REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

WATER RESOURCES ASSESSMENT STUDY
WEST POKOT DISTRICT

MAIN REPORT

DECEMBER 1984

WATER RESOURCES DEPARTMENT
NAIROBI, KENYA

GROUNDWATER SURVEY TNO
DELFT, THE NETHERLANDS

SUMMARY

Background information

Project

The Water Resources Assessment Project (WRAP) is being carried out jointly by the Water Resources Branch of the Ministry of Water Development and the TNO Institute of Applied Geoscience and forms part of the technical development cooperation between the Governments of Kenya and the Netherlands. The main objective of the project is to train Kenyan professionals and technicians in techniques of water investigation through the assessment of the quantity and quality of the available water resources in a number of selected areas.

This report deals with the southern part of the West Pokot District, a sub-humid to semi-arid area in the Rift Valley Province, Western Kenya. The area investigated covers approximately 6000 km² and the present population is estimated to be 150 000.

Physiography

The topography of the investigated area shows great variations in elevation. Several geomorphological units can be distinguished, ranging from mountains exceeding 3000 m to lowlands at an elevation below 1000 m.

Geology

The crystalline rocks of the Basement System cover the larger part of the investigated area. The Basement System principally comprises the various types of Precambrian sediments that were transformed into gneisses, schists, quartzites and marbles by regional metamorphism. These rocks are intensely folded. Several faults in the area are associated with the Rift Valley System; however, no vulcanicity accompanied the Tertiary faulting in West Pokot. A thick sedimentary cover of clayey floodplain sediments developed along the Rivers Kerio and Wei Wei during the Quaternary.

Soils

Different types of soils are found in the area. On the mountains and major scarps the soils vary from stony loam to clayey loam, whereas at the foot of the mountains and hills, deep sandy loam soils are found. In the uplands, soils vary from deep sandy clay loams to clays. These soils are in general well drained. In the floodplains along the major rivers, complex soils with various textures and drainage conditions are found.

Climate

The climatogical conditions in the project area are strongly affected by the great variations in the topography. Two distinct climatic zones are distinguished. The climate in the lower parts of the area (below 1500 m) can be described as semi-arid, with high temperatures and evaporation rates and relatively low rainfall. The climate in the higher altitude areas (over 1500 m) can be described as highland and sub-humid climate, with lower temperatures and evaporation rates and higher rainfall than in the former areas.

Meteorological network

The existing network required some rehabilitation. Four rain gauge stations were rehabilitated and equipped with new rain gauges. The network was augmented by one new rain gauge station and one evaporation pan. In most cases, rainfall data are incomplete for some years. Values for missing data on rainfall and evaporation to supplement poor records were estimated by correlation analysis.

Rainfall

Long-term monthly averages and their standard deviations were calculated for 11 rain gauge stations. The standard deviation indicates large fluctuation in monthly rainfall from year to year. Monthly or seasonal minimum average rainfall appears to be unpredictable. Most of the rain falls during the period between April and August, with a dry spell in June. In the southeast, high rainfall occurs in October/ November. The average annual rainfall varies between 1200-1600 mm in the elevated parts of the area. In the lower areas, rainfall decreases gradually to a minimum of 600 mm per annum at the Turkwel Gorge.

Rainfall map

A map showing the long-term average rainfall was prepared.

The isohyets are based on the updated long-term (1953-1978) mean annual rainfall data from 12 rain gauge stations, supplemented with data from less reliable or abandoned stations. For the period 1982-1983 monthly total rainfall was calculated for the Suam and Muruny catchment areas.

Evaporation

Long-term mean monthly evaporation and standard deviation were calculated for three evaporation stations. The highest monthly evaporation generally occurs during the period between December and April. The maximum and minimum evaporation rates occur in January and July respectively. There is a clear correlation between altitude and evaporation. At higher altitudes seasonal variation is much greater than at lower altitudes. Annual evaporation is between 1200-1400 mm at Cherengani Forest and the higher parts of the area, but in the lower parts the annual evaporation exceeds 2200 mm.

Surface water resources

Hydrology of West Pokot District

West Pokot District can be subdivided into three main catchment areas: the Suam-Turkwel Basin upstream of the Turkwel Gorge (5900 km²), the Muruny Basin upstream of Marich Pass (1355 km²) and the Wei Wei - Malmalte Basin upstream of the confluence of the Turkwel and Malmalte Rivers (2044 km²). The total catchment area covers circa 9360 km². The project activities were mainly concentrated on the Suam River upstream of Kongolai (1350 km²) and the Muruny River upstream of Marich Pass (1355 km²). Earlier data were available for the upper reaches of the Wei Wei River (170 km²) and these were analysed. The hydrological map prepared for the whole West Pokot District gives comprehensive information about the various catchment areas and the drainage pattern.

Little water is lost by sub-surface infiltration. Except in the mountainous forest areas, surface water runoff is high, as indicated by the high drainage density. There are only three perennial rivers, the Suam, Muruny and Wei Wei. Numerous floodplains of intermittent streams exist on the foothills of the range between Mount Elgon and Cherengani Hills.

River gauging stations

The strategy to rehabilitate the hydrometric network, prepared by Norconsult, was implemented in collaboration with the Ministry of Water Development. Following the recommendations of Norconsult and Tams (1980) the project installed an automatic water-level recorder in the Muruny River at Marich Pass. This location has subsequently been criticised. However, other locations did not seem appropriate because of their liability to high and very severe flooding. Flow measurements were intensified and alternative methods for measuring flow were introduced to overcome the lack of suitable equipment such as cableways. The monitoring of the present hydrometric network should be continued and if possible intensified to facilitate future analysis of the surface water potential.

Discharge rating curve

Discharges were measured regularly to establish a rating curve for the automatic water-level recorder at Marich Pass. Three different methods were used simultaneously to measure discharge: current meter, float, and the so-called "slope-area" method. Rating curves were prepared and updated for the Suam and Muruny rivers. In general, the rating curves show a high correlation. However, to improve the accuracy, especially for high river stage, more peak flow measurements are required.

River flow characteristics

During the rainy season the river discharges are characterized by flash floods. The river flow shows extreme fluctuations from hour to hour. There is very little time lag between rainfall and runoff. Peak flows at the established river gauging station generally occur at night. Runoff figures based on daily staff gauge readings are therefore considerably underestimated. The actual daily flow calculated from hydrographs is 2 - 20 times the estimated flow based on daily staff gauge readings. For annual flows the underestimation ranges between 20% to 30%.

The maximum instantaneous flows observed at Kongolai (Suam River) and Marich Pass (Muruny River) were 320 m^3/s and 150 m^3/s respectively. Minimum flows observed were 0.2 m^3/s and 4 m^3/s.

The ratios of annual runoff and rainfall were 0.18 for the Suam River and 0.14 for the Muruny River, indicating that the base flow component for the Muruny River is higher than that for the Suam River.

Surface water balance

Based on the hydrogeological conditions it was assumed that the annual regional groundwater recharge from percolating rainfall is very limited, i.e. in the order of less than 1% of the annual rainfall. The evapotranspiration is high, especially in the lower areas, being approximately 900-1000 mm per year. The total amount of surface water outflow from the two catchment areas during the observation period 1982-1983 was 500 x 10^6 m^3, i.e. 300 x 10^6 m^3 for the Suam River and 200 x $10^6 m^3$ for the Muruny River. The observation period covered one "hydrological year".

Surface water quality

Chemical analyses of surface water were available for the three major rivers, Suam, Muruny and Wei Wei - and for 18 minor rivers and streams.

The total content of dissolved solids in the majority of samples did not exceed 150 mg/l.

The fluoride concentration in all samples was below 1 mg/l.

Generally speaking, the surface water at all sampling sites is of good inorganic quality when judged against the WHO International Standards for drinking water. Only the iron concentrations exceed the recommended standards.

It must be stressed that the composition of surface water is subject to rapid changes over time. A single sample can therefore never be considered as being representative for a long period. Frequent sampling is necessary to monitor any changes in the water quality.

Groundwater resources

Exploration for groundwater

The main purpose of detailed hydrogeological investigations was to indicate suitable sites for new boreholes in areas with a high demand for water. Initially the District Water Officer proposed 11 locations for possible groundwater development.

Sites for drilling were determined by geological methods and surface geophysical methods.

The geological methods included remote sensing techniques and ground reconnaissance survey.

Detailed geophysical investigations were carried out at 13 sites in West Pokot District. The methods applied were resistivity profiling, resistivity sounding, electromagnetic profiling and seismic refraction, the main target being to locate as accurately as possible the position of fractured zones in the bedrock.

At three sites an experimental aerial electromagnetic survey was flown by Geosurvey International Limited. The results showed good correspondence with the ground data.

Fifteen boreholes were drilled at eight locations with rotary and percussion rigs. The depth of boreholes varied from 41 to 72 m.

The transmissivity of aquifers and the yields of successful boreholes were tested either by a well test or a bailer test.

Groundwater samples were collected for chemical analysis.

Occurrence of groundwater

Under the given hydrogeological conditions, the groundwater in West Pokot occurs either in weathered/fractured Basement rocks or in the fluviatile and torrent-wash sediments.

Aquifer conditions in Basement rocks

The results of drilling, test pumping and chemical analyses showed great variations in depth to groundwater, transmissivity of aquifers and groundwater quality. These variations, occurring even over short distances in the same geological unit, indicate that there are no regional aquifers in Basement rocks.

The weathering products of gneisses, the main rock type in the investigated area, generally have a high content of clay and mica. Consequently, the permeability of the aquifers is low. The transmissivity values obtained from the well tests are in the order of magnitude of 1-2 m^2/day. Similar values were found for the fractured rocks.

The differences between water struck level and water rest level indicate that conditions are confined at all drilling sites. The water rest levels are relatively shallow, being between 6.5m and 33m below surface.

Aquifer conditions in Quaternary deposits

Shallow alluvial aquifers have developed locally along the major rivers and their tributaries. They consist largely of coarse sands and gravels and might have a high transmissivity, as indicated in the Chesera borehole, where a value of 280 m^2/day was found. The alluvial aquifers are mainly recharged with the river water.

The floodplain sediments, on the other hand, contain a high percentage of clay and silt, which considerably reduce their permeability. Drilling results showed that floodplain sediments are poor aquifers. The coarse scree material which has developed locally on the hill slopes might form relatively good aquifers, if they are sufficiently recharged.

Groundwater quantity

Two of the ten new boreholes drilled in the Basement rocks were reported as dry. The yields of the other eight boreholes varied from less than 0.5 m^3/h to 3 m^3/h.

Two boreholes drilled in floodplain sediments had yields below 0.5 m^3/h, and one borehole was dry. Higher yields were obtained only from the two boreholes that tap the coarse alluvial aquifers in Serewa and Chesera. For the latter, a theoretical yield of 100 m^3/h was calculated.

The amount of abstractable water stored in the isolated Basement aquifers is difficult to estimate because neither the extent of aquifers nor the amount of recharge is known.

It is estimated that the total annual sustained yield is about 3×10^6 m^3 for an area of 4000 km^2 (Basement area without floodplains).

The sustained yield of coarse alluvial deposits along the major rivers is probably in the order of magnitude of 1×10^6 m^3/year.

Groundwater quality

Fourteen groundwater samples were collected from 11 boreholes. The total dissolved solid content, TDS, of the samples varied from 174 mg/l to 1920 mg/l. The WHO-recommended limit of 500 mg/l for the total dissolved solid in groundwater to be used for drinking water was exceeded in 5 boreholes. However, even 1500 mg/l of TDS seems to be acceptable in areas without any other alternative for drinking water.

The fluoride content in all samples was within the WHO limit.

Water from all boreholes can be used to water cattle.

Water resources assessment

Water Supplies

The number of operational water supplies in West Pokot District is limited. Surface water is the major source, being abstracted from rivers and springs either by gravity or by pumping; groundwater is obtained from approximately fifty hand-pump operated boreholes. Groundwater is also obtained from hand-dug shallow wells in the river beds during the dry season. Most water supplies are operated and maintained by the Ministry of Water Development, whereas some water supplies are under the control of church organizations.

Water Demand

The present (1984) and future (2000) demands for water for human and livestock consumption were calculated.

The total water demand will increase from 5.1×10^6 m^3/year in 1984 to approximately 7.5 10^6 m^3/year in the year 2000. The demand for livestock will remain constant at 3.3×10^6 m^3/year, which is 63% and 44% of the total water demand in 1984 and 2000, respectively.

In order to meet present water requirements, the total annual water production in West Pokot should be more than tripled. In Sigor and Kara Pokot Division the total annual water production meets only 10% of the present requirements.

Availability of water resources

The total amount of available groundwater in the part of West Pokot District studied is roughly estimated to be 4×10^6 m^3/year. This amount is sufficient to meet domestic water requirements for the

greater part of the area. Local shortages might occur in silty floodplain areas.

As for the surface water, the total combined annual surface water outflow from the Suam river at Kongolai and from the Muruny river at Marich Pass is 300 - 500 x 10^6 m^3.

Theoretically surface water is available annually, but its actual availability depends on the topographical conditions, and it is unevenly distributed in time and space. In the higher and more populated parts of the District, surface water supplies are in most cases sufficient.

The use of surface water for various purposes, including domestic supplies, is largely dependent on the minimum flows from permanent streams, the duration of the dry spell between two consecutive periods of river flow for non-permanent streams, and on suitable sites for intake structures and small or large reservoirs. Because most of the engineering aspects are beyond the scope of the project, no detailed assessment can be made of the availability of surface water for the various applications.

A water availability map was prepared to indicate the regional distribution of the water resources, using three categories of water availability: areas of high, medium or low potential.

Water development opportunities

Water development opportunities in West Pokot are considered to be fairly good and in fact much better than anticipated before the study was started.

Opportunities for groundwater development are in general restricted to hand-pump wells. Assuming an annual production of 2000 m^3 per hand-pump, the estimated amount of available groundwater is sufficient for 2000 hand-pumps. However, the available groundwater is not evenly distributed.

In the first phase of exploitation the construction of several tens of shallow wells in the alluvial deposits near the major rivers should be considered. The cost of one dug well amounts to approximately KShs.20 000. In addition, a few medium deep boreholes (circa 50 m) should be drilled in the scree fans along the hill scarps. Each borehole will cost approximately KShs.50 000. The purpose of these wells is not only water production but also further reconnaissance.

For the exploitation of Basement aquifers a detailed geophysical and hydrogeological investigation must be made for each proposed drilling site.

The results of the present study, however, indicate that at least one borehole with a yield of 1 m^3/h can be successfully drilled in an area of 5 km^2. An average depth of 60 m will probably be sufficient to strike a waterbearing zone. The drilling of deep boreholes is unnecessary in most cases, because the major weathered and fractured zones occur within 100 m depth.

On average the cost of a borehole equipped with a hand-pump will be KShs.70 000. Each hand-pump could supply approximately 300 people.

The use of hand-pumps seems to be the best solution for the abstraction of groundwater if the relatively shallow depth to groundwater, the low yield of boreholes and the availability of low-cost equipment are taken into account. Although some experimental solar pump installations can be found in West Pokot, present costs are still prohibitive for large-scale use. The installation and maintenance of any pump must be discussed with the local authorities and the members of the community involved.

Ample opportunities are present for the development of surface water for domestic use and cattle watering, even for small and large scale irrigated agriculture and hydropower. However, being beyond the scope of this study, the latter two aspects were not considered by the project.

The priority should be to develop alternative and less costly methods of exploiting surface water, such as small reservoirs for cattle watering in the valley bottoms and sand dams with shallow wells in the riverbeds of intermittent streams. To bridge the four months' dry spell between November and April, only a total storage capacity of 0.02×10^6 m^3 would be required for cattle watering, assuming evaporation losses of 800 mm.

Cattle watering could be guaranteed by 90 - 100 small reservoirs of approximately 8000 - 25 000 m^3 each, costing roughly between 100 000 and 200 000 Kenya Shillings. Properly dimensioned spillways are required to prevent overtopping of the embankment.

To guarantee domestic water supply and the supply for small-scale irrigation from surface water, detailed investigations of the various possibilities are required. In most of the area the required amount of surface water is available, but a cost-benefit analysis is always needed to identify the most feasible way of diverting water to a specific location.

