KENYA STABLE ISOTOPE ANALYSES RESULTS JULY 1982
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DATA SET OF  25 DELTA 18 O DELTA 2 H PAIRS

DELTA 18 O
MAX   -1.8  MIN   -6.2  MEAN   -3.7
ST DEV   1.00  VARIANCE    1.01
COEFFICIENT OF VARIATION   -26.96

DELTA 2 H
MAX   -4.0  MIN  -42.0  MEAN  -18.8
ST DEV   8.02  VARIANCE   64.34
COEFFICIENT OF VARIATION   -42.76

LINEAR REGRESSION ON  25 CO-O)DINATES
SLOPE   7.750   INTERCEPT   10.101
CORRELATION COEFFICIENT 0.9701
ERROR X,Y    2.03 DEVIATION,SLOPE   0.40 DEVIATION,INCPT   1.20

REGRESSION:- REDUCED MAJOR AXIS
SLOPE   7.989   INTERCEPT   10.990
DEVIATION,SLOPE   0.39 DEVIATION,INCPT   0.23

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TABLE 1. PRINCIPAL RAINFALL STATIONS[1]

| Location | Station No. | Latitude Longitude | Altitude[2] Feet | Period of Record | Comment |
|---|---|---|---|---|---|
| Chyulu Gate | 92.38.13 | 2°54'S 38°03'E | 3000 | 1971-1982 | |
| Dwa Plantation | 92.37.02 | 2°27'S 37°59'E | 3000 | 1917-1982 | |
| Kilaguni Lodge | 92.38.12 | 2°45'S 38°04'E | 2400 | 1971-1982 | |
| Makindu | 92.37.00 | 2°17'S 37°50'E | 3277 | 1904-1982 | Met. Station[3] |
| Mtito Andei (Kamboyo) | 92.38.09 | 2°45'S 38°07'E | 3000 (2756) | 1952-1982 | Discrepancy with Kamboyo HQ data. |
| Machakos-Darajani | 92.38.07 | 2°34'40"S 38°06'30"E | 2571 | 1950-1978 (minus 1956-62) | |
| Masongaleni | 92.38.03 (ex 92.37.01) | 2°29'20"S 38°02'40"E | 2891 | 1907-1982 (minus 1956-67) | |
| Kiboko Research Station | - | 2°15'00"S 37°43'30"E | 3265 | 1972-1982 | |
| Mzima Springs | 93.38.17 | 2°02'S 38°02'E | 2136 | 1950-1982 | |
| Ngulia Lodge[5] | 93.38.27 | 3°05'S 38°10'E | 3200 | 1971-1982 | |
| Voi[5] | 93.38.01 | 3°24'S 38°34'E | 1833 | 1905-1982 | Met. Station[4] |

1 Other rainfall stations not included in Meteorological Office network are at Kitani Lodge, Mzima Springs Rangers Camp, Mtito Andei Gate, and various stations in the Kiboko Ranch area.

2 Altitude from Meteorological Office Records and are usually approximations. Some bracketed readings give more accurate values.

3 Meteorological data including Pan Type A from 1958 to 1982.

4 Meteorological data including Pan Type A from 1958 to 1982.

5 Outside Figure 1 map boundaries.

TABLE 2. LONG TERM RAIN GAUGES, CHYULU HILLS

| Location | Map Ref (Fig 1) | Latitude* Longitude | Altitude (feet) | Period of Records (all intermittent) | Comments |
|---|---|---|---|---|---|
| South Chyulu Current installations | I | 2°46'31"S 37°58'38"E | 5159 | 1975-1982 | |
| | II | 2°47'17"S 37°57'41"E | 5162 | 1975-1982 | |
| | III | 2°47'56"S 37°57'19"E | 4486 | 1975-1982 | |
| | IV | ? | ? | 1977-1980 | Discontinued |
| South Chyulu Previous installations | P1 | 2°46'02"S 37°58'12"E | 4600 | 1971-1973 | |
| | P1A | 2°46'S 37°58'E | 4950 | 1955-1961 | |
| | P1S (south) | ? | | 1954-1961 | |
| | P6 | 2°45'46"S 37°55'31"E | 4700 | 1970-1974 | Some data only in 1972 |
| | P7 | 2°50'21"S 37°56'38"E | 3150 | 1971-1974 | |
| Central Chyulu Previous installations | P2 | 2°35'31"S 37°50'41"E | 6800 | 1971-1974 | |
| | P3 | 2°30'20"S 37°43'43"E | 3800 | 1970-1973 | No reliable data |
| | P4 | 2°32'04"S 37°54'48"E | 3500 | 1972-1974 | |
| | P5 | 2°41'02"S 37°52'30"E | 5700 | 1971-1974 | |
| | P2(N) | 2°35'S 37°51'E | 5720 | 1954-1961 | |

* Locations sometimes in question.

