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Natural Environment Research Council

Report

on an Advisory Visit

to the Chyulu Hills

Water Resources Study

by

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Introduction

The Chyulu Hills Water Resources Study is a project funded by ODA and the Kenya Ministry of Water Development. The contractor for the study is the British Geological Survey (BGS), with counterpart staff posted from Kenya Ministry of Water Development (MOWD). The primary objective is to determine the geological structure of the groundwater aquifer underlying the ridge of recent volcanics known as the Chyulu Hills and to assess the potential for further development utilization of this valuable water resource.

A necessary part of the study is the acquisition of good quality data on the surface hydrology of the area so that more accurate assessments of the volume and time distribution of recharge to the aquifer can be made. The Institute of Hydrology (IH) was asked to provide advice and assistance on the design and field implementation of rain gauging, springflow gauging and meteorological networks. This request has resulted in input from IH at the planning stage, the transfer to BGS of Mr H Gunston for the duration of the study and most recently a visit to the area by the author of this report.

The general terms of reference for the visit were to comment and advise on the practical field implementation of the hydrological networks outlined at the planning stage, with particular emphasis on the choice of sites and methods of measurement of streamflow from the various springs emerging from the Chyulu aquifer.

In the following sections the proposed sites for the components of the rainfall, streamflow and meteorological networks and the methods of measurement are described. The field programme necessary to operate these networks is discussed, together with methods of initial data processing and some suggestions are made for further studies.

In Appendix I an itinerary of the visit is given. It will be noted from this that a few days were devoted to work on the MOWD Kenya Hydrology Project. In part this was a matter of convenience since the author is also funded by ODA to provide advice as required on the Project.

In part also it was relevant that the Project Leader, Mr H Ndungu, and Mr Gunston should be aware of each other's activities since both studies use similar instrumentation and some cooperation could be of mutual benefit.

The location of each of the proposed network sites is plotted on the accompanying 1:125000 base map.

Rainfall

Preliminary studies by Wright(1) Makin and Pratt(2) and initial planning work at IH all emphasised the importance of gaining more detailed information on the rainfall distribution over the main Chyulu Range area. Whilst long term records are available from a number of points along the Nairobi/Mombasa railway line, which runs parallel to the Chyulu Range some 25 km to the East at a mean altitude of some 3000', only sporadic short term data have been collected on the Range itself and virtually no records are available from the plains to the West. Consequently a network was designed to sample the variations in rainfall with altitude, aspect and location from the Nairobi/Mombasa road/railway in the East across the Chyulu to the plains in the West and from The Tsavo river, collecting the main Chyulu outflows, in the South to the Kiboko River in the North. From this network the intention is to obtain an accurate picture of the rainfall distribution over the area during the two year field study. By incorporating into the network the existing long term gauges and correlating the networks results with them, it will be possible to produce more accurate estimates of rainfall input to the study area for the entire period of the long term records.

Practical constraints on the density of the network and the location of individual gauges are imposed by access and security. The general approach adopted in translating from a desirable to a practical network was to locate accessible and, wherever possible, occupied sites within the altitude, aspect and location domains to be sampled. Where a competent person is permanently resident on site a daily raingauge is used. Where security is reasonable but no regular reader is available recording raingaues are used. On the Chyulu ridge, where there are no permanent residents or secure sites, storage raingauges will be installed using appropriate security measures. These gauges will be read at monthly intervals.

As listed in Table 1, sites for a network of 24 raingauges have been identified. Of these, 12 are existing sites with records ranging in length from 80 years to 12 years whilst the remaining 12 are new sites. All the existing sites have daily read raingauges though two of them, the Met. Department site at Makindu and the Range Research Station at Kiboko, also have recording raingauges. 4 of the new sites will have daily read raingauges, 6 are storage gauge sites on the Chyulu ridge and the remaining 2 will have recording gauges.

The distribution of this network over the study area is shown on the accompanying base map. The altitude range is reasonably well sampled but gaps exist in the aspect and location ranges. These are most notable on the West facing side of the Chyulu ridge, on the Eastern approaches to the ridge and on the smaller volcanic cones at the North end of the ridge. Security and access are the problems, but it may prove possible to fill some of these gaps as further knowledge of the area is gained.

Nevertheless a reasonably accurate picture of the major trends over the the study area should be obtained from this 24 gauge network if consistent good quality records can be maintained.

All the raingauges in the network, with the exception of the six storage gauges on the Chyulu ridge, will give daily totals. The recording gauge at Kiboko and the two AWS, to be discussed later, will also give hourly totals. By comparing with adjacent gauges it will be possible to time distribute the monthly storage totals to give estimates of daily input at these sites also. This is an important requirement in using the rain data to estimate aquifer recharge. In the Chyulu aquifer catchment, mean annual totals appear to be in the range 500 - 1200 mm (1), whereas mean annual potential evaporation is in the range 1800 - 2200 mm (3). In these circumstances aquifer recharge can occur only during periods of concentrated rainfall when the excess over evapotranspiration requirements is sufficient to make good the soil moisture deficit and still leave excess water to percolate to depth. Thus it is necessary that accurate information on the time distribution of the rainfall is obtained as well as total quantities.