TABLE OF CONTENTS PAGE

SUMMARY

List of figures iii
List of tables iv
List of plates v
List of annexes vi

1. INTRODUCTION
1.1 Scope of project 1-1
1.2 Description of the project area -1

2. GEOLOGY
2.1 Previous geological studies 2-1
2.2 Geological history -1
2.3 Stratigraphy -1
2.4 Mineral deposits -3
2.5 Structure -3

3. GEOPHYSICS
3.1 Introduction 3-1
3.2 Field work -1
3.3 Data evaluation -6
3.4 Results and conclusions -8

4. HYDROLOGY
4.1 Introduction 4-1
4.2 Previous hydrological studies 4-2
4.3 Hydro-meteorological network 4-4
4.4 Rainfall 4-6
4.5 Evaporation 4-8
4.6 Surface water runoff 4-13
4.7 Water balance 4-26
4.8 Surface water quality 4-27

		PAGE
5.	HYDROGEOLOGY	
5.1	Previous hydrogeological studies	5-1
5.2	Available data	-1
5.3	Groundwater occurrence	-6
5.4	Detailed investigations	-8
5.5	Regional groundwater conditions	-17
	WATER RESOURCES ASSESSMENT	
6.1	General	6-1
6.2	Water supplies	-1
6.3	Water demand	-5
6.4	Water resources availability	-9
6.5	Water development opportunities	-13
7.	REFERENCES	7-1

PAGE

LIST OF FIGURES

1.1	Location map of areas investigated by W R A P	1-2
1.2	West Pokot project area	-4
3.1	Apparent conductivity map, Psurum area	3-0
3.2	Sides of geophysical detail investigations in western project area	-2
3.3	Contour map of depth to basement in Wei Wei basin	-5
3.4	Geophysical cross-section at Psurum	-9
4.1	Longterm mean monthly rainfall (1980-1981)	4-7
4.2	Monthly rainfall for wet, average and dry years respectively	4-9
4.3	Discharge hydrographs for Suam and Muruny rivers	4-16
4.4	Mean monthly and annual runoff (m^3/s)	4-22
5.1	Diagrammatic basement complex hydrogeology	5-19

PAGE

LIST OF TABLES

3.1	Geophysical fieldwork	3-4
3.2	Well logging	-6
4.1	Longterm mean monthly rainfall (1980-1981)	4-5
4.2	Total annual rainfall	-10
4.3	Longterm mean monthly and mean annual evaporation	-12
4.4	River gauging stations	-14
4.5	Summary of monthly and annual discharge data - (1956-1976)	-20
4.6	Monthly flow data (1982-1983)	-23
4.7	Comparison of monthly flow data	-24
4.8	Annual runoff data	-25
4.9	Chemical data from MoWD - files	-28
4.10	Chemical data from ASAL - water survey	-29
5.1	Borehole data from MoWD - files	5-2
5.2	Borehole data from WRAP	-3
5.3	Well test data	-5
5.4	Chemical data	-7
6.1	Improved water supplies in West Pokot District	6-2
6.2	Land use and agricultural potential	-4
6.3	Population data 1979, 1984 and estimate for 2000	-6
6.4	Livestock population data	-7
6.5	Water demand 1984-2000	-8
6.6	Present demand and domestic use from improved supplies in 1984	-10
6.7	Equipped WRAP boreholes	-14

LIST OF PLATES

2.1 West Pokot geological map

4.1 Hydrological map

4.2 Isohyetal map for longterm annual rainfall

5.1 Hydrogeological map

6.1 Water availability map

LIST OF ANNEXES

1.1 W R A P project staff involved in West Pokot investigation
1.2 Population figures for West Pokot (1979- census)

2.1 Lithology of the major Basement rocks

4.1 Rainfall data
-1 Raingauge station (5" standard raingauge)
-2 1982 - 1983 monthly rainfall data
4.2 Evaporation data
-1 Evaporation station (Class A-Pass)
-2 1982 - 1983 monthly evaporation

4.3 Runoff data
-1 Rating curve, Suam river RGS 2B7
-2 Rating curve, Muruny river RGS 2B31
-3 Daily flow data 1982 - 1983
,a Suam River
,b Muruny River
-4 Monthly and annual flow data
a Suam River
b Muruny River
c Wei Wei River

5.1 Geological well logs
5.2 Analysis of well test data
5.3 Groundwater level fluctuations
5.4 Borehole data West Pokot District

1. INTRODUCTION

1.1 Scope of the Project

The Water Resources Assessment Project (WRAP) is executed within the framework of technical development co-operation between the Governments of Kenya and the Netherlands. The project is executed by the Ministry of Water Development with technical assistance from TNO-DGV Institute of Applied Geoscience, (The Netherlands). The main objective of the project is the training of the Kenya professionals and technicians in techniques of water investigations through the assessment of the quantity and quality of the available water resources in a number of selected areas. (Figure 1.1).

This report is dealing with the regional assessment of the available water resources in West Pokot District. In January 1984 a Progress Report (M.o.W.D, 1984b) was issued. Based on critical comments, many new data and further analysis of data this Main Report is a completely revised edition.

The activities of the Water Resources Assessment Project covered by this report are confiened to the southern part of West Pokot District (Figure 1.2). Previous studies in the area by Viak/Norplan (1976), Norconsult (1979, 1983) and Sogreah (1981), were mainly concentrating on surface water potential for irrigation and hydro-power. Besides a general description of geology and hydrology of the project area, the present study includes detailed hydrogeological investigations in a number of locations, namely Morobus, Psurum, Chepkopegh and Chesera in Chepareria Division, and Serewa and Matembur in Kapenguria Division and a regional study of the Wei Wei basis.

The above mentioned localities which are considered to have the highest water demand, were suggested by the District Water Officer who selected them from the lists of priorities of the Divisional Development Committees. An attempt has been made to extrapolate the results of the detailed investigations over the larger areas with the purpose of indicating the availability of water resources in the project area. This study forms a basic input for integrated development activities foreseen in the District Development Plan for the period 1979-83 (Ministry of Finance and Planning, 1980).

The names of the Kenyan and Dutch personnel who are involved in the field and office work are listed in Annex 1.1.

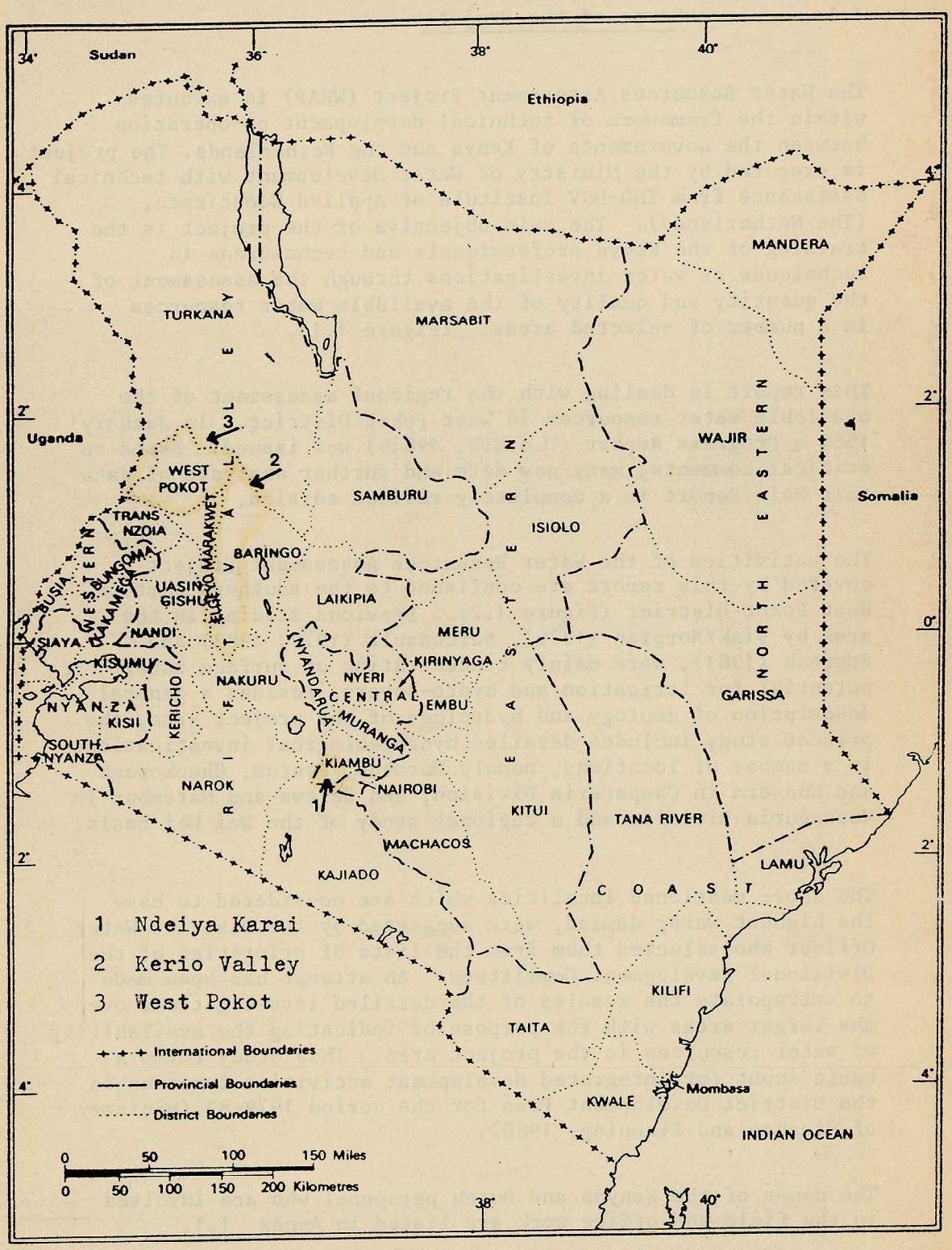


Figure 1.1 Location maps of the areas investigated by WRAP (map from Ojany and Ogendo, 1981).

1.2 Description of the project area

The project area is approximately bounded by parallels 1° 10'N and 1° 55'N and longtitudes 34° 50'E and 35° 45'E. It includes Sigor, Chepareria and Kapenguria Divisions and the southern part of Kacheliba Division (Figure 1.2).

In the south, the project area borders Trans Nzoia and Elgeyo Marakwet Districts. The northern limit coincides with the Kanyangareng and the Suam River courses and further to the north-east with the Turkana District border. The international boundary with Uganda and the Kerio River course (Baringo District border) mark the western and the eastern extent of the project area respectively. The total area is approximately 6000 km² which is about two-thirds of the district's total surface area.

The topography of the area shows great variations in elevation. The high elevated areas are dominated by the Cherangani and the Sekerr Mountains. The Cherangani Hills,.in the south-eastern part of the area rise to 3370 m above m.s.l. at Chepkotet, the highest peak on the project area. The Sekerr Mountains, rising to 3325 m above m.s.l. at Mtelo, form a large part of the northern area. South of the Sekerr Mountains, several isolated hills with a maximum height of 2300 m above m.s.l. rise between the Iyon and Muruny rivers.

The western part of the project area is formed by the West Pokot lowlands, i.e. Suam Plains, with an elevation between 1500 and 1200 m above m.s.l. The easternmost part belongs to the Wei Wei and Kerio lowlands, with an elevation between 1200 and 900 m above m.s.l. The latter two are separated by the Masol range.

The drainage system is very well developed in the area. The area is part of the Turkwel/Wei Wei drainage system, the extreme southern and eastern parts of the area are drained by the Nzoia and the Kerio rivers respectively. The upper reach of the Turkwel River is known as the Suam River and has its origin in the caldera of Mt. Elgon. The two major tributaries in the upper reach are the Kanyangareng and the Kunyao Rivers, both originating in the Karamoja Hills in Uganda. The Malmalte River, which joins the Turkwel River down stream of the Turkwel Gorge, i.e., outside the project area, has two major branches, the Wei Wei and Muruny Rivers, which originate in the Cherangani Hills. The Turkwel River discharged into Lake Turkana.

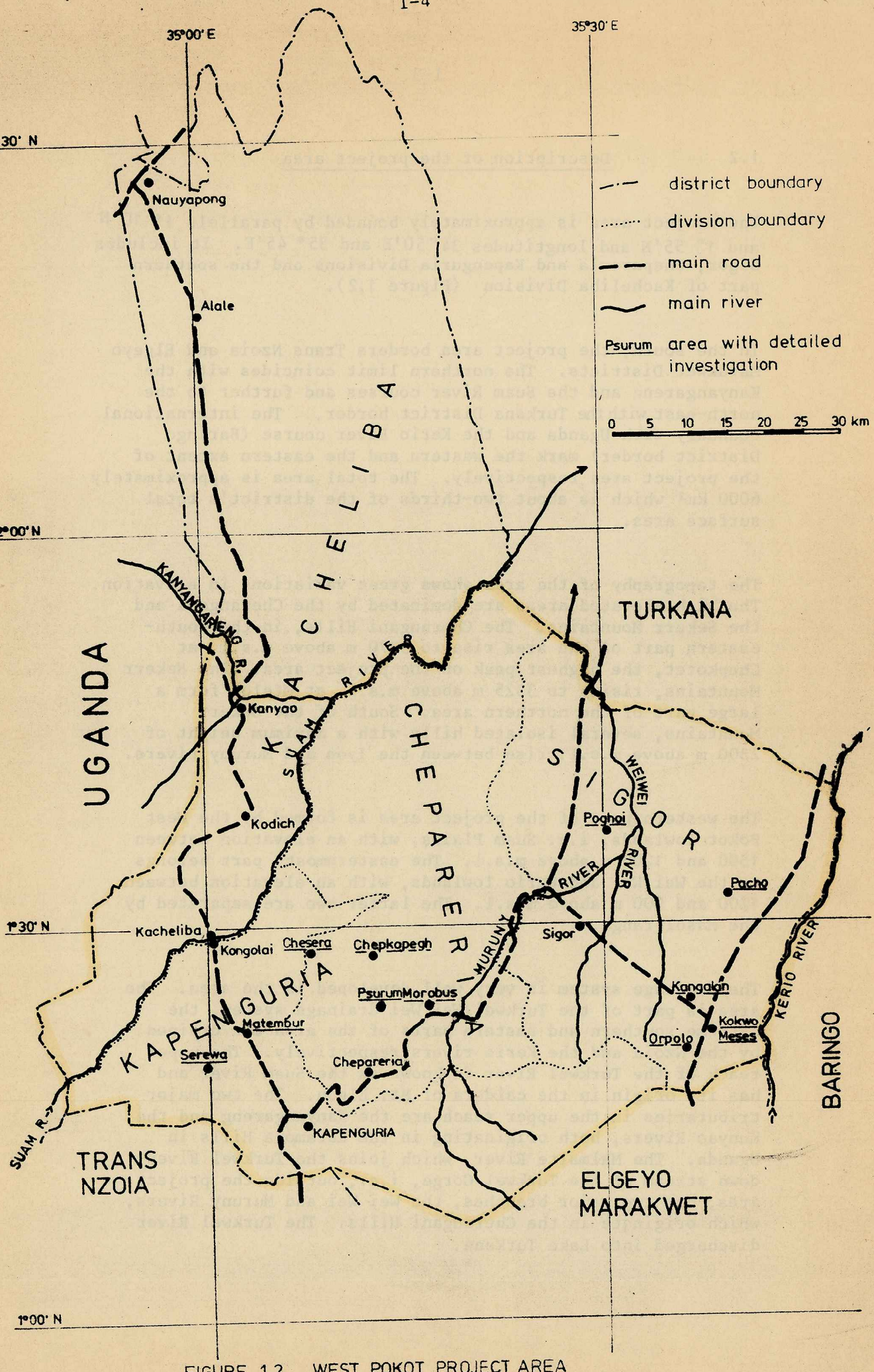


FIGURE 1.2 WEST POKOT PROJECT AREA

The great variation in topography gives rise to two distinct climatic zones: the modified tropical and semi-arid climate zone (Ojany and Ogendo, 1981). Generally, the rains occur in both between April and September with peaks in April/May and July/August.

Different types of soils are found in the area. On the mountains and major scarps the soils vary from stony loam to clay loam, whereas at the foot of the mountains and hills, deep sandy loam soils are found. In the uplands, soils vary from deep sandy clay loams to clays. The above soils have developed on either various (granitoid) gneisses or on quartzites and most of them are well drained. In the floodplains along the major rivers, complex soils with various textures and drainage conditions are found. These soils have developed on alluvial deposits. A detailed description of soil types is given in the legend of the reconnaissance soil map of the Kapenguria area (Kenya Soil Survey, 1976).

According to the 1979-population census, the population of West Pokot amounts to 159,000. The population distribution, projections and densities per division are tabulated in Annex 1.1. The Pokots, a Kalenjin subgroup, comprises about 90% of the total population. The remaining 10%, mostly including tribes from the surrounding districts, are concentrated in Kapenguria division.