TABLE 3. MEAN ANNUAL AND MEAN MONTHLY RAINFALL DATA 1972-1980 INCLUSIVE (mm)

| Location | 1 | 2 | 3 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Voi | $3^{o}24'$ | 1833 | 599 | 49 | 28 | 62 | 95 | 38 | 3 | 3 | 5 | 17 | 15 | 155 | 106 |
| Mzima Springs | $3^{o}02'$ | 2136 | 386 | 51 | 26 | 31 | 95 | 33 | 5 | 2 | 2 | 4 | 8 | 87 | 57 |
| Chyulu Gate | $2^{o}54'$ | 3000 | 468 | 44 | 19 | 45 | 101 | 30 | 6 | 2 | 1 | 5 | 5 | 120 | 91 |
| Kamboyo | $2^{o}45'$ | 2571 | 626 | 54 | 25 | 49 | 109 | 34 | 7 | 1 | 5 | 7 | 13 | 195 | 160 |
| Dwa | $2^{o}27'$ | 3000 | 695 | 66 | 36 | 68 | 107 | 33 | 2 | - | 2 | 5 | 23 | 228 | 121 |
| Makindu | $2^{o}17'$ | 3277 | 495 | 59 | 27 | 47 | 100 | 25 | 2 | 1 | 2 | 4 | 29 | 153 | 90 |
| Kiboko NRSS | $2^{o}15'$ | 3265 | 463 | 51 | 20 | 44 | 82 | 19 | - | 3 | 3 | 5 | 23 | 122 | 100 |

Column 1: Latitude south

Column 2: Altitude in feet above sea level (from Meteorological Office records)

Column 3: Mean annual rainfall (1972-80 inclusive) in mm

Subsequent columns: Mean monthly rainfall data, same period.

TABLE 4. MONTHLY RAINFALL DATA (mm), 1975, 1977, 1979 (see Table 3)

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | | | | | | | | | | | | | |
| Voi | 6.0 | 4.1 | 26.3 | 41.0 | 25.4 | - | 1.2 | - | 18.8 | 2.3 | 102.6 | 97.6 | 525 |
| Mzima | 17.1 | 2.0 | 14.6 | 88.3 | 13.3 | - | 2.4 | - | 10.0 | - | 65.0 | 5.5 | 218 |
| Chyulu Gate | 14.7 | 3.0 | 8.2 | 30.1 | 8.8 | - | 1.1 | - | 13.2 | - | 71.5 | 43.5 | 194 |
| Kamboyo | 5.0 | 5.4 | - | 21.0 | 13.7 | - | 2.0 | - | 9.4 | - | 154.6 | 103.4 | 315 |
| Dwa | 25.9 | 7.6 | 9.4 | 15.6 | 16.6 | - | 2.0 | - | 3.0 | 11.6 | 170.6 | 39.6 | 302 |
| Makindu | 101.1 | 12.1 | 0.8 | 133.7 | 9.9 | - | 5.2 | - | 4.2 | 4.3 | 120.1 | 42.7 | 434 |
| Masongaleni | - | 12.2 | 7.8 | 28.6 | - | - | - | - | - | - | 144.6 | 13.5 | 207 |
| Chyulu I, II, III* | 42.0 | - | 42.0 | 72.0 | 25.0 | - | 4.0 | - | 54.0 | 5.0 | 291.1 | 159.0 | 603 |

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | | | | | | | | | | | | | |
| Voi | 30.4 | 27.6 | 29.6 | 92.4 | 5.8 | 9.4 | - | 2.6 | 19.7 | 47.1 | 156.5 | 207.7 | 629 |
| Mzima | 62.5 | 48.6 | 11.0 | 127.9 | 9.8 | - | - | 6.7 | 14.0 | 30.5 | 164.1 | 165.0 | 640 |
| Chyulu Gate | 6.1 | 7.0 | 54.3 | 164.1 | - | 10.3 | - | - | 3.6 | 25.2 | 143.5 | 249.0 | 663 |
| Kamboyo | 9.7 | 16.6 | 26.8 | 239.6 | 12.3 | 2.7 | - | - | - | 37.6 | 224.8 | 199.6 | 770 |
| Dwa | 28.8 | 50.0 | 49.5 | 233.0 | 167.3 | 0.6 | - | 3.1 | 4.1 | 6.9 | 302.3 | 177.6 | 1024 |
| Makindu | 16.0 | 34.3 | 41.0 | 140.4 | 98.2 | 14.6 | - | 6.2 | 3.7 | 3.4 | 205.6 | 158.0 | 721 |
| Masongaleni | 13.3 | 84.0 | 50.5 | 138.5 | 19.2 | - | - | 18.1 | - | 6.5 | 218.3 | 214.9 | 755 |
| Chyulu I, II, III* | 42.1 | 100.5 | 71.0 | 153.9 | 37.6 | 9.7 | - | 32.4 | 20.2 | 75.7 | 192.9 | 142.0 | 878 |