Stream Gauging

The aim of this aspect of the study is to provide reasonably accurate estimates of the surface flow from the aquifer under the Chyulu volcanics. Ideally this would involve gauging the outflow from each significant spring at the point where it leaves the potential recharge area of the aquifer. In practice this is not possible for a variety of reasons. Most important of these is the difficulty in defining precisely where this boundary is. In a number of places also, water flows in shallow lava tongues, which extend some distance over the surrounding basement rocks, before it emerges as surface flow. In others, flow from a series of small springs on line seepage zones does not converge into a channel where measurements can be made until some way onto the basement or, in the case of the Kiboko, until it has entered a large drainage system carved out mainly by wet season run-off from the basement.

Nevertheless the locations of all the significant springs and seepage zones were known and, by examining these in detail during a particularly dry, dry season, it has been possible to identify a network of sites where it will be necessary and possible to measure flow on a regular basis. These sites are listed in table 2. Interpretation of some of these measurements will be difficult during the rains when some means of separating the rapid runoff from the basement areas and the 'Chyulu' spring flow will need to be devised.

The major outflow from the Chyulu aquifer is, of course, that occurring at Mzima Springs in the Tsavo National Park. This outflow is tapped to provide a major part of the water supply to Mombasa (some 8 mgd). The rest of the outflow is carried by the Mzima River into the Tsavo River and is monitored at a rated section some 3 km below the Springs.

In measured volume terms, the second largest outflow is that in the lower Loolturesh River. This collects contributions from several springs and seepage zones along the South West boundary of the aquifer, the most important of these being the Moilo and Kitane springs. During the rainy seasons significant flow emerges from the swamp areas in the middle Loolturesh, this water originating in drainage from Mt Kilimanjaro. Whilst three sites have been identified for monitoring 'Chyulu' flows in the lower Loolturesh in the dry season it may prove necessary to monitor flows at Iltilal, where the Loolturesh crosses the Amboseli/Tsavo road, during the rainy season.

The third most important outflow is that finding its way into the Kibwezi river. The existing rated section at Manoni lies some distance onto the basement rocks downstream of all known springs. Further up the drainage line, however, significant abstractions occur. At Umani Springs, where the flow first surfaces, water supply offtakes have been established by the Railway Co and more recently by the Kikumbulyu Water Supply Scheme. Some 2 km below these springs the residual flow disappears back into the lava. Moving Eastwards down the extended lava tongue associated with the Kibwezi drainage line, flow reappears near the Forest Research Station and additional springs also appear at Kibwezi railway station, at Chai and at Manoni. The outflow at Kibwezi is negligible, but significant flow ocurrs at the latter two. Flow in the main stream and from the springs is utilized immediately in sisal treatment and in irrigation. Thus the flow observed at Manoni section in the dry season is the residual flow after major abstractions upstream whilst in the rains it is augmented by surface run-off from the basement areas.

Of the other rivers to the East of the Chyulu the Kiboko, the Makindu, the Masongaleni, the Kambu and the Mtito Andei all recieve spring flow contributions, though the stream bed topography is primarily the result of rainy season runoff from the basement rocks.

Measured or estimated flows as of August 1984 from all of these drainage systems are listed in decending volume order in Table 3. At this point in time there was emphatically no surface flow contribution to any of them, since the 'long' rains period of April/May 1984 produced less than half the normal yield. The total of the flows listed in Table 3 is 6.67 m^3/s. This is of course an underestimate of the total outflow from the aquifer since it takes no account of the water supply, irrigation and borehole extractions from the springs, streams and wells on the Eastern side. Of these, the

Railway and Kikumbulyu W.S. offtakes at Umani Springs were estimated at ∿ 1 mgd (0.05 m^3/s). The irrigation and processing offtakes further downstream on the Kibwezi probably accounted for a similar quantity. Assuming, as a rough estimate, that all the other small offtakes and borehole supplies amount to a similar quantity (ie 1 mgd), this gives an additional outflow of 3 mgd or 0.16 m^3/s and a total estimated outflow of 6.83 m^3/s. Using the estimated area of the aquifer of 1938 km^2 (1) the above total outflow is equivalent to

0.30 mm/day, or 111 mm/year.

This estimate of total outflow is comparable with the higher range of mean annual totals listed in table 12 of Wright (1). It also suggests that, as of August 1984, the Mzima outflow represented some 75% of the total outflow.

Whilst the proposed network of flow gauging sites will give some basic indication of the total outflow and its seasonal variations, it must be recognised that there is a need to obtain more accurate estimates of the net volumes being removed from the aquifer in water supply offtakes and for boreholes. Also, the network is designed primarily to gauge dry season spring flow. Interpretation of the records during the rainy seasons will present some difficulties. For the 'Eastern' drainage lines these will arise from the passage through the gauging sites of large but relatively short lived flows of rapid runoff from the 'basement' soils. Interpretation of these records will be discussed at a later stage in the study. As indicated earlier, it will also be necessary to obtain some estimate of the 'Kilimanjaro' contribution to the Loolturesh flow during these periods. To this end Mr Gunston has been asked to identify a suitable gauging site on the Iltilal - Moilo reach of this stream.