The Pokots living in the lower semi-arid areas are pastoralists, leading a semi-nomadic life. Farming is practised in the high potential areas in Chepareria and Sigor Divisions (Dietz-van Haastrecht, 1982). The most important crops in the lower zones are maize, sorghum, millet, cassava and locally also cotton and bananas. In higher zones pyrethrum, coffee, sunflower and vegetables are also grown. The latter is practised in Kapenguria Divisions. The commercial sector in West Pokot is limited and includes small scale traders, with the major centres in Kapenguria and Makutano. The prospecting of alluvial gold provides variable incomes for a number of people near Marich Pass, the Turkwel Gorge area and the northern locations of Kacheliba Division. The road network is still poor. The Kitale-Kapenguria-Marich Pass-Lodwar road is the only tarmac road within the area. Some of the earth roads are impassable during rainy seasons. Telephone facilities are available only in Kapenguria, i.e., the District Headquarters. With the exception of the Kapenguria Division, schools are sparsely distributed. West Pokot District has a reasonable network of health facilities.

Water supplies are limited in the project area. Half of them are located in the southern part of the area, which is drained by the Nzoia river. They are based on surface water pumped from permanent streams. The Muruny and Wei Wei are the only perennial rivers within the Turkwel drainage area. Most of the rivers are of the sand-river type in their lower reaches, permanent streams and springs are only seen in the high areas. The sand-rivers are only carrying water for short periods during wet months. In the dry period (i.e. between October and March), apart from the perennial rivers, water is obtained from a number of hand-pump operated boreholes (mainly Kacheliba Division) and hand-dug shallow wells especially in the river-beds.

2. GEOLOGY

2.1 Previous geological studies

The area in study was geologically mapped by the Geological Survey of Kenya. Five reports have been published, describing the geology of the area North-West of Kitale (Searle, 1952), the Kitale-Cherangani Hills area (Miller, 1956), the Kalossia-Tiati area (Mason and Gibson 1957), the Sekerr area (McCall, 1964) and the Karasuk area (Walsh, 1966). These reports provide the basic information on geomorphology, lithostratigraphy and structure of the West Pokot region and give also a brief summary on the availability of surface and ground water. The insight in the structural features of the area has been deepened by the interpretation of Landsat (satellite) data, carried out by Geosurvey International Ltd. in 1982, and presented on a preliminary structural map on scale 1:250,000. However an official copy was not yet available during the writing of this report.

2.2. Geological history

The crystalline rocks of the Basement System ("Mozambique Belt"), apart from local alluvial deposits, occupy the whole project area. The Basement System comprises in principle various types of sediments which were laid down in a geosyncline during the Precambrian (McCall, 1966). These sediments, including shales, sandstones and limestones were transformed by regional metamorphism into gneisses, schists, quartzites and marbles. A small part of the metamorphic Basement system originally developed from volcanic rocks. The rocks changed into amphibolites and amphibolitic schists. The Basement System includes also some ultra-basic and acid intrusions which occur as peridotites, gabbros, granites and pegmatites. They are all sill-like bodies and are believed to be of Precambrian to early Paleozoic age (McCall, 1964). The orogenic movements during Precambrian resulted in the intensive folding of the Basement rocks. Some faults in West Pokot are considered to be a result of Precambrian tectonic movements along the original lines of weakness (Miller, 1956).

The period between Precambrian and Tertiary was rather stable and is connected with epeirogenic movements and denudation. The Tertiary is characterized by the peneplanation and the tectonic movements.

Although the greater part of the project area is situated outside the Rift Valley, several faults are related to the same movements which gave origin to the Rift System. However, the faulting in West Pokot was not accompanied by volcanism.

During the Quaternary, alluvial deposits developed along the major rivers.

2.3 Stratigraphy

The description of the rocks in this section is mainly based on the geological reports Nrs. 19(Searle, 1952), 35 (Miller, 1956), 41 (Mason and Gibson, 1957) and 65 (McCall, 1964). The Precambrian

metamorphic rocks occupy almost the whole project area. The Turkana Grits in the Western part of the area are the only Tertiary sediments. The Tertiary volcanic rocks are absent, except for small nephelinite plugs and a few basalt dykes. The Quaternary sediments developed locally along the major rivers. The distribution of the rock formations in the project area is shown on the geological map (Plate 2.1).

2.3.1 Basement System

The rocks of Basement System in the project area can be divided into 3 groups, according to their origin:
- Metasediments
- Metavolcanics
- Intrusions

Metasediments include gneisses, quartzites, schists and marbles which originally developed from semi-pelitic, psammitic and calcareous sediments.

Metavolcanics include amphibolites and amphibolite schists which have been derived from basic and ultrabasic volcanic rocks.

The intrusive rocks include acid, basic and ultrabsic rocks, which have been partly affected by metamorphism. They are in general represented by granites, pegmatites, gabbros and pyroxenites.

A detailed description of the Basement rocks is given in Annex 2.1.

The Basement rocks in the westernmost and easternmost part of the area have not been mapped in detail. On the geological map (Plate 2.1), these rocks are indicated as undifferentiated Basement System.

2.3.2 Tertiary rocks

The sediments of the Turkana grits series are the only significant Tertiary rocks in the project area. They are believed to be of Middle Miocene age. The sediments vary in grade from fine-grained sandstone to coarse grit. They contain fragments of Basement gneisses and abundant quartz. The Turkana grits are found in a large belt north-west of Lomut.

The Tertiary volcanic rocks are represented only by two small nephelinic plugs in the surroundings of Nakujit and by two small nephelinic plugs in the surroundings of Nakujit and by few basanite dykes near the Kunyao - Kacheliba road. The fault breccias, which occur at some places along the major faults are believed to be Tertiary in age (Gibson and Mason, 1956; McCall, 1969). They are derived from the Basement rocks and contain secondary chalcedonic quartz.

2.3.3 Quaternary deposits

The Quaternary deposits include fluviatile sediments and lateritic soils. Small patches of alluvial sand and gravel developed near all major rivers. On the geological map (Plate 2.1), however only areas with a large continuous belt of alluvial sediment are indicated. In the southern part of the project area, alluvial deposits are found along the Chesera and the Wei-Wei Rivers. At Ortum a large alluvial cone, built up by the Ortum River and adjacent rivers has been mapped by Miller (1956).

The fluviatile sediments along the Kerio River, in the eastern most part of the area, belongs to the so-called Kerio River Beds. These sediments consists of red and brown silts and earths with ill-sorted lenses of torrent wash.

In the northern part of the area, alluvial deposits, containing reddish gravel with abundant calcareous concretions are found only along the river Muruny (McCall, 1969). Most of the Quaternary sediments in the project area are described as red lateritic sandy and stony soils. They cover a large area west of Nakujit and east of Turkwel and Sekerr faults.

2.4 Mineral deposits

The mineral deposits in West Pokot include gold, chromite, copper and nickel. With the exception of alluvial gold, which is found in the rivers Muruny, Suam and Iyon, the deposits are of a low economic value. The origin and occurrence of mineral deposits is discussed in detail in the geological reports.

2.5 Structure

The structural features in the project area are related either to the Precambrian orogenic movements or to the formation of the East African Rift System in the Tertiary.

2.5.1 Precambrian folds

The orogenetic movements during precambrian produced a series of folds which can be traced in the Basement rocks all over the area.

In the southern part of the area the strike of the fold axes is usually between north-northwest and north and follows the strike of the original sediments. Most of the folds are overturned to the west. The folding pattern is rather complex with both anticlinal and synclinal structures included.

In the northern part of the project area, the north-south fold trend predominates. Several folds with west-east trend also occur. The folds in this part are both open and closed, and they are arranged in large-scale anticlinoria and synclinoria.

In the westernmost strip of the project area, Mason and Gibson (1957) reported a north-south strike of the Basement rock, with a steep dip to the east.

2.5.2 Precambrian faults

According to Miller (1956), the Muruny Fault and Mwino Fault in the southern part of the project area are related to the tectonic movements which have occurred in the Precambrian. The Muruny Fault runs in Southwest-northeast direction along the lower Muruny River. The northern part of this fault has a dowthrow to the east. South westward from Kibonet the fault downthrows to the north west and is considered by Miller as a reverse fault. The Mwino Fault running in South north direction along the western bank of Wei-Wei River has downthrown to the east.

The northern extensions of the Mwino Fault, called by McCall (1964) the Sekerr Fault and Turkwel Fault are believed to be Tertiary in age. However, these faults are located along precambrian structural zones of weakness. The Ortum Fault and the Sebit Fault, which cross and displace the Muruny Fault are considered to be younger than the latter fault.

2.5.3 Tertiary faults

The largest faults in the area are related to the origin of the Rift Valley System, in particular of its western border.

The northern continuation of Elgeyo Fault System, which is the major tectonical structure in the Kerio Valley, marks the eastern side of the project area. The Elgeyo Fault diverges into two branches: the Kula Fault and Lomut Fault. The Kula Branch continues the north-northeast trend while the Lomut branch trends northwest along the northern end of the Cherangani Hills. The Lomut Fault joins the Mwino and Sekerr Faults, which run parallel to the Elgeyo and Kula Faults. In the northwestern part of the area, the Orwa and Turkwell Fault trend to the northwest.

Although all above mentioned faults are believed to originate from the Tertiary, it is generally assumed that the movements took place along much older (Precambrian) zones of weakness.

The tectonic movements in the western and northwestern part of the area produced pronounced scarps. The total downthrow of the faults is however, not known.

The continuation of the faults is in many cases only inferred, because of the sediment cover. The presence of faulting is at some places manifested by the occurrence of tectonic breccias.

2.5.4 Landsat interpretation by Geosurvey

The preliminary structural map, prepared by Geosurvey International Ltd. (1982, unpublished) shows the major faults with more or less

the same trends as described above, although the position of faults differs at some places. The diversion of the Lomut Fault from the Elgeyo Fault is placed about 7 km further to the north than indicated on the geological map. The Landsat interpretation shows also a very complex pattern of lineaments, running in both south-north and west-east directions. These lineaments can be interpreted as minor faults or fractures.

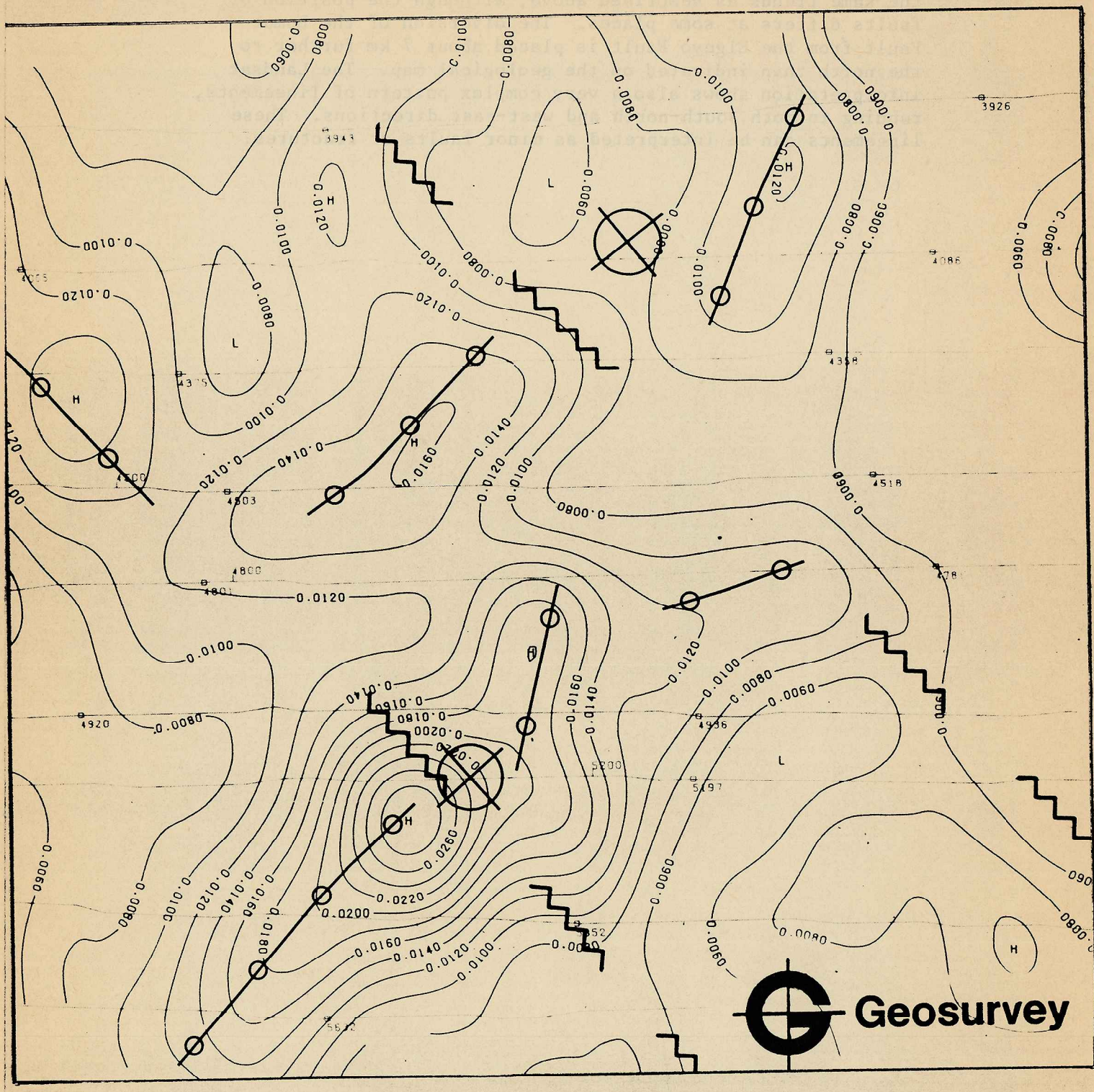


Figure 3.1 - Apparent conductivity map of the Psurum area.
Contourlines in Siemens/m (or mhos/m).
Zigzag lines denote fractured zones.
Lines with open circles indicate zones of relative high conductivity.
Large circles with crosses are proposed drill sites.
(Reproduced by courtesy of Geosurvey International Ltd)

3. GEOPHYSICS

3.1 Introduction

In this chapter a summary is given of the geophysical investigations that were carried out in West Pokot District. A more detailed account of the theoretical aspects, the methods applied, the fieldwork and the interpretation of the results is contained in a separate report (Geophysical Investigations in West Pokot District, 1984).

Some geophysical work was done in 1977 by the Geology Section of the Ministry of Water Development in order to locate a site for a borehole at Marich Pass. Five soundings were made near Marich Pass all indicating shallow basement. The drill site was chosen 2 km north of here on the basis of sounding R 9190 (WRG 77-063) which showed low resistivity values (less than 20 Ohmm) at a depth exceeding 30m. Borehole C 4557 was drilled at this site, and gave a yield of 6 m^3/hr with a drawdown of only 3m. This is, as far as the records show, the only geophysical work done in the area prior to the start of the project.

During the course of the project, Geosurvey International Ltd., carried out an airborne electromagnetic survey at three sites in the project area (Morobus, Psurum and Chepkopegh) using the Tridem EM system. A map showing the interpreted apparent conductivity results of Psurum area is shown in Figure 3.1. Zones of higher conductivity indicate in general areas with greater weathering thickness and can sometimes be correlated with faulted zones detected from aerial photographs. The greater thickness of the sediments in the Wei Wei - Moruny Basin inhibits interpretation of electromagnetic anomalies in the underlying basement. Some geological boundaries can be picked up though. Where the basement is shallow as in most of West Pokot District, the anomalies are noticeable as the example shows. The experiment showed that much time can be saved by first flying with the Tridan system and only pick small areas for detailed ground geophysics.

3.2 Fieldwork

As described in Chapter 2, two geologically distinct zones can be recognized: the western zone where the basement is shallow and the eastern part in the Wei Wei-Moruny Basin which is part of the Great Rift Valley system, and where sediments reach several hundreds of metres thickness. In the shallow basement zone the hydrogeologically most important areas are found within the fractured zones. In the Wei Wei Basin the sediments are of more importance. It was therefore decided to adopt different approaches for each zone in order to provide the most useful geophsycal information.

Most of the villages with a high demand for water are located in shawllow-basement area. It was decided to employ here resistivity profiling, shallow seismic refraction, resistivity soundings and (in some cases) electromagnetic profiling in order to locate as precisely as possible the fractured zones in the basement. A map showing the sites of investigation in the basement area is given in Figure 3.2.