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1979 | | | | | | | | | | | | | |
| Voi | 144.1 | 26.5 | 67.5 | 165.2 | 56.2 | 10.1 | 5.8 | 0.3 | 3.8 | 23.4 | 79.4 | 220.3 | 803 |
| Mzima | 45.4 | 28.6 | 35.2 | 86.1 | 58.1 | 7.2 | - | - | - | - | 91.9 | 48.3 | 401 |
| Chyulu Gate | 104.6 | 70.0 | 54.0 | 118.4 | 114.1 | 9.4 | 4.3 | - | - | 0.7 | 61.7 | 57.4 | 595 |
| Kamboyo | 237.0 | 33.3 | 141.3 | 237.5 | 115.8 | 4.2 | - | 6.9 | - | 14.5 | 295.6 | 202.4 | 1289 |
| Dwa | 371.7 | 25.5 | 71.1 | 190.6 | 55.3 | 5.1 | 2.3 | 2.3 | 1.1 | 53.6 | 219.6 | 195.6 | 1196 |
| Makindu | 234.2 | 48.3 | 21.5 | 127.0 | 61.0 | 1.5 | 5.5 | - | 2.3 | 19.5 | 138.5 | 117.3 | 777 |
| Masongaleni | 324.5 | 16.7 | 39.8 | - | 67.3 | 2.8 | - | - | - | 18.1 | 251.1 | 195.1 | 941 |
| Chyulu I, II, III* | 153.3 | 33.8 | 251.9 | 292.0 | 229.0 | 21.4 | 0.7 | - | - | - | 262.5 | 118.6 | 1191 |

* Mean of 3 stations; some months are combined in gauge and data has been interpolated.

TABLE 5. ANNUAL RAINFALL DATA (mm)

| | Chyulu Foothills | | | | | | | | South Chyulu | | | | Central Chyulu | | | | South Chyulu | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 1981 | - | 678 | 835 | 722 | 548 | - | - | - | 540 | - | 552 | 546 | - | - | - | - | - | - | - |
| 1980 | 213 | 408 | 691 | 535 | 402 | - | - | - | 900 | 1007 | - | 953 | - | - | - | - | - | - | - |
| 1979 | 401 | 595 | 1289 | 1195 | 777 | 941 | - | - | 1110 | 1413 | 1050 | 1191 | - | - | - | - | - | - | - |
| 1977 | 640 | 663 | 770 | 1024 | 721 | 755 | - | - | - | 1030 | 802 | 878 | - | - | - | - | - | - | - |
| 1975 | 218 | 194 | 315 | 302 | 434 | 207 | - | - | 346 | 794 | 668 | 603 | - | - | - | - | - | - | - |
| 1974 | 251 | - | 422 | 576 | 404 | - | 455 | 500 | - | - | - | - | 1067 | 406 | 495 | - | - | - | 484 |
| 1973 | 303 | - | 392 | 590 | 409 | 398 | 587 | 267 | - | - | - | - | 1702 | 597 | 406 | - | - | - | 292 |
| 1972 | 346 | - | 338 | 548 | 418 | 674 | 653 | 650 | - | - | - | - | - | - | - | - | - | - | - |
| 1971 | 438 | | 567 | 666 | 591 | 776 | 458 | 488 | - | - | - | - | 704 | - | 861 | - | - | - | 432 |
| 1961 | 156 | - | 908 | 976 | 978 | - | - | - | - | - | - | - | - | - | - | 851 | 762 | 546 | - |
| 1960 | 315 | - | 568 | 374 | 411 | - | - | - | - | - | - | - | - | - | - | 1295 | 1994 | 597 | - |
| 1959 | 84 | - | 812 | 628 | 462 | - | - | - | - | - | - | - | - | - | - | 1283 | 1003 | 864 | - |
| 1958 | - | - | 513 | 533 | 500 | - | - | - | - | - | - | - | - | - | - | 1130 | 787 | - | - |
| 1957 | 568 | - | 875 | 933 | 622 | - | - | - | - | - | - | - | - | - | - | 1943 | 1080 | 1003 | - |
| 1956 | 628 | - | 574 | 704 | 743 | - | - | - | - | - | - | - | - | - | - | 1359 | 1626 | 1407 | - |
| 1955 | 365 | - | 568 | 360 | 382 | - | - | - | - | - | - | - | - | - | - | 711 | 1283 | 864 | - |
| 1954 | 582 | - | 439 | 546 | 352 | - | - | - | - | - | - | - | - | - | - | 609 | - | - | - |

Column 1: Mzima
Column 2: Chyulu Gate
Column 3: Kamboyo
Column 4: Dwa
Column 5: Makindu
Column 6: Masongaleni
Column 7: Ngulia Lodge
Column 8: Darojani
Column 9: Chyulu I
Column 10: Chyulu II
Column 11: Chyulu III
Column 12: Mean of I, II, III
Column 13: Chyulu P2
Column 14: Chyulu P4
Column 15: Chyulu P5
Column 16: Chyulu P2(N)
Column 17: Chyulu P1
Column 18: Chyulu P1(S)
Column 19: Chyulu P7