With regard to the network of gauging sites outlined in table 2, it will be seen that only four of the sites positively identified during the visit are existing rated sections. Of these the Mzima site, 3G3, is the most stable and is likely to require no more than the normal routine checks on the accuracy of the rating.

The Manoni site (3F6) on the lower Kibwezi is also reasonably stable but a series of current meter checks on the rating, particularly at the lower flows,is advised. The site 3G13 on the Tsavo is a good rock section fitted with a recorder. It does not appear to have been fully rated however and some work on this both by the Study team and by the local MOWD hydrologist will be necessary. The dry season flow range is the main interest in this site for the Study but the complete records are of value to the MOWD network. The fourth existing site listed, 3F7 on the main Kiboko river, is of marginal value to the study. Because of the sand bed nature of the site, any low flow extrapolation of the existing rating will be very inaccurate. The best course of action for study purposes will be to treat this site in the same way as those requiring regular current metering (see below).

The Umani Springs site listed differs from all the others in that it has a rectangular sharp-crested structure fitted. This is sited immediately above the Railway and Kikumbulyu water supply offtakes. After some minor repairs, this structure offers the best opportunity anywhere on the Eastern side of the Chyulu to monitor accurately variations in yield and hence in aquifer head. For this reason it is proposed that a water level recorder be installed on it. As the flow emerges within the aquifer area at this site and disappears back into the lava some 2 km downstream this record will not feature directly in the water balance of the aquifer but will provide valuable data on its behaviour.

Originally this structure was installed as part of a method of monitoring the volume offtake by the Railways. A second similar structure was installed downstream of their offtake and the difference gave the volume taken off. Unfortunately, when the Kikumbulyu offtake was installed the attempt to repeat this arrangement downstream of the railway offtake was not successful. The geometry of the layout past this second offtake has resulted in a 'drowning' of the second structure and a turbulent approach to the third, so that neither produces a reliable stage discharge relationship. Thus it is not possible to obtain, on site, a measurement of the abstraction.

Five of the new gauging sites listed are on sections sufficiently stable to warrant the development of rating curves. These are the Hunters Lodge site on the lesser Kiboko, the Mtito Andei river, the Loolturesh above its confluence with the Tsavo, the Tsavo above the Mzima/Tsavo confluence and the stream entering the Mzima between 3G3 and its confluence with the Tsavo. In the first instance staff gauges will be installed at four of these sites which will be read daily by locally based observers and a water level recorder will be installed at the Loolturesh site. As soon as current metering equipment is delivered to the Team, regular visits to these sites will begin and volume flow/stage ratings for each site will be built up.

At the remaining five sites listed in table 2, namely the Makindu river, Thange springs on the Masongaleni river, the Kambu river and the two sites on the Loolturesh, the only means of assessing flow will be by regular current metering. At the first three of these sites there is no stable section which can be rated and at the latter two it is not possible to organise regular staff readings.

The streamflow programme outlined above calls for a great deal of current metering. Discussion with MOWD revealed that their existing stocks of current metering equipment are in frequent, regular use. Consequently it has been necessary to acquire current metering equipment specifically for the Study. This should be delivered in October 1984

Meteorology

In attempting to estimate net recharge to the Chyulu aquifer the greatest uncertainty concerns the loss from the area by evapotranspiration

Considering the water balance over a year,

		Q	AE	ΔSM		ΔGS
Cumulative precipitation	=	Cumulative streamflow	Cumulative evapotranspiration	Net increase in soil moisture	+	Net aquifer recharge

P and Q can be determined with reasonable precision by the networks previously described. The diversity of soil types and depths over the area makes it unrealistic to attempt any form of direct measurement of soil moisture. However, the seasonal rainfall pattern is such that the net change, ΔSM, between the end of one June - September dry season and that in the following year is likely to be small relative to P, Q and AE. AE, on the other hand, will have a magnitude somewhere between that of Q and P. If estimates of annual net recharge are to be obtained,

$$\text{ie} \quad \Delta GS \simeq P - Q - AE$$

then clearly some means of estimating AE is required.

The most productive approach is to use a Penman type estimate. This is based on the fact that evapotranspiration rates from any given vegetation cover are determined by meteorological conditions when there is adequate soil moisture available. This 'potential' rate can be calculated for each cover from meteorological variables. As available soil moisture diminishes, the rate falls progressively further below the potential one. The response characteristics of each of the major vegetation types to soil moisture stress can be estimated to model the actual water use, AE, given the time distributed rainfall inputs, the meteorological variables necessary to compute potential evapotranspiration and some estimate of soil moisture storage.