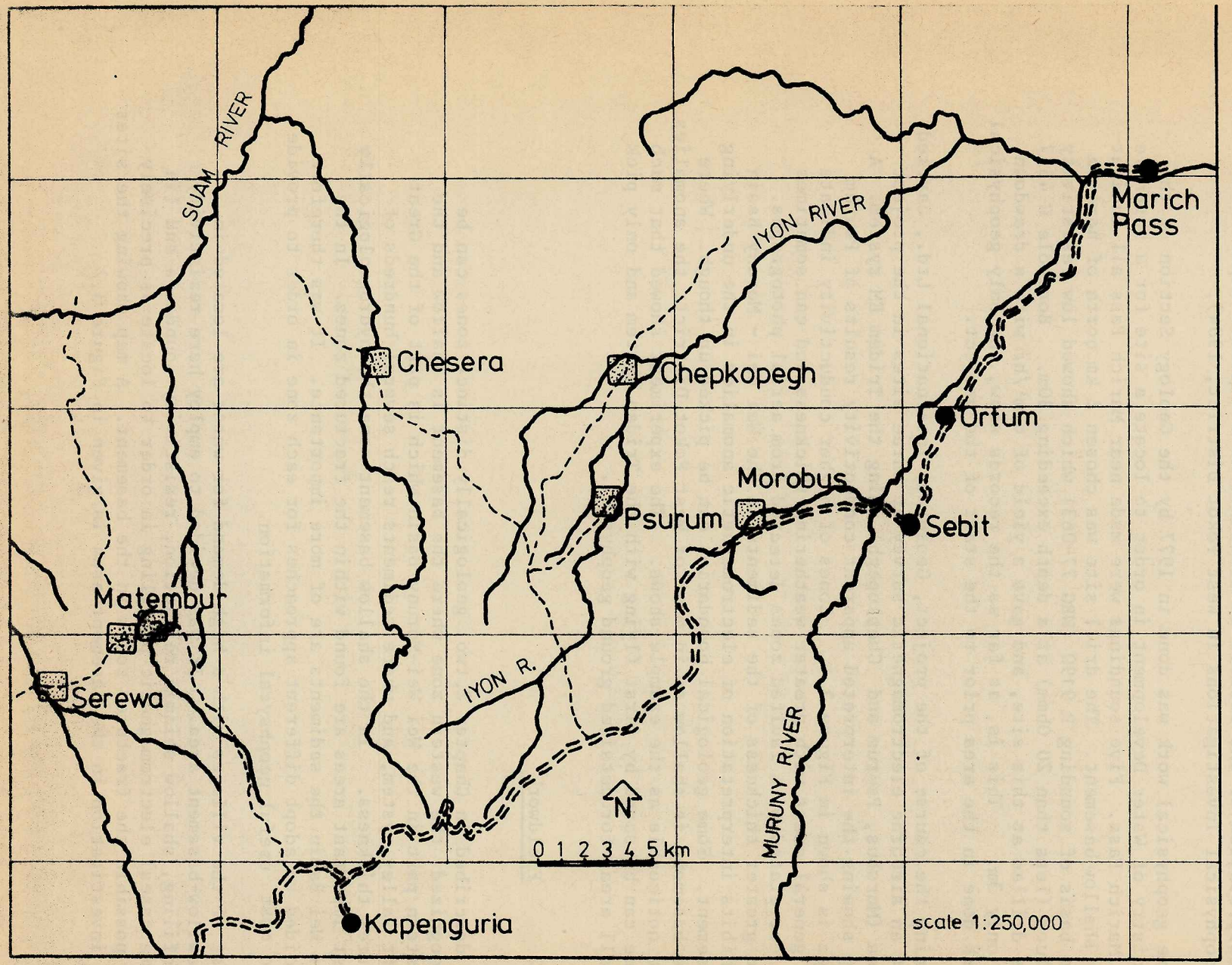


Figure 3.2 Sites of geophysical detail investigations in western project area

In the Wei Wei-Muruny Basin where the base is quite deep, neither of the profiling techniques was expected to be suitable because any aquifer would be found within the sediments rather than in fractured basement rocks. To obtain a general picture of the hydrogeological composition of the basin vertical electrical soundings were made at convenient sites within the basin (Figure 3.3). A summary of the field work accomplished is given in Table 3.1.

3.2.1 *Resistivity soundings*

A total of 70 vertical electrical soundings were made in the area. The Schlumberger configuration was used. The largest AB/2 was 750 m. The resistivity equipment used was GEA 51 from the Institute of Applied Geoscience, TNO and the ABEM SAS 300. For the site investigations soundings were usually made near lineaments interpreted from aerial photographs.

3.2.2 *Resistivity profilings*

After the approximate depth to the basement had been established from the soundings, resistivity profiling was carried out to try to determine the position of geological structures like faults or fractures that might be present within the basement. A total length of 22.4 km of profiles were covered. At most sites AB/2 was 50 m while at a few others it was 25 m. Readings were taken at intervals of 25 m. The equipment used for profiling was the ABEM SAS 300 on account of its portability.

3.2.3 *Electromagnetic profiling*

Electromagnetic profiling was carried out a Morobus West, Psurum and Chepkopegh to try to pick up any anomalies along profiles so as to establish the exact position of the faulted zones. The total length of the profiles was 19.8 km. The equipment used was APEX Maxmin II from the Ministry of Environment and Natural Resources. A coil separation of 50 m was used. Frequencies used were 888 Hz and 3555 Hz. The former was for error detection in the coil separation. A penetration depth of about 70 m for horizontal and 40 m for vertical conductors was possible under favourable circumstances with this arrangement. Measurements were taken at 25 m intervals.

3.2.4 *Seismic refraction*

Seismic refraction gives information on the thickness of and the velocity in different layers of the subsurface. It also gives information on the configuration of the refractor. For each spread of 12 geophones spaced at 10 m, five shots were fired to achieve an average penetration of about 50 m. The location of the seismic profiles was determined from both the resistivity and electromagnetic

Table 3.1 - Geophysical fieldwork

	Resistivity		Resistivity Profiling				E M Profiling		Seismic Refraction			
S I T E	No.of V E S	AB/2 max (m)	No.of profiles	AB/2 (m)	Interval (m)	Total length (Km)	No.of profiles	Total length (Km)	No.of profiles	No.of spread	Geoph spacing (m)	Total length (Km)
Morobus W	5	400	4	25/50	25	2.375	2	1.95	3	11	5/10	0.80
Morobus E	-	-	2	50	25	1.150	-	-	1	8	10	0.93
Psurum	7	200	5	50	25	2.950	4	10.2	2	12	10	1.20
Chepkopegh	4	200	2	50	25	2.000	5	7.65	3	12	5/10	0.80
Chesera	4	200	1	50	25	1.000	-	-	1	8	10	0.87
Matembur	8	200	3	50	25	2.425	-	-	3	14	10	1.64
Serewa	9	200	4	50	25	1.925	-	-	2	11	10	1.25
Kokwo Messes	2	500	2	50	25	0.900	-	-	1	2	10	0.22
Kangalan	3	320	5	50	10/50	1.850	-	-	3	10	10	1.07
Ploot	1	320	3	50	25	3.150	-	-	2	5	10	0.58
Poghoi	3	400	-	-	-	-	-	-	1	2	10	0.22
Kodukoy	1	400	3	50	25	2.675	-	-	4	6	10	0.68
Wei Wei	23	750	-	-	-	-	-	-	-	-	-	-
Totals	70	-	34	-	-	22.4	11	19.8	26	101	-	10.26

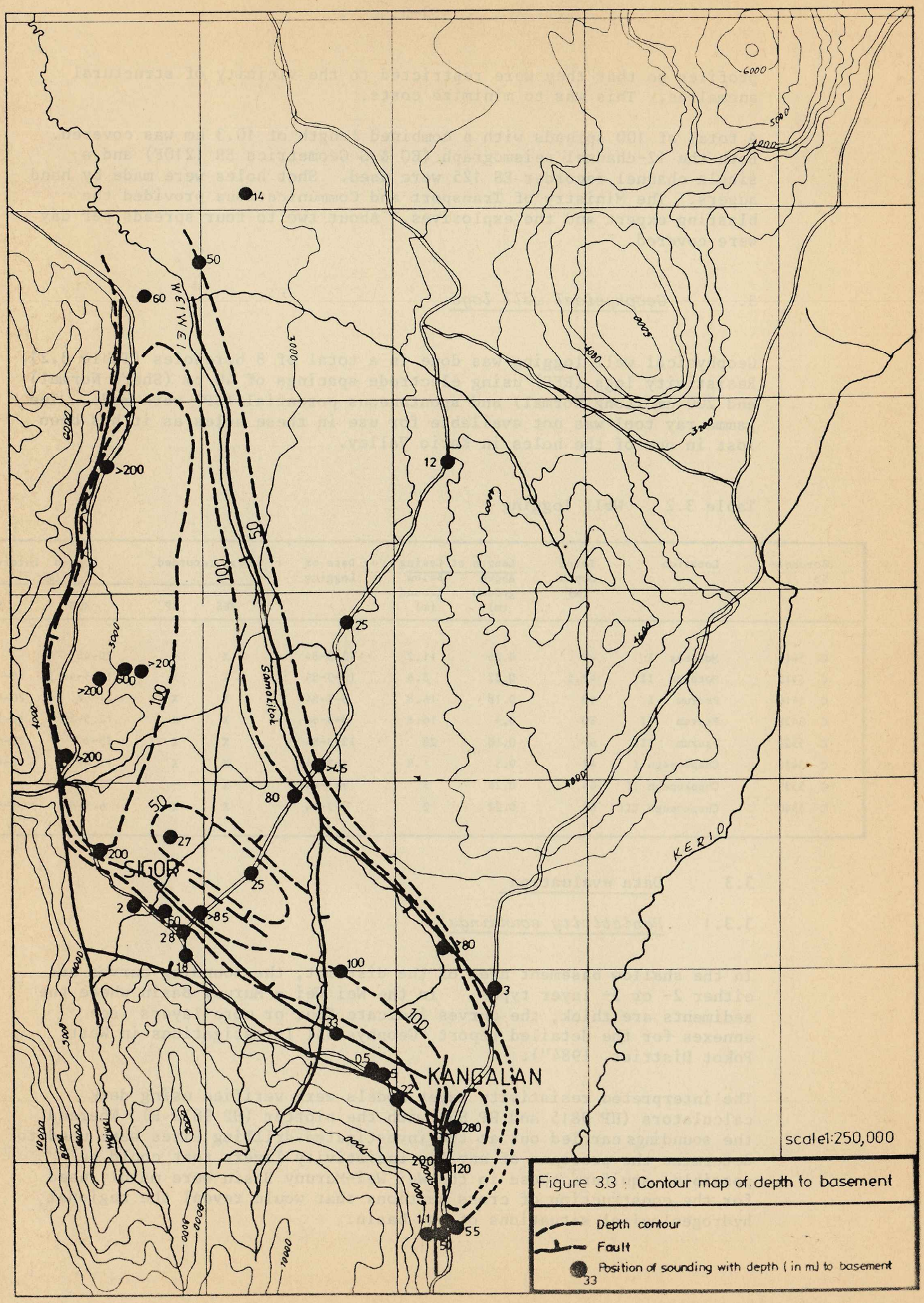


Figure 3.3 : Contour map of depth to basement

profiles so that they were restricted to the vicinity of structural anomalies. This was to minimize costs.

A total of 100 spreads with a combined length of 10.3 km was covered. Both the 12-channel seismograph (EG & G Geometrics ES 1210F) and a single channel recorder ES 125 were used. Shot holes were made by hand augers. The Ministry of Transport and Communications provided the blasting expert and the explosives. About two to four spreads per day were covered.

3. *Geophysical well logs*

Geophysical well logging was done in a total of 8 boreholes (Table 3.2). Resistivity logs (RES) using electrode spacings of 40 cm (Short Normal) and 200 cm (Long Normal) and spontaneous potential (SP) were made. The gamma ray tool was not available for use in these holes as it has been lost in one of the holes in Kerio Valley.

Table 3.2 Well logging

Borehole No.	Location	Total Depth (m)	Length of Casing: Above ground (m)	Length of Casing: Below ground (m)	Date of Logging	Log recorded: RES	Log recorded: SP	Logged interval (m): RES	Logged interval (m): SP
C 5414	Morobus I	48	0.35	11.2	13-3-84	X	-	20-48	-
C 5415	Morobus II	47.5	0.22	5.6	13-3-84	X	X	17.5-47.5	15-47.5
C 5416	Psurum I	68	0.18	16.8	8-3-84	X	X	21-68	20-68
C 5428	Psurum II	50	0.4	16.8	8-3-84	X	X	12.5-50	18-50
C 5538	Psurum III	67	0.18	28	12-3-84	X	X	25-67	28-67
C 5429	Chepkopegh I	47	0.5	1.8	9-3-84	X	X	13.47	13-43
C 5539	Chepkopegh II	64	0.26	5	9-3-84	X	-	32.5-64	-
C 5540	Chepkopegh III	64	0.22	2	9-3-84	X	X	6.5-64	5-64

3.3 Data evaluation

3.3.1 *Resistivity soundings*

In the shallow basement area of the district, the sounding curves are either 2- or 3- layer types. In the Wei Wei - Muruny Basin where the sediments are thick, the curves indicate four or more layers (see annexes for the detailed report "Geophysical Investigations in West Pokot District, 1984").

The interpreted resistivity layer models were verified using desk calculators (HP 9815 and HP 85) with the plotter (HP 9872 B) Whereas the soundings carried out at the investigated drilling sites were used to determine the presence of any low resistivity layers that could be possible aquifers, those in the Wei Wei-Muruny Basin were mainly used for the construction of cross sections that would reveal the regional hydrogeological situations of the basin.

3.3.2 *Resistivity profiles*

A change in apparent resistivity along a profile indicates a lateral discontinuity in the subsurface. This could be in the form of a fracture, a fault zone or an intrusion. These structures are of special interest for groundwater. Where these were encountered on any profile, they were mapped for correlation with results from other profiling methods to confirm their presence. The interpretation of resistivity profiles is thus mainly qualitative.

3.3.3 *Electromagnetic profiles*

The interpretation of electromagnetic data involves the contouring of the smoothed "in-phase" component. The values of the smoothed in-phase are proportional to the conductivity-thickness product of the weathered layer of the basement. The higher the in-phase component the greater the thickness of this layer. The "quadrature" component reveals anomalies along the profile. The location of these anomalies can be determined from the plot of the quadrature reading versus the station distance along the profile.

3.3.4 *Seismic refraction*

The plot of the first arrival times against distance on the so-called T-X graph is done for two opposite shots (normally the Forward and the Reverse). Using the "intercept-time" method of interpretation, the layer thickness can be determined. The arrival times from the Far-Forward and Far-Reverse shots are used in determining the refractor configuration and the lateral variation in velocities in the refractor. This is done using the "Plus-Minus method" of interpretation. The lateral variations in velocities can help to locate fractures in the refractor.

3.3.5 *Resistivity logs*

The resistivity logs are useful in determing layer boundaries (short-normal or SN) and the formation resistivities (long-normal or LN). The logs obtained from the boreholes in West Pokot are in the annex of the separate report "Geophysical Investigations in West Pokot District, 1984". The layer boundaries are not quite obvious from the logs, especially where the basement has been described from the samples as thin weathered zones less than 5 m thick. The long-normal however shows the formation resistivities of the weathered zones to be distinctly lower than for fresh basement.

3.4 Results and conclusions

For each site the geophysical data were evaluated together, and combined with the geological information of the area. Suitable drilling sites could thus be selected.

Figure 3.4 gives an example of a geophysical cross-section at Psurum. At the bottom part of the figure the EM profile reveals three anomalies on the quadrature record. The in-phase record indicates over the traject 150 to 500 m a relative thick weathered layer. On the resistivity profile in the middle part of the figure the same anomalies at 200 and 450-500 m can be observed. But they are much less pronounced and the anomaly at 300 m is lacking. Over the central part of the section (approximately 250 to 500 m) three seismic spreads were shot. The upper part of the figure shows the result. A very undulating interface between fresh and weathered bedrock is found. Two vertical electrical soundings (3 and 4) were made. They indicated a low resistvity surface layer of 10 Ohmm and below an intermediate layer of 30 - 45 Ohmm, probably consisting of clayey weathered bedrock. The drill site was selected at BH C 5538, at the most pronounced anomaly. Subsequent drilling confirmed the prognosis. A surface layer of mainly clay was found till a depth of 10 m. Below this layer sand clays and weathered gneisses were found until fresh bedrock was struck at 24 m. Several zones of fractured gneisses were met at greater depth. Water was struck at 35 m in fractured rock.