## TABLE 6. SPRINGS

| Map Ref. (Fig. 1) | Location | Altitude (feet) | Discharge (m³/sec) Date | Temperature (°C) | Conductance (micromhos/25°C) | Cl (ppm) | Stable Isotopes δ¹⁸O‰ | δ²H‰ |
|---|---|---|---|---|---|---|---|---|
| 1 | Kiboko | [illegible] | 0.012* 6.5.82 | 26.5 | 1300 | 142 | -3.8 | -20 |
| 2 | Makindu Railway | 3278 | - 6.5.82 | - | 1000 | - | - | - |
| 3 | Makindu Ranch | 3323 | 0.0078 6.5.82 | 24.1 | 740 | 23.5 | -3.8 | -19 |
| 4 | Maneni | 2494† | 0.017* 5.5.82 | - | 1700 | 272 | -3.4 | -15 |
| 5 | Choi | 2838† | 0.16 5.5.82 | 22.9 | 650 | 56 | -3.7 | -18 |
| 6 | Kibwezi | 2988 | - 12.5.82 | - | 700 | 25 | - | - |
| 7 | Umani | 3222 | - 12.5.82 | - | 425 | 6.5 | -3.7 | -17 |
| 8 | Kisimani | 2895 | 0.09 11.5.82 | 24.6 | 1000 | 105 | -3.2 | -19 |
| 9 | Mangolete | 2708 | 0.155 11.5.82 | 25.8 | 805 | 30 | -3.2 | -14 |
| 10 | Mzima Group | | | | | | | |
| | Cataract | 2231 | - 7.5.82 | 24.1 | - | 15 | - | - |
| | Swamp | 2231 | - 7.5.82 | 25.2 | - | 50 | - | - |
| | Banana | 2231 | - 7.5.82 | 24.3 | - | 20 | - | - |
| | Bathing Pool | 2231 | - 7.5.82 | 24.1 | 471 | 32 | -3.5 | -14 |
| 11 | Kamba ya Simba | 2629 | 0.077 9.5.82 | 25.6 | 805 | 1020 | -3.7 | -18 |
| 12 | Mailu | 2716 | - 10.5.82 | - | 805 | 53 | -4.0 | -20 |
| 13 | Lolturesh | 5020 | 0.178 10.5.82 | - | 191 | 11.5 | -6.0 | -33 |
| 14 | Kitane | 2596 | 0.127 9.5.82 | 25.1 | 850 | 51.5 | -3.6 | -18 |

* Measured at reservoir outlet    † Estimated from map

TABLE 7. RIVERS AND LAKE

| Map Ref. (Fig. 1) | Location | Altitude (feet) | Discharge ($m^3$/sec) / Date | Temperature ($^oC$) | Conductance (micromhos/25$^oC$) | Cl (ppm) | Stable $\delta^{18}O$‰ | Isotopes $\delta^2H$‰ |
|---|---|---|---|---|---|---|---|---|
| R1 | Kambu River<br>Nairobi-Mombasa Road Crossing | 2651 | 0.19 / 6.5.82 | 25.4 | | 150 | | |
| R2 | Lolturesh River<br>Kibwezi-Oloitokitok Road | 4256 | 0.367 / 10.5.82 | 19.1 | 239 | 8.5/6.2 | -5.8 | -35 |
| R3 | Lolturesh River<br>(near Kitane Lodge) | | 9.5.82 | 22.9 | | 42.5 | | |
| R4 | Mtito Andei River on<br>track north from Kamboyo | | 1.5 / 11.5.82 | | | 78.7 | -3.0 | -16 |
| R5 | Kiboko River<br>Mombasa-Nairobi Road Crossing | | 0.009 / 6.5.82 | 24.9 | 2660 | 227 | | |
| R6 | Lake Embu<br>Track west of Mtito Andei | 3008 | - / 11.5.82 | 27 - 28 | | 10 | | |

TABLE 8. BOREHOLES AND WELLS

| Map Ref. (Fig. 1) | Location BH No. | Altitude (feet) | Discharge ($m^3$/sec) | SWL (feet bgl) / Date | SWL (feet msl) / Date | PWL (feet bgl) / Date | Temperature (°C) | Conductance (micromhos/25°C) | Cl (ppm |
|---|---|---|---|---|---|---|---|---|---|
| B1 | Kiboko Ranch | 3221 | | | | | | 1900 | 136 |
| B2 | Kiboko Wildlife Camp | 3495 | | | | | | 2450 | 107. |
| B3 | Mathioni Dug Well | | | | 3498 | | | 3150 | 23. |
| B4 | C3322 | | | | | | | | |
| B5 | C2476 | 3422 | | 390 / - | 3052 | | | | |
| B6 | - | 2923 | | 64 / 15.5.82 | 2859 / 15.5.82 | | | | |
| B7 | C2944 | 2921 | | 52 | 2869 | 920 / 15.5.82 | | | 100 |
| B8 | Chyulu Gate HD Well | 2544 | | 14.3 / 15.5.82 | 2528.7 | | | | 20. |
| B9 | Dilal (northernmost) | | | c.20 | 2842 / 10.5.82 | | 24.5 | | 8. |
| B10 | Dilal (southernmost) | | | c.20 | 2837 / 10.5.82 | | | | |