It is proposed, as part of the routine data collection during the study, that meteorological data be acquired from five sites within the area (Table 4). As with the rainfall network, the approach is aimed at determining variability with altitude and location within the area during the two year field operation and relating this to the records of a long term existing site so that areal estimates over an extended period can be derived from the latter.

The long term site within the network is that operated by the Meteorological Department at Makindu. Records from this synoptic station started in 1938. Two other existing manually operated sites, at the Kiboko Range Research Station and at Tsavo West Park HQ at Kamboyo are included in the network. These three sites span the SE → NW extent of the area but are all at close to 3000' altitude. To sample the altitudinal variation and the climatic variation to the West of the Chyulu Ridge, two new sites have been incorporated. These are on the East of the Chyulu ridge near the mid point at an altitude of 6100' and at the Oltiasika Training Centre under the West side of the Ridge at 4600'. The latter site will also be a manually operated station but with the inclusion of solar radiation in the variables measured. The Chyulu ridge site will be equipped with an Automatic Weather Station (AWS) which samples and records on magnetic tape at 5 minute intervals all the variables necessary to compute Penman potential estimates. Since this data is much more comprehensive than that observed at the manual stations, a second AWS will be sited alongside the manual station at Makindu so that direct correlations between the manual and AWS data can be obtained.

It is necessary to use an AWS at the Chyulu ridge site since there is no possibility of stationing an observer there. Nevertheless the same security and access considerations as for the raingauge sites applied in the choice of this site. That identified is immediately adjacent to a military communications establishment which is visited at regular intervals. Negotiations for the use of the site with the Parks Dept, on whose land it is, and with the military are in hand.

Methods whereby Penman potential data from these five sites can be combined with appropriate factors relating to vegetation cover and soil moisture availability to give estimates of actual evapotranspiration, AE, for the area as a whole are being developed.

Field Programme

At the time of the visit no counterpart staff had been allocated to Mr Gunston. This was due in part to extensive demands for staff within MOWD and in part to the need for Gunston to carry out extensive field survey before precise requirements for staff could be presented. By late August these difficulties had been overcome and it was agreed that the Study team should comprise

H. Gunston	Leader	Based in Mombasa
Mr Mnyamezi	Counterpart Hydrologist	

1	Assistant Hydrologist	Based in MOWD/Voi
2	Hydrological Assistants	

In addition an MOWD trained field observer will be posted in the Oltiasika Training Centre to operate the manual meteorological site and the local raingauges when these are installed.

It was also agreed that the MOWD Construction Team under Mr Okoth would be available in September to instal the raingauges, staff gauges, water level recorders, etc., called for in the networks.

Reading and maintaining the networks described in the previous sections will require that the Team spends a considerable amount of time each month in the field. Whilst the small building at Parks HQ rented by Mr Gunston has proved useful in the initial survey stages, a more suitable field centre for the Study would be the MOWD Rest House close to Mzima. This has adequate sleeping accommodation for the numbers likely to be in the field and office cum equipment storage space in the adjoining unused treatment works. Access from Voi via the pipeline road is much shorter and quicker than driving through Tsavo West Park.

.Once field installation is complete the basic data collection routine can be established. The present concept is that this should be essentially a monthly cycle. The critical factors determining the cycle length are the storage raingauges on the Chyulu ridge, the Automatic Weather Stations, the water level recorders and the frequency of current metering. The storage raingauges should, ideally, be read on the 1st of each month. The numbers of daily read and recording gauges within the network will make it possible to adjust for a few days either side of this target but nevertheless the monthly dates should be the target times for reading.

The AWS are perhaps the most critical factor in deciding whether a monthly cycle can be achieved or whether more frequent visits will be necessary. As designed, these instruments call for fortnightly visits to change batteries and tape cassettes. By using C90 tape cassettes in place of the standard C60s it is possible to extend the recording time to one month, but with virtually no margin for error. The batteries however will not last for one month without recharging. Since neither the Makindu nor the Army communications site at Chyulu have the hoped for power generating facilites, the alternative is to instal solar panels at each site to maintain battery charge. This approach has been used with great success on IH AWS installations elsewhere, including the Kenya Hydrology Project sites. Whilst such panels are expensive, (approx £200 each) the cost must be considered against that of an additional round trip from Mombasa each month.

The water level recorders available to the Project have variable time and water level range gearing. Adjusting these to give a monthly interval between chart changes should present no particular difficulties.

The choice of interval between visits to sites requiring current metering is more problematical. This is really a function of the rate of change of flow rather than of calendar dates. As a starting point, however, it is recommended that readings are taken at the six 'current metering only' sites as part of the monthly round. Each of the five new 'rated section' sites should be inspected on this round and, if the stage has changed significantly from the previous visit, current metering should be carried out. The above comments will also apply to the additional site on the Loolturesh still to be identified. Less frequent current metering will be necessary at the established rated sections. Programmes for these sites should be agreed with the MOWD Hydrologist based at Voi.