A detailed description of all site investigations is given in the separate report "Geophysical Investigations for Groundwater in West Pokot District" (WRAP/MoWD, 1984, in preparation).

In the Wei Wei Basin 23 resistivity soundings were made. Figure 3.3 shows the contour map of the depth of the basement. A narrow trough extends north-south just east of the Sekerr Mountains. The depth of the basement exceeds here 200 m. Further south in the Sigor Kangalan area several small grabens are found, but having a much lesser thickness of the sedimentary fill. The resistivity values indicate that most of the sediments in the Wei Wei Basin are of a clayey composition and this very little promising for groundwater development. Only near the escarpments scree fans can be found at a few places, which offer possibilies of water walls.

As already stated two very distinct zones are present in West Pokot. Each area requires a different approach when investigating for groundwater.

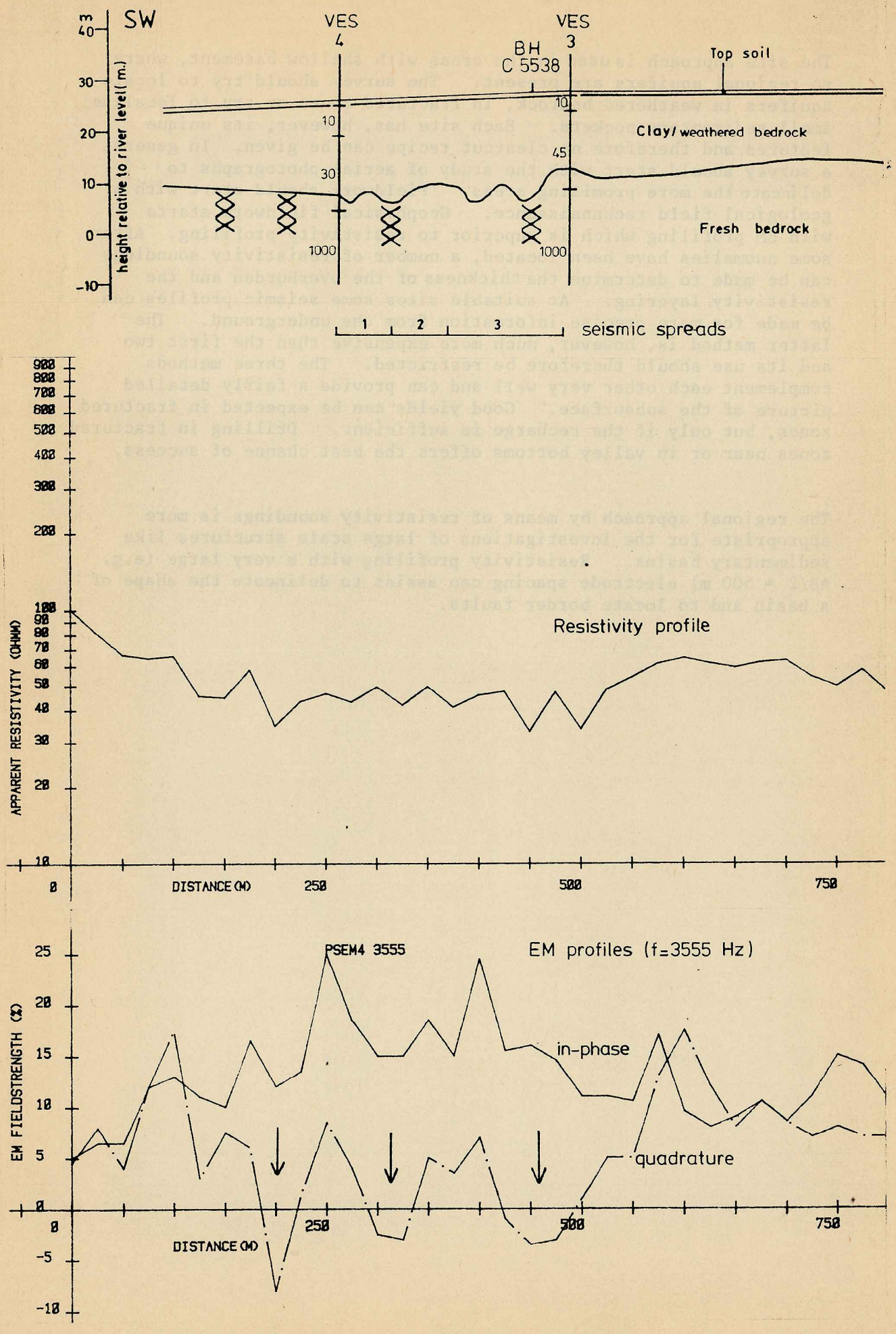


Figure 3.4 Geophysical cross-section at Psurum

The site approach is used in the areas with shallow basement, where no regional aquifers are present. The survey should try to locate aquifers in weathered bedrock, in fractured zones or try to localise small sedimentary pockets. Each site has, however, its unique features and therefore no clearcut recipe can be given. In general a survey should start with the study of aerial photographs to delineate the more promising areas. Fieldwork should start with a geological field reconnaissance. Geophysical fieldwork starts with EM profiling which is superior to resistivity profiling. After some anomalies have been located, a number of resistivity soundings can be made to determine the thickness of the overburden and the resistivity layering. At suitable sites some seismic profiles can be made for more precise information from the underground. The latter method is, however, much more expensive than the first two and its use should therefore be restricted. The three methods complement each other very well and can provide a fairly detailed picture of the subsurface. Good yields can be expected in fractured zones, but only if the recharge is sufficient. Drilling in fractured zones near or in valley bottoms offers the best chance of success.

The regional approach by means of resistivity soundings is more appropriate for the investigations of large scale structures like sedimentary basins. Resistivity profiling with a very large (e.g. AB/2 = 500 m) electrode spacing can assist to delineate the shape of a basin and to locate border faults.

4 HYDROLOGY

4.1 Introduction

The hydrological study is aimed at obtaining a basis for the estimation of both the surface water potential and the ground water recharge. The surface water potentials in the West Pokot area have been investigated in the past by different consultants (Viak/Norplan, 1976, Norconsult (1979) and Sogreah (1981). However, these studies were mainly concentrated on the use of surface water for large scale irrigated agriculture and hydropower. The Water Resources Assessment Project mainly investigated the groundwater availability in selected areas, because this is virtually an unknown resource.

For the hydrological study the project area covers the catchment areas of the Suam and Wei Wei Rivers. The hydrological boundaries are formed by the respective surface water divides, including part of the catchments of Kunyao and the Kanyangareng rivers in Uganda. The total area covers approximately 8,725 km^2, bounded by parallels 1° 10'N and 2° 20'N and longitude 34° 35'N and 35° 45'E (Plate 4.1). To the South, the investigation area borders on the Trans Nzoia and Elgeyo Marakwet district boundaries marked by Mount Elgon in the west, from which the river Suam originates, and the Cherangani Hills in the east, the main source for the Muruny and Wei Wei Rivers. The northern boundaries are marked by the water divide of the rivers Kanyangareng and Suam, the Karasuk Hills and further to the east the Turkana District border. The western boundary follows the water divide of the rivers Suam, Kunyao and Kanyangareng in Uganda, marked by the Kadam Forest and the Karamoja area. The eastern boundary follows the water divide between the Kerio River and the River Wei Wei. However, the hydrological investigations were mainly concentrated on the catchments of the Suam and Muruny Rivers, upstream of Kongolai and Marich Pass respectively.

The physiographic features of the area are described in Section 1. The climatoligical conditions in the project area are strongly effected by the great variation in the topography and are considered to be mainly a fuction of the altitude. Two distinct climatic zones can be distinguished; the modified tropical climate zone and the semi arid climate zone (Ojany and Ogendo, 1981). They are mainly governed by the inter tropical convergence zone and the modification is due to high and varied relief.

a) The modified tropical climate covers the Cherangani Hills and Mount Elgon regions and is characterised by low temperatures and evaporation rates and high rainfall figures depending on the position in relation to the rain bearing winds.

The annual maximum temperatures range from 5° - 25°C at high altitude areas to 10° - 35°C in the lower areas and the evaporation rates do not exceed 1800 mm/year. Annual rainfall figures vary between 1600 mm/year at high altitudes to 900 mm/year at lower altitudes.

The rainy season is between April and September with two distinct peaks in April/May and July/August, the rainfall during June is lower than in the other months. There is a considerable variation in seasonal and annual rainfall, i.e. high standard deviation from mean annual rainfall, which makes rainfall prediction very unreliable.

In general vegetation is abundant with good soil cover ranging from mountain forests with evergreen and semi evergreen bushland to savanna and upland acacia woodland.

b) The semi arid climate zone covers the rest of the region, except where there is a high relief, i.e. Sekerr Forest area. Compared with the modified tropical climate the semi arid climate is characterized by higher temperatures, annual maximum ranging from 25°-40°C, and evaporation, ranging from 1800 - 2200 mm/year, and lower rainfall, between 600 - 900 mm/year. In general the rainfall distribution over the year exhibits more or less the same pattern with lower rainfall in June.

4.2 Previous hydrological studies

Before the start of the project, a number of studies have been carried out within the project area with great emphasis on water resources and development.

The most important ones are:

- Turkwel basis hydrological survey by P. Tollenaar, 1975. UNDP/FAO project AGOAFT/KEN 28.
- Turkwel dam and reservoir reconnaissance survey by Norplan and Viak, 1976.
- Feasibility study for Turkwel Gorge multipurpose project by Norconsult, 1979.

- TAMS (1980), the National Master Water Plan, stage 1. This report deals with all aspects of water resources assessment, planning, developing and management.

- Water resources study for Kerio Valley basis by Sogreah Consulting Engineers (1981) which covers the Turkwel, the Kerio and the Lake Baringo basins.

- Turkwel Gorge multipurpose project - Hydrological survey by Norconsult, 1983.

The water resources study for the Kerio Valley Basin by Sogreah Consulting Engineers covered the Suam, Turkwel, Muruny, Wei Wei and Malmalte River Basins. The study is based on the inventory and preliminary evaluation of past records of rainfall, evaporation and runoff. The main general conclusions from the Sogreah study are as follows:

- Water resources are quite abundant, but very unequally distributed over the study area. Resources appear to be plentiful in the zones which lie above the 800 mm isohyet. Below this zone, losses due to evapotranspiration and direct evaporation predominate.

- Productive zones are situated directly above zones where there is a deficit.

- Water resources are unequally distributed in time.

- While water resources appear to be quite abundant upstream on the main rivers, the scarcity of suitable dam sites and the heavy sediment transport may constitute major constraints in the regulation of resources.

- Present information on available surface water resources is not sufficiently precise.

- In order to gain a better idea of the water resources which could be mobilised by storage, water gauging installations should be set up urgently.

The Norconsult study October 1981 - December 1982 was carried out specifically to collect more reliable data in order to update and verify the hydrological conclusions from the Feasibility Report of the Turkwel Gorge Multipurpose Project (Norconsult, 1979). As the WRAP and Norconsult studies were carried out simultaneously, neither project could wait for the results and conclusions from the other project. Although to a certain extent the two projects worked in close cooperation, duplication and overlap appeared to be unavoidable. The most important outcome of the hydrological survey for the Turkwel Gorge Multipurpose Project is:

- an improved estimate of the longterm annual flow of the Turkwel at the Turkwel Gorge.

- more reliable flow estimates for the Rivers Suam, Kanyangareng, Kunyao and Malmalte.

- an automatic water level recorder at Kongolai - Suam River, made it possible to compare flow estimates based on two daily levels and continuous levels. The past records may now be corrected with greater confidence.

- the present four months records at Kongolai - Suam River, should be increased to nine months when the records upto and including April 1983 are received and analysed.

4.3 Hydro-meteorological network

Initially the network was inadequate for a water balance study. Additional investigations were carried out which included surveying, rehabilitation and installation of equipment. Part of the foregoing activities were executed by Norconsult A.S. as well. Their studies were related to the proposed construction of the Turkwel Dam. To avoid duplication of work the upgrading of the existing hydro-meteorological network was executed in liaison with the Hydrology Division of the Ministry of Water Development and Norconsult.

Fieldwork started with a reconnaissance survey of the project area in December 1981. An inventory of the existing network was made and new sites for additional stations were identified. Actual rehabilitation of non-operational and poorly operating stations and the installation of new equipment started in February and continued up to May 1982. Additional honorary observers were appointed and properly trained.

The operation and management of the network is one of the responsibilities of the Assistant Hydrologist stationed in Kitale. Monthly each station is supposed to be visited, to check the procedures and to collect the record sheets from the foregoing month. However, since the field programme of the Assistant Hydrologist from Kitale office was mainly determined by the availability of transport and, when available, only attention was given to the hydrological survey for the Turkwel Gorge Multipurpose Project, little attention was given to the specific requirements from the WRAP-project. Consequently the quality and quantity of the data collected between February/May 1982 and October 1983 for a number of stations appeared to be below the expectations.

Table 4.1 Longterm mean monthly rainfall:

Rain gauge-station KMD ref. no. Record period	Elevation m.m.s.l.		Monthly rainfall data												Annual mean (mm)
			Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
Mt. Elgon F.S	2225	$\bar{x}$	24	51.3	91.3	153.3	157.9	119.1	168.4	173.2	99.4	97.5	77.1	38.8	1250.7
88.34.01		%	1.9	4.1	7.3	12.3	12.6	9.5	13.5	13.8	7.9	7.8	6.2	3.1	
1930-81		s	29.7	64.3	107.5	68.9	64.4	49.3	59.5	57.0	42.4	49.2	61.3	38.2	
		c_v	1.24	1.25	1.18	0.45	0.41	0.42	0.35	0.33	0.43	0.50	0.80	1.01	
Kapenguria D.C	2134	$\bar{x}$	18.0	42.1	74.8	159.4	206.0	123.9	189.7	181.7	111.6	76.5	61.9	27.8	1273.4
88.35.04		%	1.4	3.3	5.8	12.5	16.2	9.7	14.9	14.3	8.8	6.0	4.9	2.2	
1931-80		s	24.2	79.3	76.0	95.3	88.6	57.4	77.9	70.0	75.3	53.6	68.1	39.5	
		c_v	1.34	1.88	1.02	0.60	0.43	0.46	0.41	0.39	0.67	0.69	1.10	1.42	
Lomut	975	$\bar{x}$	23.5	46.9	67.2	129.4	108.3	78.7	147.9	87.7	53.6	65.6	55.8	31.6	896.2
88.35.17		%	2.6	5.2	7.5	14.4	12.1	8.8	16.5	9.8	6.0	7.3	6.3	3.5	
1953-78		s	25.6	49.4	48.2	78.9	52.4	54.9	136.2	58.9	41.9	49.8	40.1	42.1	
		c_v	1.10	1.05	0.72	0.61	0.48	0.70	0.92	0.67	0.78	0.76	0.72	1.33	
Tamkal	1219	$\bar{x}$	36.3	78.5	111.4	279.9	210.0	99.3	140.5	133.3	85.4	104.0	132.4	90.2	1501.2
88.35.18		%	2.4	5.2	7.4	18.7	14.0	6.6	9.4	8.9	5.7	6.9	8.8	6.0	
1953-78		s	33.3	83.2	72.2	138.1	114.1	60.0	67.7	51.3	59.6	62.4	103.7	90.5	
		c_v	0.93	1.06	0.65	0.49	0.54	0.60	0.48	0.38	0.70	0.60	0.78	1.00	
Kongolai	1311	$\bar{x}$	25.9	35.2	51.6	95.9	140.5	85.6	149.4	150.9	87.0	62.5	50.7	28.4	963.6
88.35.26		%	2.7	3.7	5.0	10.0	14.6	8.9	15.5	15.7	9.0	6.5	5.3	2.9	
1953-78		s	29.9	35.8	49.5	74.3	69.0	47.0	76.1	73.1	60.0	36.7	72.4	39.3	
		c_v	1.15	1.02	0.96	0.77	0.49	0.55	0.48	0.48	0.69	0.59	1.43	1.38	
Sebit	1311	$\bar{x}$	19.3	37.9	85.2	160.5	111.5	54.7	123.3	91.9	67.3	80.3	68.9	32.7	933.4
88.35.27		%	2.1	4.1	9.1	17.2	11.9	5.9	13.2	9.8	7.2	8.6	7.4	3.5	
1953-78		s	26.0	38.0	170.2	87.4	41.2	38.7	114.7	52.0	70.7	86.9	61.0	31.60	
		c_v	1.35	1.01	2.00	0.54	0.37	0.71	0.93	0.6	1.05	1.08	0.89	0.97	
Chepareria	1800	$\bar{x}$	15.4	43.2	59.6	120.0	135.6	104.1	160.1	151.5	77.2	67.8	69.0	16.0	1019.5
88.35.28		%	1.5	4.2	5.8	11.8	13.3	10.2	15.7	14.9	7.6	6.6	6.8	1.6	
1953-78		s	16.5	87.5	72.4	95.0	67.1	66.7	54.3	97.2	50.0	40.0	116.9	24.1	
		c_v	1.07	2.03	1.21	0.79	0.49	0.64	0.34	0.64	0.65	0.59	1.69	1.51	
Sigor	1067	$\bar{x}$	23.4	38.7	57.7	146.3	123.7	67.1	106.8	92.4	55.8	63.9	76.3	37.3	889.4
88.35.29		%	2.6	4.4	6.5	16.4	13.9	7.5	12.0	10.4	6.3	7.2	8.6	4.2	
1953-78		s	24.9	41.5	42.0	84.0	84.2	46.1	62.6	51.5	40.4	37.7	56.4	46.1	
		c_v	1.06	1.07	0.73	0.58	0.68	0.69	0.59	0.56	0.72	0.59	0.74	1.24	
Kaibuibich	2743	$\bar{x}$	31.7	49.1	93.9	168.7	211.4	158.0	207.7	231.1	144.5	146.8	106.5	35.5	1586.1
88.35.31		%	2.0	3.1	5.9	10.6	13.3	10.0	13.1	14.6	9.2	9.3	6.7	2.2	
1963-78		s	35.2	47.4	92.8	104.8	99.7	68.4	70.1	64.5	67.7	57.4	80.8	56.9	
		c_v	1.1	0.97	0.99	0.62	0.47	0.43	0.34	0.28	0.47	0.39	0.76	1.60	
Chebunyal	1960	$\bar{x}$	25.8	22.9	58.8	110.9	128.6	99.4	162,0	144.5	81.7	60.8	59.7	22.9	978.0
88.35.32		%	2.6	2.3	6.0	11.3	13.2	10.2	16.6	14.8	8.4	6.2	6.1	2.3	
1953-78		s	29.2	19.8	66.6	78.8	75.9	56.3	102.7	70.7	57.2	40.6	61.3	2.3	
		c_v	1.13	0.86	1.13	0.71	0.59	0.57	0.63	0.49	0.70	0.67	1.03	1.45	
Labot	2987	$\bar{x}$	32.1	57.4	62.9	110.5	151.8	112.8	172.3	209.4	80.0	94.3	80.4	42.4	1206.3
88.35.35		%	2.7	4.7	5.2	9.2	12.6	9.4	14.2	17.4	6.6	7.8	6.7	3.5	
1957-78		s	47.6	57.8	39.7	69.5	136.7	93.0	107.3	65.5	59.6	48.7	57.6	48.8	
		c_v	1.48	1.01	0.63	0.63	0.90	0.82	0.62	0.31	0.75	0.52	0.72	0.88	