## TABLE 9. BOREHOLE LOGS

| C2476 | | C2944 | |
|---|---|---|---|
| 0 - 380 | Lava | 0 - 38 | Lava |
| 380 - 420 | Lava + Red soil | 38 - 183 | Weathered basement |
| 420 - 470 | Weathered basement | 183 - 250 | Basement |
| 470 - 475 | Basement | | |

Casing now pulled

## TABLE 10. MZIMA SPRINGS: CHLORIDE AND CONDUCTANCE (SOURCE MOWD)

| Date | Cl | Conductance |
|---|---|---|
| 31.7.65 | 9 | 760 |
| 19.7.66 | 10 | - |
| 29.3.68 | 16 | - |
| 24.9.72 | 8 | - |
| 29.11.74 | 11 | 580 |
| 9.9.75 | 8 | 560 |
| 31.5.78 | 9.4 | 510 |
| 21.4.80 | 8.5 | 600 |
| 21.4.80 | 12.9 | 550 |

TABLE 11. CALCULATION OF DEEP INFILTRATION USING A VARIABLE ROOT CONSTANT AND POTENTIAL EVAPORATION ESTIMATES CALCULATED BY CORRECTED MAKINDU PAN DATA ON A MONTHLY BASIS.

| Year | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1953 | (i) | | | | | | | | | | | 48.2 | | 48.2 |
| | (ii) | | | | | | | | | | | - | | |
| | (iii) | | | | | | | | | | | - | | |
| 1954 | | | | | | | | Nil | | | | | | |
| 1955 | | | | | | | | Nil | | | | | | |
| 1956 | (i) | | | | | | | | | | | 153.2 | | 153.2 |
| | (ii) | | | | | | | | | | | 72.7 | | 72.7 |
| | (iii) | | | | | | | | | | | - | | |
| 1957 | | | | | | | | Nil | | | | | | |
| 1958 | | | | | | | | Nil | | | | | | |
| 1959 | | | | | | | | Nil | | | | | | |
| 1960 | | | | | | | | Nil | | | | | | |
| 1961 | (i) | | | | | | | | | | | 385.6 | 26.3 | 411.9 |
| | (ii) | | | | | | | | | | | 305.1 | 26.3 | 331.4 |
| | (iii) | | | | | | | | | | | 224.7 | 26.3 | 251.0 |
| 1962 | | | | | | | | Nil | | | | | | |
| 1963 | (i) | | | | | | | | | | | 223.4 | 159.8 | 383.2 |
| | (ii) | | | | | | | | | | | 142.9 | 159.8 | 302.7 |
| | (iii) | | | | | | | | | | | 62.5 | 159.8 | 222.3 |
| 1964 | (i) | | | | | | | | | | | | 104 | 104 |
| | (ii) | | | | | | | | | | | | - | |
| | (iii) | | | | | | | | | | | | - | |
| 1965 | | | | | | | | Nil | | | | | | |
| 1966 | | | | | | | | Nil | | | | | | |
| 1967 | (i) | | | | 64.1 | | | | | | | 38.0 | | 102.1 |
| | (ii) | | | | | | | | | | | - | | |
| | (iii) | | | | | | | | | | | - | | |
| 1968 | (i) | | | | 164.3 | | | | | | | 188.9 | 44 | 397.2 |
| | (ii) | | | | 92.6 | | | | | | | 108.4 | 44 | 245.0 |
| | (iii) | | | | 19.2 | | | | | | | 26.9 | 44 | 90.1 |
| 1969 | | | | | | | | Nil | | | | | | |
| 1970 | | | | | | | | Nil | | | | | | |
| 1971 | | | | | | | | Nil | | | | | | |
| 1972 | (i) | | | | | | | | | | | 15 | | 15 |
| | (ii) | | | | | | | | | | | - | | |
| | (iii) | | | | | | | | | | | - | | |
| 1973 | | | | | | | | Nil | | | | | | |
| 1974 | | | | | | | | Nil | | | | | | |
| 1975 | | | | | | | | Nil | | | | | | |
| 1976 | | | | | | | | Nil | | | | | | |
| 1977 | (i) | | | | | | | | | | | | 54.5 | 54.5 |
| | (ii) | | | | | | | | | | | | - | |
| | (iii) | | | | | | | | | | | | - | |
| 1978 | (i) | | | | | | | | | | | 51.1 | 154.5 | 205.6 |
| | (ii) | | | | | | | | | | | | 125.0 | 125.0 |
| | (iii) | | | | | | | | | | | | 44.5 | 44.5 |
| 1979 | (i) | 147.0 | | | | | | | | | | | | 147.0 |
| | (ii) | 147.0 | | | | | | | | | | | | 147.0 |
| | (iii) | 147.0 | | | | | | | | | | | | 147.0 |
| 1980 | | | | | | | | Nil | | | | | | |

(i) Root Constant : 75 mm

(ii) Root Constant : 125 mm

(iii) Root Constant : 175 mm

TABLE 12. DISCHARGE-RECHARGE CORRELATION OF CHYULU HILLS USING MAKINDU RAINFALL AND EVAPOTRANSPIRATION DATA.