Whilst there are no fixed time constraints on the collection of the remaining rainfall data it is desirable that these data should reach the Team at Voi on a regular basis so that checking and tabulation are kept up to date. For the daily read gauges the team must use the most convenient method for each site, whether it be posting at weekly/monthly intervals, delivery to a convenient collecting point or collection on the monthly round. The 'Simple' recording raingauges have a memory capacity of 86 days but should be visited at more frequent intervals to ensure that they do not become blocked or otherwise inoperative.

The data from the manually operated Meteorological sites will be recorded on standard Kenya Met. Department monthly forms, copies of which will either be collected by or posted to the Team at monthly intervals.

As a matter of good field practice the Team should make a point of visiting those observers and sites not on the regular monthly round at intervals of not more than three months.

Initial Data Processing

The detailed organisation and management of data processing are of course matters for the Team Leader to organise. The following comments are aimed at summarising the work that needs to be done and suggesting a general approach whereby the accumulating data can become available for various forms of analysis as quickly as possible.

With the exception of the AWS, all data collected in the field will require considerable initial manual processing. This will comprise checking and tabulation of the daily rainfall and staff readings, checking and Penman computation from the manual met. data, stage abstraction from the water level charts, stage/flow conversion, checking and tabulation of the current metering computations. Most of this work can be done by the junior staff to be based in Voi.

The tapes from the AWS will be sent to the Institute of Hydrology for translation and initial processing. This will produce hard copy listings of hourly means/totals of the meteorological variables plus computation of various versions of Penman potential evaporation. These listings, with comments on station performance, will be returned to the team. If it is considered desirable the data can also be retained in store on the computer for subsequent analysis.

At an early stage in the study decisions must be made on whether manual tabulation or computer disc is to be the primary method of data storage. This is a necessary preliminary to designing data forms etc., so that time spent in tabulating, coding and transposing is minimised. If possible, early transfer to computer is recommended, with hard copy as a security back-up. Much of the subsequent processing and analysis will then become easier to handle. In this context access to graph plotting facilities will be invaluable.

Whilst the major emphasis during the two year period must be on data collection and initial processing, there is much initial analysis that can be carried out during this period. This applies particularly to determining altitude, aspect, location and between-site relationships for the rainfall and meteorological networks as a preliminary to determining the best methods of computing mean areal values. By starting this type of work at an early stage there is also the prospect of identifying and rectifying any major gaps in the networks.

Further Studies

The Land Use Study of the area by Makin and Pratt(2) is a valuable starting point in estimating the distribution of soil and vegetation types. Any additional information that can be gained on these facets will help to reduce the uncertainty in computing actual loss, AE, from the meteorologically determined potential evaporation. The detailed soil and soil/water relations survey proposed in (2) would undoubtedly be of great value in this context.

Much additional information of a qualitative or semi-qualitative nature can also be accumulated by intelligent, systematic observation during the regular monthly field trips. This would cover such aspects as the extent of vegetation cover and its growth and transpiration status on each of the major soil types and vegetation zones and the moisture status of the surface soils. When time permits it would be useful also to dig a few pits to examine the depth and composition of soil profiles and the root distribution within them.

The formidable difficulties which preclude any attempt to quantify systematically soil moisture status over the area have been detailed in (2). Nevertheless it should be possible to identify a few 'index' sites on the regular monthly route, preferably close to raingauges, where soil moisture can be monitored. Whilst the time consuming operations necessary to obtain full volumetric estimates of soil moisture are unlikely to be a practical proposition, the Team Leader has the expertise to do this and the equipment and facilities required are available in Kenya (within MOWD, KARI and NAL). The acquisition of semi-quantitative or even qualitative estimates of relative changes in the moisture profiles, either by gravimetric sampling or by the use of gypsum blocks, is a more realistic option.

The patches of montane 'rain' forest on the upper Chyulu ridge represent a very small proportion of the total aquifer recharge area. Nevertheless the fact that they appear to transpire throughout the year suggests that they could account for a more significant proportion of the total evapotranspiration from the area. A full scientific investigation of the hydrometeorological characteristics of these forest areas is beyond the resources of the Study and estimates of evapotranspiration from them must be based on models developed from studies elsewhere. The data from the high level AWS will be valuable in this context, but its value would be greatly enhanced if some measurements of interception of both rain and mist (low cloud) by the forest canopy could be obtained.

References

(1) Wright, E.P. Groundwater resources of the Chyulu Hills : Progress Report, September 1982. BGS Hydrogeology Unit, Wallingford.

(2) Makin, M.J. and Pratt, D.J. Land Use and Development in the Chyulu Area of Kenya. Project Report 135. LRDC, Tolworth, 1984.

TABLE 1.