not revised, as from MoWD - records.

The present hydro-meteorological network is shown on the hydrological map (Plate 4.1) and listed in Annex 4.1-1.

4.4 Rainfall

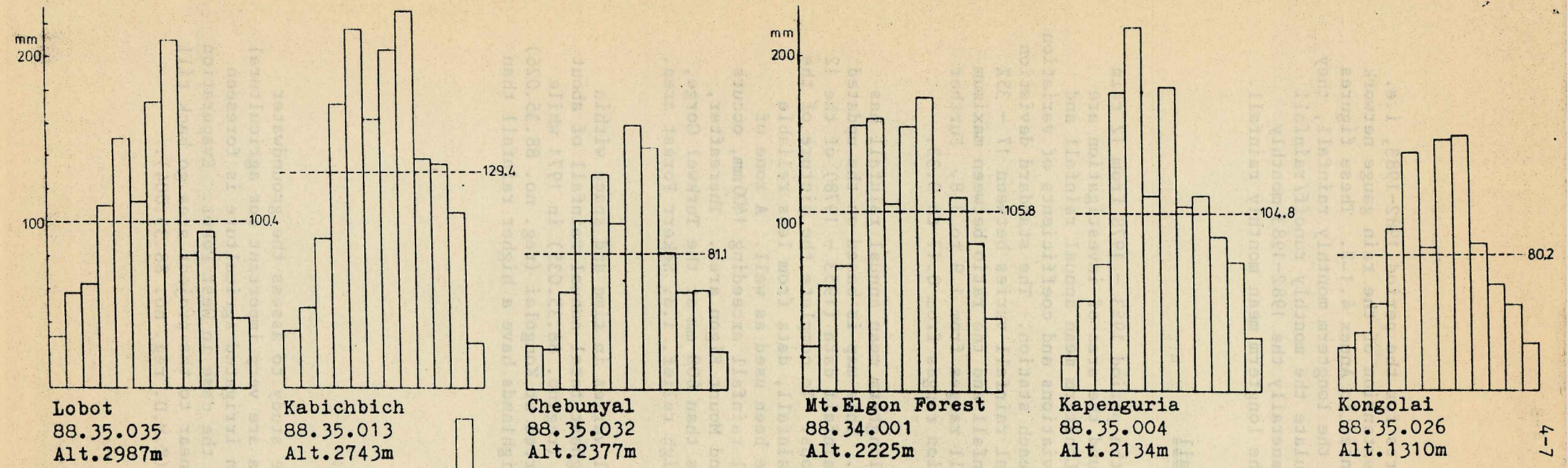
4.4.1 General

Rainfall observations in the area have been made since 1912 at Kacheliba rain-gauge stations (reg. No. 89.35.002). However, the majority of rain-gauge stations used in this study have been operated for much shorter periods. Although in principle all monthly records were available considerable time has been spent to update and complete raw data. This included the conversion of data prior to 1965 from inches into millimeters. On the basis of a test of significance, the 1953-1978 period was selected as the representative common record period for 11 selected rain-gauge stations (Annex 4.1). The stations are shown on Plate 4.1. Only monthly and annual rainfall data will be discussed in this report. For more detail on data elaboration and filling in of missing data through correlation and double mass analysis reference is made to the West Pokot Hydrological Report (MoWD/WRAP, 1984).

4.4.2 Monthly rainfall

Long term mean monthly rainfall for the selected stations are presented in Table 4.1, together with the standard deviation, the coefficients of variation and the average distribution of monthly rainfall as percentage of the long term average annual rainfall. The average distribution of monthly rainfall has been visualised in Figure 4.1. Most rain gauge stations exhibit more or less the same rainfall pattern with 2 distinct consecutive peaks in April/May and July/August and a dry spell in June. In the south-east (Cherangani Hills and surrounding areas) some high rainfall occurs in the months of October/ November which is otherwise absent in the remaining areas.

The long term monthly mean and the standard deviations presented in Table 4.1, show clearly that the rainfall in general fluctuates heavily from year to year. The standard deviations are of the same magnitude as the monthly averages, indicating that a monthly rainfall fluctuation interval can be expected varying between zero and two upto even three times the long term average rainfall. This phenomenon is also clearly indicated by the bar diagrams for monthly rainfall during the wettest, driest and an average year, Figure 4.2. Altogether monthly or seasonal minima or average rainfall appears unpredictable, which is a great drawback for agricultural planning.



Lobot
88.35.035
Alt.2987m

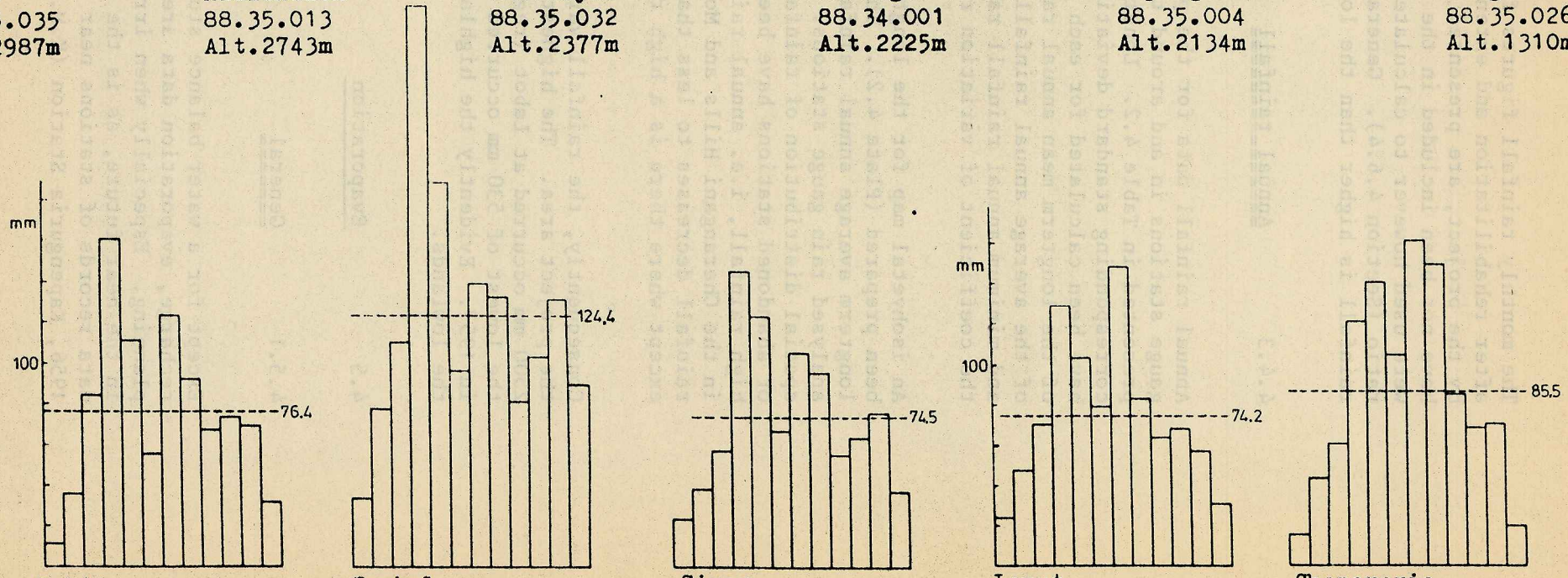
Kabichbich
88.35.013
Alt.2743m

Chebunyal
88.35.032
Alt.2377m

Mt.Elgon Forest
88.34.001
Alt.2225m

Kapenguria
88.35.004
Alt.2134m

Kongolai
88.35.026
Alt.1310m



Sebit
88.35.027
Alt.1310m

Tamkal
88.35.018
Alt.1219m

Sigor
88.35.029
Alt.1067m

Lomut
88.35.017
Alt.975m

Chepareria
88.35.028
Alt.1524m

Figure 4.1 Longterm mean monthly rainfall (mm)

The monthly rainfall figures for the period 1982-1983, i.e. after rehabilitation and extension of the rain gauge network by the project, are presented in Annex 4.1-2. These figures have not been included in the longterm monthly rainfall, they were used however to calculate the monthly runoff/rainfall ratio (Section 4.6.4). Generally the 1982-1983 monthly rainfall is higher than the longterm mean monthly rainfall.

4.4.3 Annual rainfall

Annual rainfall data for the period 1953 - 1978 from 12 rain gauge stations in and around the area of investigation are presented in Table 4.2. Longterm mean annual rainfall and corresponding standard deviations and coefficients of variation have been calculated for each station. The standard deviation of the longterm mean annual rainfall varies between 17 - 35% of the average annual rainfall and the ratio between maximum and minimum annual rainfall ranges from 1.9 to 3.8. Further the coefficient of variation ranges from 0.17 to 0.33.

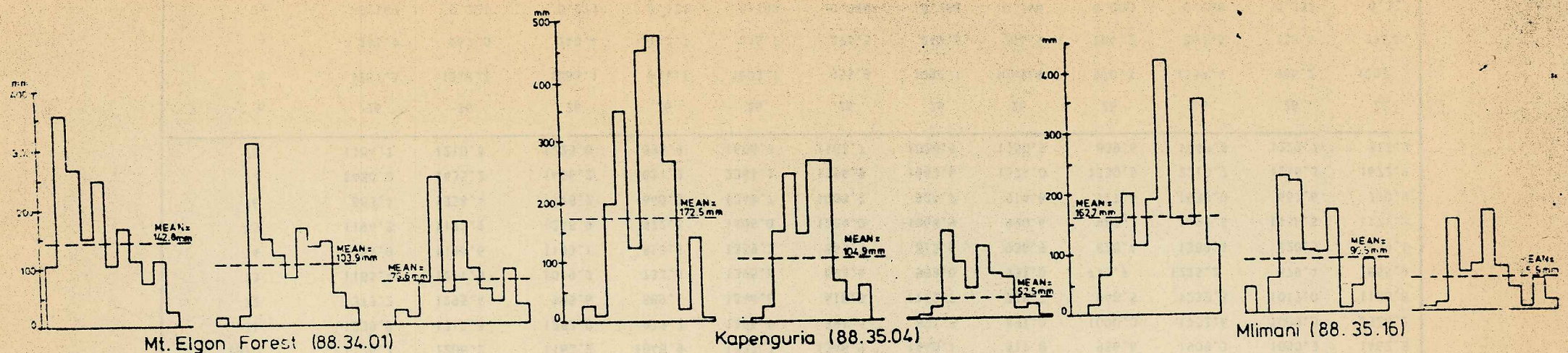
An isohyetal map for the longterm mean annual rainfall has been prepared (Plate 4.2). This map is based on the updated longterm average annual rainfall data (1953 - 1978) of the 12 analysed rain gauge stations. To complete the picture of the spatial distribution of rainfall, data from less reliable or abandoned stations have been used as well. A zone of high rainfall, i.e. annual rainfall exceeding 1400 mm, occurs in the Cherangani Hills and Mount Elgon area. Thereafter, rainfall decreases to less than 600 mm at the Turkwel Gorge, except where there is a high relief, i.e. Sekerr Forest area.

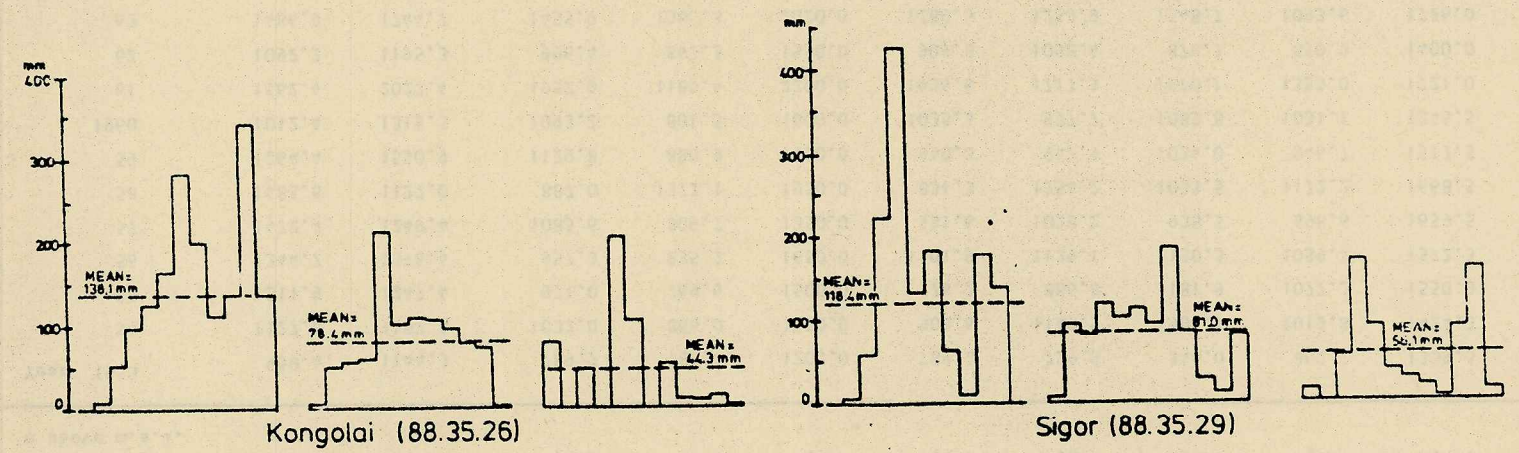
Consequently, the rainfall varies in time and space within the project area. The highest total annual rainfall of about 2500 mm occurred at Labot (reg.no. 88.35.035) in 1971 while the lowest of 530 mm occurred at Kongolai (reg. no. 88.35.026) in 1957. Evidently the highlands have a higher rainfall than the lowlands.