(i) Area of Chyulu Hills - Below 4000 feet : 1,438 sq km
Above 4000 feet : 500 sq km
Total : 1,938 sq km

(ii)

| Year | Mzima Springs Mean Annual Flow $m^3/sec$ | Total Chyulu Discharge (a) | Total Chyulu Discharge (b) | Equivalent of Discharge in mm height over total catchment (a) | Equivalent of Discharge in mm height over total catchment (b) | Recharge in mm (Table 12) | Chloride* Content mg/1 (Mzima Springs) |
|---|---|---|---|---|---|---|---|
| 1957 | | | | | | - | |
| 1958 | | | | | | - | |
| 1959 | | | | | | - | |
| 1960 | | | | | | - | |
| 1961 | 3.33 | 4.73 | 4.16 | 77 | 68 | 412 | |
| 1962 | 3.47 | 4.96 | 4.34 | 81 | 71 | - | |
| 1963 | 3.45 | 4.94 | 4.31 | 80 | 70 | 383 | |
| 1964 | 3.56 | 5.09 | 4.45 | 83 | 72 | 104 | |
| 1965 | 3.86 | 5.51 | 4.83 | 90 | 79 | - | 9 |
| 1966 | 4.12 | 5.89 | 5.15 | 96 | 84 | - | |
| 1967 | 4.21 | 6.02 | 5.26 | 98 | 86 | 102 | |
| 1968 | 4.14 | 5.93 | 5.18 | 96 | 84 | 397 | 16 |
| 1969 | 4.54 | 6.50 | 5.68 | 106 | 92 | - | |
| 1970 | 5.45 | 7.80 | 6.81 | 127 | 111 | - | |
| 1971 | 5.26 | 7.52 | 6.58 | 122 | 107 | - | |
| 1972 | 4.59 | 6.56 | 5.74 | 107 | 93 | 15 | 8 |
| 1973 | 3.83 | 5.48 | 4.79 | 89 | 78 | - | |
| 1974 | 3.78 | 5.40 | 4.73 | 88 | 77 | - | 11 |
| 1975 | 3.80 | 5.43 | 4.75 | 88 | 77 | - | 8 |
| 1976 | 3.60 | 5.15 | 4.50 | 84 | 73 | - | |
| 1977 | 3.41 | 4.88 | 4.26 | 79 | 69 | 55 | |
| 1978 | 2.97 | 4.24 | 3.71 | 69 | 60 | 206 | 9.4 |
| 1979 | 3.55 | 5.08 | 4.49 | 83 | 73 | 147 | |
| 1980 | 4.39 | 6.28 | 5.48 | 102 | 89 | - | 8.5 |

(a) Assumed that Mzima Flow is 70% of total Chyulu discharge

(b) Assumed that Mzima Flow is 80% of total Chyulu discharge

Total Discharge <u>1963 - 1977</u> in mm height over catchment:

Case (a) : 1433 mm
Case (b) : 1252 mm

Total Recharge <u>1961 - 1975</u> in accordance with Table 12 : 1414 mm (75 mm Root Constant)

* Data from MOWD Lab.

TABLE 13. HYDROCHEMICAL DATA

| Sample No. (MOWD) | Locality | Date Sampled | pH | Conductivity (25°C) | Ca | Mg | Total Hardness ($CaCO_3$) | Total Alk. ($CaCO_3$) | Cl | $SO_4$ | Fe | Mn | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPRINGS | | | | | | | | | | | | | |
| 482 | Kiboko | 5.5.82 | 7.9 | 1500 | 180 | 70 | 730 | 194 | 97 | 375 | 0.3 | 0.2 | 0.18 |
| 483 | Manone | 6.5.82 | 7.6 | 1700 | 73 | 105 | 548 | 554 | 235 | 95 | 0.1 | <0.1 | 1.6 |
| 484 | Kitane | 9.5.82 | 7.9 | 800 | 42 | 58 | 340 | 440 | 40 | 45 | 0.3 | <0.1 | 0.17 |
| 485 | Kamba ya Simba | 9.5.82 | 7.8 | 740 | 16.4 | 39 | 200 | 400 | 23 | 39 | 0.2 | <0.1 | 0.18 |
| 486 | Mailu | 10.5.82 | 7.8 | 840 | 31 | 47 | 242 | 452 | 36 | 40 | <0.1 | <0.1 | 0.19 |
| 487 | Lolturesh | 10.5.82 | 7.4 | 220 | 3 | 2.6 | 20 | 106 | 6 | 17 | 0.6 | <0.1 | 0.06 |
| 488 | Mangolete | 11.5.82 | 7.3 | 790 | 97 | 61 | 519 | 452 | 34 | 14 | 1.3 | <0.1 | 0.12 |
| 491 | Umani | 12.5.82 | 7.7 | 400 | 10.4 | 14.4 | 85 | 198 | 12 | - | 0.4 | <0.1 | 0.11 |
| 492 | Makindu Ranch | 6.5.82 | 7.8 | 800 | 21 | 40 | 216 | 452 | 24 | - | 0.3 | 0.1 | 2.3 |
| RIVERS | | | | | | | | | | | | | |
| 489 | Lolturesh Nr. Oloitokitok | 10.5.82 | 7.8 | 200 | 7.3 | 11.4 | 63 | 132 | 8.5 | - | 17 | 0.2 | 0.06 |
| BOREHOLES | | | | | | | | | | | | | |
| 490 | BH 2944 | 11.5.82 | 7.8 | 900 | 94 | 37 | 386 | 364 | 108 | - | 0.3 | <0.1 | 0.77 |
| 493 | Chyulu Gate | 6.5.82 | 8.1 | 540 | 30 | 15.6 | 139 | 232 | 23 | - | <0.1 | <0.1 | |