Proposed Raingauge Network

NO	SITE	GRID REF	ALT.(Ft)	GAUGE TYPE	STATUS
	KIBOKO Range Reseach Station	CH583514	3260	DAILY (+ Dines)	EXISTING
2	MAKINDU Met. Site	CH691482	3250	DAILY (+ Dines)	EXISTING
3	DWA Plantation	CH900352	2760	DAILY	EXISTING
4	UMANI SPRINGS	CH786268	3260	DAILY	NEW
5	MASONGALENI Railway Station	CH944253	2790	DAILY	EXISTING
6	ELMAU Near P3 Site	CH583230	3800	STORAGE	NEW
7	KIMITUNDU Primiary School	CH738181	4200	DAILY	NEW
8	N.CHYULU RIDGE Near P2 Site	CH728135	6168	STORAGE	NEW
9	DARAJANI Railway Station	DH018143	2575	DAILY	EXISTING
10	MUTHINGIINI Primary School	CH936130	2969	DAILY	NEW
11	OLTIASIKA Training Centre	CH723045	4590	DAILY	EXISTING
12	CENTRAL CHYULU RIDGE Near P5 Site	CH754034	6100	STORAGE	NEW
13	SOITPUS SWAMP	CH634993	3346	RECORDING	NEW
14	KAMBOYO Tsavo Park HQ	DG033966	2890	DAILY	EXISTING
15	SW CHYULU RIDGE Near P6 Site	CG805945	5050	STORAGE	NEW
16	SE CYULU RIDGE Near Parks I Site	CG845947	4790	STORAGE	NEW
17	KAMBOYO BOREHOLE	CG958923	2950	RECORDING	NEW
18	SHAITANI	CG871870	4170	STORAGE	NEW
19	ILTILAL Primary School	CG744828	2900	DAILY	NEW

TABLE 1 (Cont'd)

NO	SITE	GRID REF	ALT.(Ft)	GAUGE TYPE	STATUS
20	CHYULU GATE	CG934791	2560	DAILY	EXISTING
21	KILAGUNI LODGE	CG956788	2710	DAILY	EXISTING
22	KITANE LODGE	CG878688	2360	DAILY	EXISTING
23	MZIMA SPRINGS Ranger Post	CG909704	2260	DAILY	EXISTING
24	MZIMA MOWD Rest House	CG917677	2200	DAILY	EXISTING

NOTE P2, Parks I, etc, refer to sites listed in (1)

TABLE 2

NO	SITE	GRID REF	ALT.(Ft)	METHOD	STATUS
1	KIBOKO RIVER Near 3F7	CH548557	3050	CM	NEW
2	LESSER KIBOKO d/s of Hunters Lodge	CH569558	3020	RATED SECTION Daily Staff	NEW
3	MAKINDU RIVER Near railway bridge	CH673495	3200	CM	NEW
4	KIBWEZI MANONI 3F6	CH972373	2427	RATED SECTION Daily Staff	EXISTING
5	UMANI SPRINGS Above offtake	CH786268	3264	STRUCTURE WLR	NEW
6	THANGE SPRINGS Masongaleni River	CH912238	2886	CM	NEW
7	KAMBU RIVER above road	CH966160	2657	CM	NEW
8	MTITO ANDEI RIVER above road	DH064028	2427	RATED SECTION Daily Staff or CM	NEW
9	LOOLTURESH KYS Near Kampi ya Simba	CG785758	2624	CM	NEW
10	LOOLTURESH DRIFT Near Kitane	CG844698	2394	CM	NEW
11	LOOLTURESH CONFLUENCE with Tsavo	CG884667	2250	RATED SECTION WLR	NEW
12	TSAVO BRIDGE above Mzima Confluence	CG929660	2100	RATED SECTION Daily Staff	NEW
13	MZIMA 3G3	CG918674	2180	RATED SECTION Daily Staff	EXISTING
14	TSAVO 3G13	DG006633	2030	RATED SECTION WLR	EXISTING
15	MZIMA TRIBUTARY below 3G3	CG924664	2120	RATED SECTION Daily Staff	NEW
16	LOOLTURESH ILTILAL	site and method still to be determined			NEW

NOTE

CM indicates regular current metering
WLR indicates water level recorder

TABLE 3

CHYULU AQUIFER OUTFLOWS

AUGUST 1984

MZIMA SPRINGS	Stage at rated section : 0.33 m	= 4.7 m^3/s
	Pipeline flow = 7.8 mgd	= 0.41 m^3/s
	i.e. Total outflow	= 5.11 m^3/s
LOOLTURESH	At confluence with Tsavo. This includes spring flow from Moilo and Kitane. Current metering gave	0.68 m^3/s
KIBWEZI RIVER	at Manoni (3F6). This is below all known springs but also after substantial water supply offtakes at Umani, Dwa, etc., and substantial irrigation offtakes. Stage at rated section = 0.42 m	= 0.41 m^3/s
KIBOKO RIVER	Main river at (3F7) had trickle only, estimated at $\sim$ 0.01 m^3/s. Most flow coming from Hunters Lodge springs, estimated at 0.14 m^3/s.	
	i.e. Total outflow	= 0.15 m^3/s
MAKINDU RIVER	No good gauging site (reeds) Estimated flow	$\approx$ 0.1 m^3/s
MTITO ANDEI RIVER	Possible gauging site Much water being taken in debes Estimated flow	$\approx$ 0.1 m^3/s
KAMBU RIVER	Sand bed and minor irrigation below seepage area from lava Current metering gave	0.08 m^3/s
MASONGALENI RIVER	Thange Springs, d/s of road. Current metering gave	0.04 m^3/s