4.5 Evaporation

4.5.1 General

Except for a water balance study to assess the groundwater recharge, evaporation data are very important for agricultural planning. Especially when irrigated agriculture is foreseen in the near future, as is the case in West Pokot. Evaporation data records of stations near to the project area go back till 1956, Kapenguria Station (K.M.D. reg. no. 88.35.004).





Monthly rainfall for wet, average and dry years respectively

Figure 4.2

Table 4.2 Total annual rainfall 1953 - 1978:

Station Name	Mt.Elgon F.S.	Kapenguria D.C.	Kitale Mlimani	Lamut	Tamkal	Kongolai	Sebit	Chepareria	Sigor,	Kaibui-bich	Chebunyal	Labat
KWD reg. no.	88.3 .001	88.35.004	88.35.016	88.35.017	88.35.018	88.35.026	88.35.027	88.35.028	88.35.029	88.35.031	88.35.032	88.35.035
Elevation in m above m.s.l.	2,225	2,134	1,920	975	1,219	1,311	1,311	1,800	1,067	2,743	1,960	2,987
Year 1953	959.4	1144.3	789.7	789.4	1200.0	789.2	729.9	844.0	862.7	1309.3	740.0	-
54	1127.8	1182.4	1032.0	886.0	1500.0	908.6	1140.5	908.1	1019.8	1424.3	900.0	-
55	1311.9	1247.4	971.0	769.6	1500.0	776.2	886.8	1181.9	1077.2	1550.0	1000.0	-
56	1344.7	1376.4	957.3	835.2	1650.0	1101.9	1129.1	1130.3	1059.4	1572.3	1100.0	-
57	1472.4	1249.4	1085.6	806.7	1350.0	531.6	1028.2	938.5	698.6	1659.5	830.0	1341.6
58	1485.6	1127.0	887.0	1372.1	1950.0	831.3	1254.2	1033.5	1172.2	1668.5	1220.0	1090.7
59	1264.4	1550.9	1129.8	880.9	1450.0	940.8	947.9	1034.0	846.7	1517.5	800.0	1058.9
1960	1012.4	1315.5	1093.2	801.5	1600.0	1035.3	977.7	1082.8	1031.1	1245.5	950.0	1042.9
61	1562.4	2027.4	1952.0	1185.4	2200.0	1656.6	1717.3	1670.1	1353.0	1721.0	1416.0	1354.3
62	1092.2	1195.3	996.4	847.3	1550.0	909.8	1098.4	878.3	850.9	1400.0	947.2	1234.2
63	1486.9	1744.7	1455.9	1380.3	2020.0	1289.6	1253.9	1348.7	1093.6	1726.0	1382.2	1133.1
64	1378.5	1513.1	1092.2	874.8	1641.5	796.3	1073.6	973.6	971.6	1883.9	1054.4	1395.5
65	1002.5	948.8	723.5	702.4	1110.1	538.0	1068.6	680.8	673.6	1079.4	561.0	1133.7
66	1298.0	1359.9	909.8	1043.0	1635.1	1022.5	866.4	1664.3	1108.4	1815.9	870.8	1267.0
67	1706.6	2070.0	1282.0	1182.0	2074.2	1039.0	1197.3	1260.0	1391.1	1797.4	1206.7	1379.2
68	1332.3	1094.2	1098.8	866.3	1481.4	684.8	948.0	950.0	796.8	1324.0	1176.6	1265.9
69	1713.9	1095.9	939.4	661.4	2011.5	784.4	994.4	910.3	770.1	1247.1	644.4	1088.9
1970	1126.7	1206.2	1162.2	1048.9	1327.3	1348.5	1640.1	911.0	956.6	1909.3	1050.3	1462.8
71	1239.3	1312.5	1282.0	972.2	1496.9	891.3	891.8	891.0	1000.0	1752.6	1009.0	2528.2
72	1313.2	1295.4	985.6	889.1	1544.6	618.5	1162.7	739.7	948.5	1232.3	1017.0	1108.6
73	1185.4	1211.3	1019.2	733.9	1395.2	692.6	909.0	931.0	775.7	1225.2	679.4	665.9
74	1154.0	1190.6	1133.1	813.6	1359.2	845.3	813.6	936.9	828.4	1388.4	820.9	699.1
75	1194.2	1172.9	1248.9	972.2	1406.0	1224.9	1068.9	990.6	987.3	1699.5	1156.5	1171.2
76	883.4	1258.4	778.2	640.3	1249.7	1003.7	924.7	914.6	777.6	1635.0	667.6	770.9
77	1480.3	1435.2	1496.2	1021.9	2361.1	1394.9	1643.6	1574.0	1330.5	2210.7	1216.3	1672.9
78	1184.7	1210.8	1223.0	895.9	1606.3	1162.7	1028.5	1350.9	839.6	1449.8	1223.7	717.3
n	26	26	26	26	26	26	26	26	26	26	26	22
x	1281.3	1328.3	1083.1	914.7	1602.7	955.9	1092.1	1065.8	970.3	1559.4	986.2	1205
s	215.9	267.0	240.4	192.7	316.7	275.5	248.6	264.6	194.5	261.5	228.6	395.5
Cv	0.169	0.201	0.221	0.221	0.198	0.288	0.288	0.248	0.200	0.168	0.232	0.328

Re dat n dou ass sis gres equa (KWD a)

Woodhead (1968) developed a regression equation to relate the annual potential evaporation Eo (mm) to altitude h(m) :

$$Eo = 2422 - 0.358\ h \quad (r^2 = 0.66,\ n = 78).$$

The above formula can only be applied to obtain approximate figures. Potential evaporation estimates have been prepared for Kapenguria D.C. (reg. no. 88.35.004) and Atumatak (Uganda) (reg. no. 76.34.011). The mean annual potential evaporation is 1588 and 2035 mm respectively. The minimum potential evaporation occurs in July at both stations while the maximum varies, with Atumatak occurring in January and Kapenguria in March. Generally, January, February and March have relatively high evaporation rates at both stations. On the whole the mean annual potential evaporation varies from less than 1400 mm on highlands to 2200 mm on the lowlands in the project area.

From 3 evaporation stations in and around West Pokot the available data have been updated, data from before 1965 have been transferred from inches into millimeters. The evaporation stations used in this report (Annex 4.2-1) are shown on Plate 4.1. Only monthly and annual evaporation data will be discussed in this report.

4.5.2 Monthly evaporation

The longterm mean monthly evaporation for three evaporation stations are presented in Table 4.3, together with the standard deviation, the coefficient of variation and the average distribution of monthly evaporation as percentage of the mean annual evaporation. In general it can be observed that in all stations the highest monthly evaporation occurs during the period between December and April. The maximum and minimum evaporation rates occur in January and July respectively. Seasonal variation at higher altitude is considerably greater compared to the variation at lower altitude. The standard deviations vary between 10-30% of the mean monthly evaporation.

The monthly evaporation figures for the period 1982-1983, i.e. after rehabilitation and extension of the network by Norconsult and the project, are presented in Annex 4.2-2.

4.5.3 Annual evaporation

The mean annual evaporation from the three stations with the most reliable records are presented in Table 4.3. The annual variability is moderate as indicated by the standard deviations, being in the order of 10% of the mean annual evaporation and the coefficients of variation of less than 0.20.

Table 4.3 Longterm mean monthly and mean annual evaporation:

Evaporation Station KMD/MOWD reg. no Altitude Record Report		JAN	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL MEAN
Atumataka 87.34.011 / - 1500 m above m.s.l. 1959 - 1974	$\bar{x}$	295	260	261	194	148	147	136	154	180	221	231	268	2495
	n	16	16	16	16	16	16	16	16	16	16	16	16	16
	s	43	52	58	39	34	25	21	21	32	36	58	46	230
	Cv	0.15	0.20	0.22	0.20	0.23	0.17	0.15	0.14	0.18	0.16	0.25	0.17	0.09
	%	12	10	10	8	6	6	5	6	7	9	9	11	100
Sigor 88.35.029/114 1070 m above m.s.l. 1966 - 1982	$\bar{x}$	234	215	235	181	165	164	151	161	190	201	171	213	2281
	n	18	18	18	18	18	18	17	17	17	17	17	17	17
	s	27	36	46	29	16	20	20	23	20	18	24	33	124
	Cv	0.12	0.17	0.20	0.16	0.10	0.12	0.13	0.14	0.11	0.09	0.14	0.16	0.05
	%	10	9	10	8	7	7	7	7	8	9	8	9	100
Cherengani 88.35.34/60 2200 m above m.s.l. 1957 - 1982	$\bar{x}$	130	122	132	107	190	78	67	70	98	106	98	122	1222
	n	27	27	27	27	27	26	26	26	26	26	27	27	26
	s	28	32	37	29	26	24	24	25	30	29	24	41	218
	Cv	0.22	0.26	0.28	0.27	0.29	0.31	0.35	0.35	0.30	0.27	0.24	0.34	0.18
	%	11	10	11	9	7	6	5	6	8	9	8	10	100

4.6 Surface water runoff

4.6.1 General

When the project started in the West Pokot District, Norconsult, in close cooperation with the Hydrology Division of the Ministry of Water Development, had already made up a rehabilitation plan for the hydrometric network. The implementation of the rehabilitation of the river gauging stations (RGS) was more or less completed in the second half of 1982. Following the recommendations of Norconsult and Tams (1980), the project installed an automatic water level recorder (AWLR) in the Muruny River at Marich Pass, just down stream of the bridge. Although this location appeared not to be ideal, at the particular site the river bed is wide and not very stable, it seemed better than sites upstream of the bridge. In the past all staff gauges installed upstream of the bridge have been flushed away by very strong floods. Even so, the begin 1982 reinstalled staff gauge at the location proposed by Norconsult, which disappeared with the first flood of the following rainy season. A complete list of all river gauging stations presently operational in the project area, is presented in Table 4.4. River stages are only read once per day by local observers, in most cases no readings are taken on Sundays, Public Holidays and during leave periods. Flow measurements by wading are being carried out at irregular time intervals. Depending on the availability of funds and transport, the accessibility and the importance of the gauging stations the number of flow measurements varies considerably from station to station. Except for the river gauging station at the Turkwel Gorge - 2B 27A, where there is a cable way to monitor peak flows, peak flows have not been monitored in the past. Consequently rating curves are only accurate up to limited stage heights, i.e. the maximum wading depth.

It has been the policy of the project not to duplicate the considerable amount of analysis of past data carried out by consultants in relation to the surface water availability for irrigated agriculture and hydropower. As mentioned previously, the project mainly aimed at the assessment of groundwater availability in selected areas. In close cooperation with the District Water Officer and the A.S.A.L-Coordinator for West Pokot, both stationed at Kapenguria, it was decided to concentrate the project activities in the catchment of the Suam River, the Muruny River and the Wei Wei River.

4.6.2 The catchment areas (MoWD drainage area 2B)

The West Pokot District can be sub-divided into three main catchment ageas: the Suam-Turkwel Basin upstream of the Turkwel Gorge, the Muruny Basin upstream of Marich Pass and the Malmalte - Wei Wei Basin upstream of the confluence of the Turkwel and Malmalte Rivers.

Table 4.4 River gauging stations (RGS)

MoWD ref.No.	River of Stream	Location	Co-ordinates Sheet no 32-12/16 Scale.1:250.000 X	Co-ordinates Sheet no 32-12/16 Scale.1:250.000 Y	RGS = type W = Wier S = Staff gauge R = Recorder	Record Period Opened	Record Period Closed	Rated Q-h curve	Catchment area Sq. Km	Remarks
2 B 1	Suam	-	697	134	S	.50	.52	NO	-	
2	Kaptega	-	698	134	W, S	.49	-	YES	58	
5	Suam	-	693	135	W, S	.52	-	YES	135	
7*	Suam	Kangolai	724	164	,S, R	.55	-	YES	1350	
8*	Wei Wei	Sigor	775	157	W, S	.55	.62	YES	190	
9*	Muruny	Marich Pass	773	170	S	.55	.80	YES	1350	1) Rating curve updated WRAP
12*	Wei Wei	Sigor	775	157	S	.62	.69	YES	196	
15*	Wei Wei	Sigor	775	157	S	.69	.77	YES	195	
20	Kunyao	Kunyao	727	198	W,S	.74	-	NO	700	1)
23	Kanyangoreng	Kunyao	729	200	S,R	.75	-	NO	1900	1)
24	Muruny	Marich Pass	772	170	S	.75	-	YES	1330	
26	Malmalte	-	771	211	S	.75	-	NO	2893	
27A	Turkwel	Turkwel Gorge	761	213	S,R	.78	-	NO	5900	1)
28*	Wei Wei	Sigor	775	157	S	.78	-	NO	195	1)
30	Malmalte	-	771	211	S	.81	-	NO	3257	2)
32	Muruny	Marich Pass	759	156	S,R	.82	-	NO	1355	3) Preliminary rating curve by W R A P
31	Muruny	Ortum	773	177	S	.82	-	YES	700	2)

1) Station rehabilitated by Norconsult

2) Station instaled by Norconsult

3) Project instaled automatic water level recorder (AWLR)

* Station used for preliminary analysis

i The Suam-Turkwel Basin

The Suam-Turkwel drainage area is dominated by the Suam, Kanyangareng and Kunyao Rivers from which the Suam River is the only perenial river. The Suam River originates from the Mount Elgon region, while the rivers Kanyangareng and Kunyao originate from the Karamoja Hills in Uganda. Except for two minor river gauging stations in the upper catchment of the Suam, RGS 2B 3 and 5, one quarter of the total catchment (1350 km²), is monitored by a staff gauge and level recorder at Kongolai, RGS 2B 7. Near the confluence with the Suam River the Kanyangareng and Kunyao rivers are respectively monitored by RGS 2B 23 (1900 km²) and 2B 20 (700 km²). The total catchment of 5900 km² is monitored by RGS 2B 27A. The latter river gauging station consists of staff gauges, a water level recorder and cable way. Because the catchments of the Kanyangareng and Kunyao are outside the actual project area and because already a lot of analysis have been carried out by other, the project only did some additonal analysis on the Suam catchment upstream of Kongolai.