TABLE 14. DATA ON MZIMA SPRINGS (MOWD LAB.)

| Source | Date Sampled | pH | Colour | Turb. | Cond. | Pv | Fe | Mn | Ca | Mg | Na | T.H. | T.Alk. | $Cl^-$ | $Fl^-$ | $NO_2$ | $NO_3$ | $SO_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mzima Springs Pipeline | 31-7-65 | 8.0 | Nil | Nil | 760 | - | 0.1 | - | 21.0 | 24 | 58 | 151 | 100 | 9 | 2.5 | Nil | Nil | |
| Mzima Springs | 29.3.68 | 7.8 | - | Nil | - | - | <0.1 | - | 22 | 23 | 60 | 148 | 119 | 16 | 1.3 | Trace | 0.5 | 50 |
| Mzima Pipeline at Mzima Springs | 24.9.72 | 7.8 | <5 | Nil | - | - | - | - | 23 | 22 | 63 | 146 | - | 8 | 1.1 | <0.01 | 1.3 | 56 |
| Mzima Springs | 29.11.74 | 7.9 | <5 | Nil | 580 | - | 0.2 | Nil | 11 | 23 | 64 | 146 | - | 11 | 1.2 | 0.02 | 1.1 | 28 |
| Mzima Springs TezoRoka Tap No. 43 | 9.9.75 | 8.2 | <5 | Nil | 560 | - | Nil | Nil | 24 | 20.5 | 62 | 146 | - | 8 | 2.1 | Trace | 0.55 | 43 |
| Mzima Springs | 31.5.78 | 8.2 | <5 | 7 | 510 | 6 | 0.24 | 0.21 | 25 | 4.3 | | 145 | 200 | 9.4 | 0.42 | - | - | - |
| Mzima Springs | 21.4.80 | 8.6 | - | 0.5 | 600 | Trace | - | - | - | - | - | 105 | 245 | 8.5 | - | - | - | - |
| Mzima Springs | 21.4.80 | 8.6 | - | 1.6 | 550 | Trace | - | 0.1 | - | - | - | 100 | 216 | 12.9 | - | - | - | - |

TABLE 15. CHLORIDE AND FLUORIDE DATA (mg/l)