TABLE 4

Proposed Meteorological Network

NO	SITE	GRID REF	ALT.(Ft)	METHOD	STATUS
1	KIBOKO Range Research Station	CH583514	3260	MANUAL	EXISTING
	MAINDU Met Site	CH691482	3250	MANUAL + AWS	EXISTING NEW
	N. CHYULU RIDGE near communication site	CH728135	6168	AWS	NEW
	OLTIASIKA Training Centre	CH723045	4590	MANUAL	NEW
	KAMBOYO Tsavo Park HQ	DG033966	2890	MANUAL	EXISTING To be upgraded

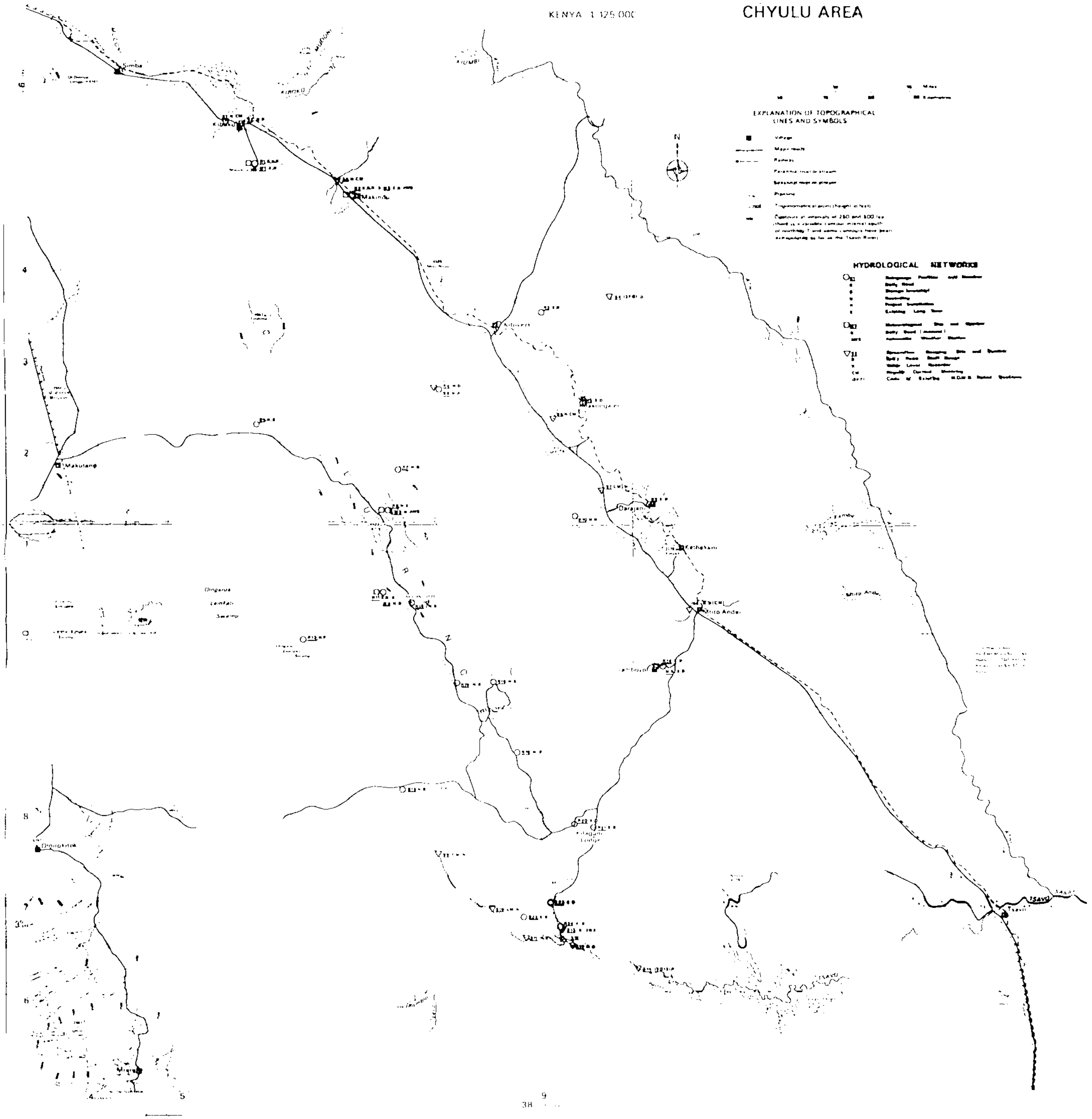
APPENDIX I

Itinerary of Visit by J R Blackie to the Chyulu Water Resources Project

29/7/84	Arrive Nairobi 0710. Met by H GUNSTON. Initial discussions on current status of project and planning of timetable of visit.
30/7/84	To Ministry of Water Development In absence of Chief Hydrologist (in Hararè), discussion with J O Nyagua on present status progress on MOWD counterpart appointments, proposed programme for JRB's visit, availability of MOWD construction team. To British High Commission Aid Section. Discussion of present status of project and proposed programme with Mr P Jenkins. Unscheduled meetings with Dr B Ngundo (Director KARI(ARD)) and Dr H Lamprey (UNESCO IPAL PROJECT) Domestic arrangements for 4 day safari to Chyulu/Tsavo area.
31/7/84	Collected missing map roll from Lufthansa at Nairobi Airport en route for Chyulu area. Examined existing gauging site on Kiboko river and looked for alternative low flow site. Idenitified gauging site on lesser Kiboko below Hunters Lodge. Looked for sites also on Makindu, Kambu and Mtito Andei rivers and made rough flow estimates. Visited Kenya Meteorological Department site at Makindu. To MOWD Rest House at Mzima.
1/8/84	To temporary project office at Kamboyo Planning session with 1:50,000 maps. Examination of Mombasa Water Supply pipeline offtake and control unit, Mzima gauging station (3G3), Tsavo gauging sites, Kitane springs. Search for possible gauging sites on Loolturesh River. Identified reasonable site near Loolturesh/Tsavo confluence. Return to Mzima Rest House.
2/8/84	Chyulu Hills. Survey of proposed storage raingauge sites, present land use, proposed met site and recording raingauge site near Oltiasika Training centre and the proposed AWS site near the military communications installation. Return via Kibwezi track and Mtito Andei to Mzima Rest House.

3/8/84	Further hydrological exploration of Mzima/Tsavo River including visit to gauging site 3G13, and identification of possible gauging site on Tsavo above Mzima confluence. To Tsavo West Park HQ at Kamboyo. Discussion with Chief Warden (Planning), Mr Woodley. To Mombasa.
4/8/84	Collected, unpacked and assembled AWS.
5/8/84	Assembled second AWS. Checked and attempted repairs.
6/8/84	To MOWD, Kisauni Discussion with Adams, Carruthers. To MOWD, Coast Office. Meetings with G W Dugdale, C N Irungu (Water Resources) and H M'Inyingi (Hydrology) Prolonged attempt to rectify faults in AWS 09. Checked storage and recording raingauges.
7/8/84	To MOWD Changamwe (HG's Office) To MOWD Voi. Collected Mr Mukera (District Hydrologist) and Mr Nyamwezi (Hydrologist from Nairobi HQ) To Mzima via Pipeline road. Examination of proposed Tsavo and Lower Loolturesh sites. Current metering at latter. Brief visit to Kitane Springs.
8/8/84	To Kibwezi. Detailed examination of Umani Springs and W/S offtakes, and possible raingauge site. Visit to Kikumbulyu W/S pumping station. To Manoni gauging station. To Thange Springs on Masongaleni River. (Current metering) To Kambu River (Current metering) Brief look at Mtito Andei River.
9/8/84	Further work on Mzima and middle reach of Loolturesh. Current metering at two sites. Visit to Kampi ya Simba springs. To Park HQ at Kamboyo. Discussion with Chief Warden Mr M P Muenge and with Research Staff (Chege, Oliver and Harrington). Left Mr Mukera at Mtito Andei. Proceeded to Nairobi looking again at Kiboko River and Hunter's Lodge springs en route.
10/8/84	Notes and work on base map. To MOWD Maji House. Meetings with J O N Nyagua (Hydrology) and Mr E M Mwai and Mr Mukiri (Geology).
11/8/84	Rest day. Lunch with Mr C Field (UNESCO IPAL Project).
12/8/84	Map work. Preparation for MOWD Meeting. Dinner with Dr B Ngundo (Director, KARI (ARD)).
13/8/84	MOWD, Maji House. Lengthy and detailed discussion with Mr Charania (Chief Hydrologist) and his deputy, Mr Nyagua, on installation of Chyulu networks and posting of MOWD counterpart staff to the Project. BHC. Aid Section. Meeting with Mr P Jenkins.

14/8/84	MOWD, Maji House. Discussions and work on KENYA HYDROLOGY PROJECT.
15/8/84	Field trip to two Kenya Hydrology Project experimental catchments.
16/8/84	a.m. Follow-up discussion on Chyulu plans with Mr Charania at Maji House. Final discussions with HG prior to his departure to Mombasa. p.m. Further meeting at Maji House on Kenya Hydrology Project, followed by discussion of this with P. Jenkins at BHC
17/8/84	Work on Kenya Hydrology Project.
18/8/84	Notes, drafting reports. Wrap-up discussion over lunch with Chief Hydrologist, Mr Charania.
19/8/84	Rest Day. Departure for U.K.


KENYA 1:125 000
CHYULU AREA
EXPLANATION OF TOPOGRAPHICAL LINES AND SYMBOLS
HYDROLOGICAL NETWORKS
Simba
Makindu
Makutano
Darajani
Mtito Andei
Kilaguni Lodge
Tsavo

Natural
Environment
Research
Council