| IGS Sample No. | Locality | Cl (IGS) | Kenya (MOWD) | Fluoride (IGS) | Kenya (MOWD) | Date Sampled |
|---|---|---|---|---|---|---|
| Rainfall | | | | | | |
| 82/588 | Chyulu I* | 7.8 | | <0.1 | | May 1982 |
| 589 | Chyulu II* | 4.1 | | <0.1 | | " |
| 590 | Mtito Andei† | 1.3 | | <0.1 | | " |
| | (Gate) | | | <0.1 | | " |
| 591 | Manoni Plantation† | 4.9 | | <0.1 | | " |
| 592 | Dwa Plantation | 2.3 | | | | " |
| - | Makindu Ranch Spring Site+ | 1.8 | | | | " |
| - | Makindu Met. St.† | 2.5 | | | | " |
| - | Kilaguni Lodge+ | 6.9 | | | | " |
| Springs | | | | | | |
| 594 | Kiboko Upper | 94.0 | 97 | 2.55 | 0.18 | |
| 595 | Lolturesh | <5 | 6 | 0.41 | 0.06 | |
| 596 | Manone | 228 | 235 | 1.48 | 1.6 | |
| 597 | Kamba ya Simba | 33 } | 23 | 2.1 | 0.18 | |
| | Kamba ya Simba | 24 } | | | | |
| 598 | Chai | 33 | 40 | 1.37 | - | 5.5.82 |
| 599 | Mangolete | 30 | 34 | 1.08 | 0.12 | |
| 601 | Umani | 7.7 | 12 | 1.17 | 0.11 | |
| 602 | Mailu | 33 | 36 | 2.5 | 0.19 | |
| 603 | Bathing Pool (Mzima) | 16.5 | 15 | 1.34 | - | 7.5.82 |
| 604 | Makindu Ranch | 23.5 | 24 | 3.1 | 2.3 | |
| 605 | Kitane | 32 | 25 | 2.05 | 0.17 | 9.5.82 |
| - | Makindu Railway | - | 31.2 | | | 6.5.82 |
| 606 | Kithimani | 105 | 110/115 | 1.3 | - | 11.5.82 |
| - | Swamp (Mzima) | | 50 | | | 7.5.82 |
| - | Cataract (Mzima) | | 15 | | | 7.5.82 |
| - | Banana (Mzima) | | 20 | | | 7.5.82 |
| - | Kibwezi Station | | 25 | | | 12.5.82 |
| Boreholes/Wells. | | | | | | |
| BH 2944 | Mtito Andei | 100 | 108 | 0.52 | 0.77 | |
| - | Chyulu Gate (H/D Well) | 20.4 | 23/31 | 1.3 | - | |
| - | Dilal Wells (H/D) | | 8.7 | | | 10.5.82 |
| - | Mathioni Well (H/D) | | 23.7 | | | 12.5.82 |
| - | Kiboko Ranch | | 136 | | | 6.5.82 |
| - | Wildlife Camp | | 107.5 | | | 12.5.82 |
| Rivers. | | | | | | |
| 82/593 | Lolturesh (nr. Oloitokitok) | 5.4 | 8.5/6.2 | 0.62 | 0.06 | |
| - | Lolturesh (close to Kamba ya Simba) | | 41.2 | | | 9.5.82 |
| - | Lolturesh (near Chyulu Gate) | | 6.2 | | | 10.5.82 |
| - | Lolturesh (near Kitane Lodge) | | 42.5 | | | 9.5.82 |
| - | Kambu on Mombasa Road | | 150 | | | 5.5.82 |
| | Kiboko River on Mombasa Road | | 227 | | | 6.5.82 |
| - | Mangolete | | 68.7 | | | 17.5.82 |
| - | Mtito Andei (north of Kamboyo) | | 78.7 | | | 11.5.82 |
| Lakes. | | | | | | |
| - | Lake Embu | | 10 | | | 11.5.82 |

* Two months accomulation
† Two weeks accumulation
\+ Single event

TABLE 16. STABLE ISOTOPE DATA

| No. | Location (elevation in ft asl) | Date Sampled | $\delta^{18}O$‰ ±0.1 | $\delta^{2}H$‰ ±1 | Notes |
|---|---|---|---|---|---|
| Rain. | | | | | |
| K 1 | Chyulu I (5159) | 8.5.82 | -3.4 | -14 | Two months accumulation |
| K 2 | Chyulu III (4486) | 8.5.82 | -2.9 | -12 | " " " |
| K 3 | Chyulu I (5159) | 8.5.82 | -3.7 | -17 | " " " |
| K 6 | Collected near Makindu Ranch Spring (3323) | | -1.8 | - 4 | Single event |
| K12 | Chyulu III (4486) | 8.5.82 | -2.8 | -11 | Two months accumulation |
| K15 | Makindu Met. Station (3277) | | -2.8 | -13 | Two weeks accumulation |
| K20 | Mtito Andei Gate (2494) | | -4.8 | -28 | " " " |
| K21 | Manoni Plantation (2494) | | -2.8 | -13 | " " " |
| K22 | Dwa Plantation (3000) | | -3.9 | -23 | " " " |
| K23 | Kilaguni Lodge (2400) | 8.5.82 | -6.2 | -42 | Single event |
| Springs. | | | | | |
| K 4 | Kithimani | 11.5.82 | -3.3 | -19 | |
| K 7 | Manoni | 5.5.82 | -3.4 | -15 | |
| K 9 | Makindu Ranch | 6.5.82 | -3.8 | -19 | |
| K10 | Kiboko | 6.5.82 | -3.8 | -20 | |
| K11 | Mangolete | 11.5.82 | -3.2 | -14 | |
| K14 | Kamba ya Simba | 9.5.62 | -3.7 | -18 | |
| K16 | Umani | 12.5.82 | -3.7 | -17 | |
| K17 | Bathing Pool (Mzima) | 7.5.82 | -3.5 | -14 | |
| K18 | Lolturesh | 10.5.82 | -6.0 | -33 | |
| K19 | Mailu | 10.5.82 | -4.0 | -20 | |
| K24 | Kitane | 9.5.82 | -3.6 | -18 | |
| K25 | Chai | 5.5.82 | -3.7 | -18 | |
| Rivers. | | | | | |
| K 8 | Mtito Andei | 11.5.82 | -3.0 | -16 | |
| K13 | Lolturesh near Oloitokitok | 10.5.82 | -5.8 | -35 | |
| Boreholes/Wells. | | | | | |
| K 5 | Chyulu Gate | 14.5.82 | -3.6 | -16 | |