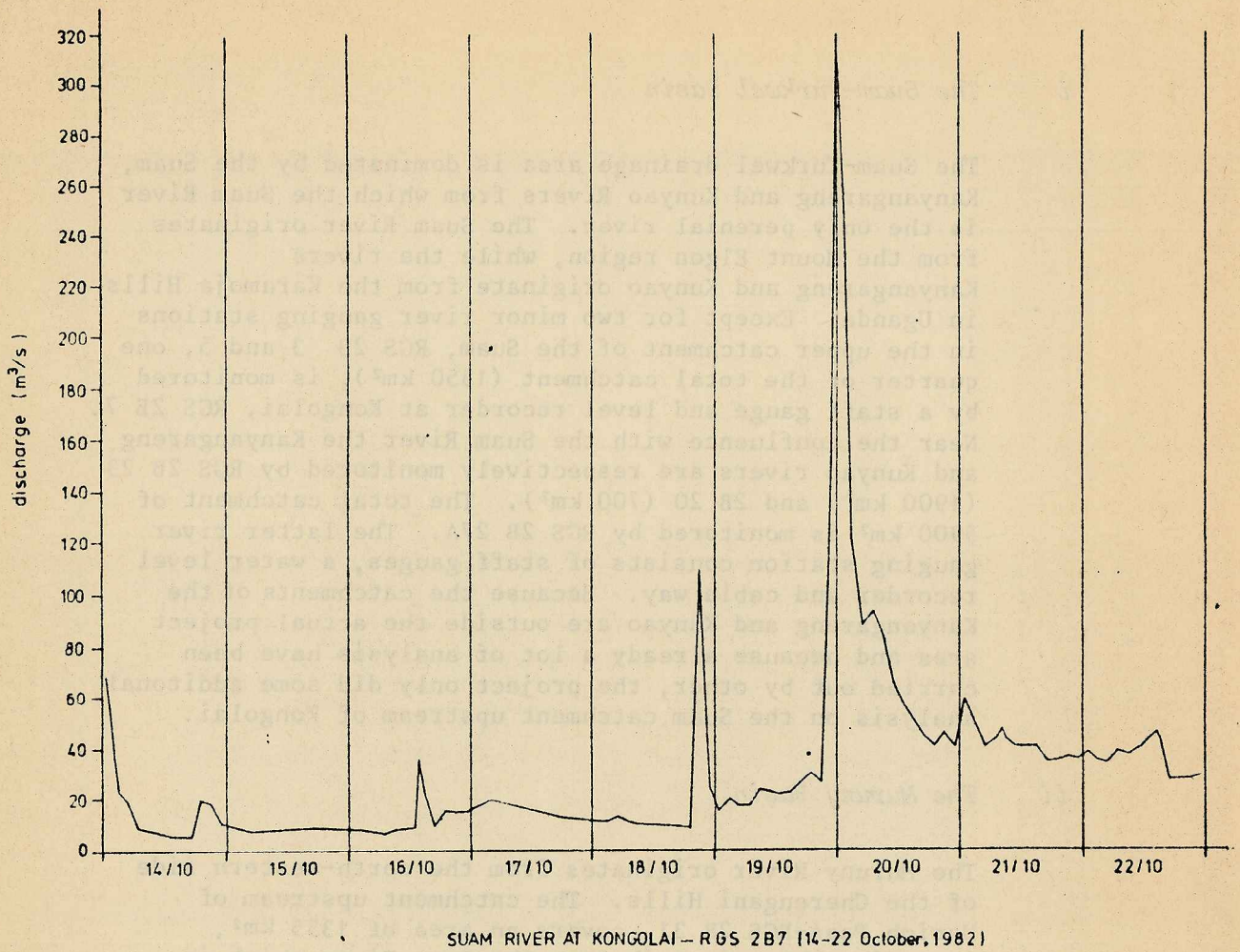
ii The Muruny Basin

The Muruny River originates from the north-western side of the Cherengani Hills. The catchment upstream of Marich Pass-RGS 2B 31, covers an area of 1355 km², including the main tributary the Iyon River which is, contrary to the Muruny River itself, a seasonal river. At present two river gauging stations are operational; one staff gauge installed at the bridge near Ortum, - RGS 2B 32 (700 km²) and a staff gauge plus a water level recorder downstream of the bridge near Marich Pass, RGS 2B 31. The data from the latter, which covers the total Muruny catchment area, have been analysed by the project.

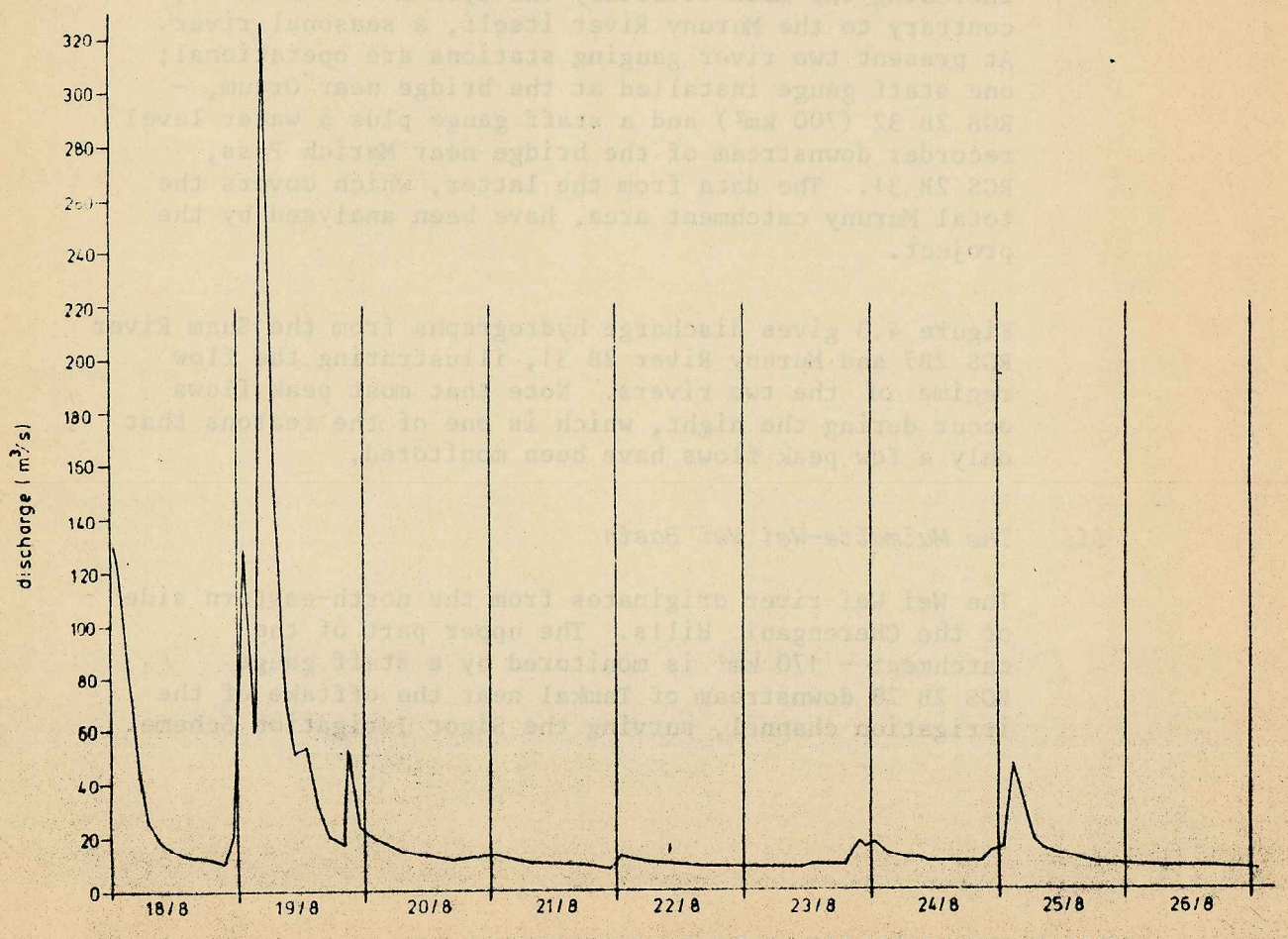
Figure 4.3 gives discharge hydrographs from the Suam River RGS 2B7 and Muruny River 2B 31, illustrating the flow regime of the two rivers. Note that most peak flows occur during the night, which is one of the reasons that only a few peak flows have been monitored.

iii The Malmalte-Wei Wei Basin

The Wei Wei river originates from the north-eastern side of the Cherengani Hills. The upper part of the catchment - 170 km² is monitored by a staff gauge RGS 2B 28 downstream of Tamkal near the offtake of the irrigation channel, surving the Sigor Irrigation Scheme.



SUAM RIVER AT KONGOLAI – RGS 2B7 (14-22 October, 1982)



MURUNY RIVER AT MARICH PASS – RGS 2B31 (18-26 August, 1983)

Figure 4.3

Unfortunately, due to reconstruction works on the inlet structure, this river gauging station has been out of function for most of the time, during the project investigation period. Therefore only the past records could be analysed.

Upstream of the Sigor-Tot road the Wei Wei River flows through a well defined valley. Very high floods occur, due to heavy regional rainfall and the relatively narrow river-bed, which demolished regularly the staff gauges. Although peak flow measurements have not been taken, peak flow estimates range from a couple of hundred m^3/S up to 690 m^3/s., during the disastrous flood in 1969 (Sogreah, 1981). Downstream of the Sigor-Tot road the river widens and flows through the alluvial plain north of the Cherengani Hills. After the confluence with the Muruny River, the river becomes the Malmalte River. Just downstream of the confluence with the Turkwel River the total catchment (3257 km^2) of the Muruny, Wei Wei and Malmalte is monitored by a staff gauge - RGS 2B 30. However, this station has not been analysed by the project.

4.6.3 Discharge rating curves

The stage-discharge relation is defined by the complex interaction of the river channel characteristics, including cross-sectional area, shape, slope and roughness of the river bed. Through a permanent control structure in the river channel, i.e. a weir or a natural control formed by a non-erodable river bed, the relation between river stage and discharge becomes a straight line function when plotted on double logarithmic paper. In case no control structure is present different relations exist during the rising and falling limb of a flood. Most river gauging stations in the project are uncontrolled.

Rating curves are only valid for limited time periods and have to be continuously adopted, especially when the river bed is unstable as a result of scouring and silting. One of the constraints to establish reliable discharge-rating curves is the limited number of peak flow measurements. This certainly is the case when most peak flows occur around midnight (Figure 4.3).

The following methods for discharge measurements have been applied by the project:

- by current meter through wading, this method can be applied up to a maximum water depth of one meter (Ott, Braystoke current meter equipment.

- by float, in case the water depth exceeds one meter and no bridge or cable way is present. This appropriate method gives a rough estimate of the surface velocity. To use this method effectively, the ratio between surface water velocity and average velocity has to be established from regular discharge measurements.

- by the so-called "slope-area" method (Chow, 1964). This method is based on the Manning equation (4-1) and requires accurate cross-section to establish the relationship between the stage (h) and the area (A), and between the stage (h) and the hydraulic radius (R). Both can be plotted in graphs. The Manning roughness coefficient (n) has to be calculated from regular discharge measurements combined with slope measurements.

In order to get a proper insight into the interrelationship between the different parameters, i.e. between the slope and the Manning coefficient, the three methods have to be carried out simultaneously. This way peak flows can be fairly accurately estimated in case appropriate equipment for peak flow measurements is lacking.

To extrapolate rating curves beyond the highest measured discharge, high flows are estimated by use of the Manning formula:

$$Q = 1/n \quad A.R.^{2/3} \, S^{\frac{1}{2}} \qquad (4-1)$$

in which
- Q = discharge in m^3/s
- A = cross-sectional area in m^2
- R = hydraulic radius in m
- S = surface water slope
- n = Manning's roughness coefficient

Under favourable conditions an error of 10-20% may be expected in a slope-area estimate of flow which more or less is double the measuring error in current meter measurements.

The project tentatively updated and established rating curves for the following stations:

- Suam River at Kangolai: - RGS 2B 7 (Annex 4.3-1)

  The rating curve is based on the discharge measurements taken during the period 1982/83. Two curves valid for different periods have been calculated using the analytical method:

$$Q = a\ H^{b} \quad m^3/s.$$

in which Q = discharge in m^3/s

H = stage height in m

a and b = constant

- Muruny River at Marich Pass - RGS 2B 31 (Annex 4.3 2):

  The rating curve has been prepared on the basis of the available discharge measurements up to a stage height of one meter and applying the slope-area method per stage hights between one and 2.5 meters. As the measuring points show very little deviation and no peak flows have been monitored, this rating curve still needs confirmation. Nevertheless the rating curve has been applied to estimate the order of magnitude of flow at this point.

4.6.4 Runoff

Daily flows

Runoff figures from previous hydrological studies have been based on daily staff gauge readings. As the instanteous peaks occur mostly around midnight, these flow data represent the flows six to ten hours after the recession of flow started. From Figure 4.3 it can be seen that during the rainy season calculated daily flows are considerably under-estimated. Applying the rating furves for each station, the stage hydrographs from the two automatic water level have been elaborated into daily flows.

During floods and peak flows, discharges were calculated at a two hours interval from which the actual daily outflow and the average daily flow couldbe calculated:

$$\text{total daily outflow} = \sum_{n=1}^{12} (Q_n \times \Delta t) \text{ in } m^3$$

The calculated actual daily fow amounts to 2-20 times the estimated flow based on daily staff gauge readings.

Due to mechanical problems with the operation of the water level recorders, the hydrograph records sometimes show an interruption. In those cases daily flows were estimated from the daily staff gauge readings. Daily flow data for the two river gauge stations are presented in Annex 4.3-3.

Table 4.5 Summary of monthly and annual discharge data (m^3/s).

		JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	A N U A L	
	Period 1956 - 1972 Suam River RGS - 2B7, Kangolai Catchment area: 1350 Km^2													mean	mm/year
SUAM RIVER	Max	7.94	12.04	36.63	83.11	47.06	22.65	38.57	55.39	40.98	28.35	55.59	21.49	21.02	490
	Min	0.46	0.93	0.89	1.50	4.62	3.28	4.86	3.91	4.11	1.44	1.44	2.23	6.21	145
	Mean	2.76	3.56	7.47	17.26	20.41	11.52	21.73	28.57	15.66	12.22	13.15	6.39	13.39	315
	n	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	S	2.09	3.18	8.24	8.48	12.50	6.44	11.03	13.68	9.13	7.31	12.93	5.64	3.08	95
	Cv	0.76	0.89	1.10	1.07	0.61	0.56	0.51	0.48	0.58	0.60	0.98	0.88	0.30	0.30
	Period 1957 - 1972 Muruny River RGS- 2B9, Marich Pass Catchment area = 1355 Km^2														
MURUNY RIVER	Max	6.15	5.21	5.72	12.84	7.06	16.65	53.56	17.87	10.11	7.87	22.94	10.85	11.03	260
	Min	1.48	1.32	1.34	1.68	3.06	2.46	2.91	3.89	2.94	1.70	2.33	1.88	3.47	80
	Mean	2.76	2.87	3.27	4.53	5.97	5.09	11.52	9.42	6.16	5.01	5.57	3.94	5.51	128
	n	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	S	1.40	1.43	1.34	2.69	1.11	3.45	11.82	3.84	2.21	1.73	4.95	2.38	1.77	40
	Cv	0.50	0.50	0.14	0.59	0.19	0.68	1.03	0.41	0.36	0.35	0.89	0.60	0.32	0.32
	Period 1957 - 1976 Wei Wei River RGS: 2B28, Tamkal Catchment area= 170 Km^2														
WEI WEI RIVER	Max	4.99	3.57	4.45	11.98	9.37	5.70	8.50	9.46	5.78	13.23	31.41	9.63	6.73	1250
	Min	1.29	1.15	0.86	1.72	3.25	1.96	1.96	1.78	1.48	1.84	2.13	1.49	2.54	470
	Mean	2.23	2.81	2.51	4.08	5.88	3.33	4.44	5.2	3.91	3.90	5.75	3.40	3.90	725
	n	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	S	0.98	0.84	1.52	2.27	1.53	1.04	1.71	1.92	1.14	2.51	6.65	2.09	1.16	215
	Cv	0.44	0.39	0.60	0.56	0.26	0.31	0.38	0.37	0.29	0.64	1.16	0.62	0.30	0.30

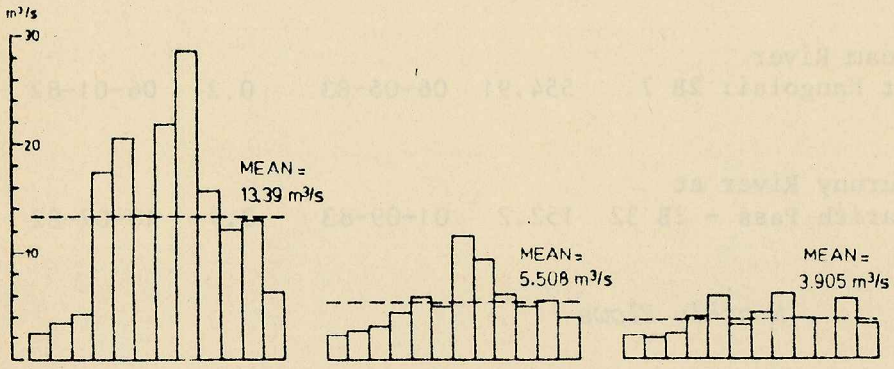
During the observation period the following maximum (instanteous) and minimum flows have been recorded:

	Maximum m^3/s	Date	Minimum m^3/s	Date
- Suam River at Kangolai: 2B 7	554.91	06-05-83	0.2	06-01-82
- Muruny River at Marich Pass - 2B 32	152.2	01-09-83	3.9	10-07-82

Monthly Flows

Mean monthly runoff data over the period 1956-1976 have been calculated for the Suam (RGS - 2B 7), Muruny (RGS - 2B 9) and Wei Wei (RGS - 2B 28) Rivers. The monthly runoff data for each river gauging station are presented in Annex 4.3-4. A summary of the mean monthly runoff, together with the standard deviation and the coefficient of variation are given in Table 4.5, a bar diagram presentation is given in Figure 4.4. Comparing the monthly rainfall distribution (Figure 4.1) with the monthly runoff vairation it is obvious that the monthly flows follow the same pattern as the monthly rainfall, with three peaks occurring in May, July/August and November on all three rivers. Minimum flows occur during January and February, from the mean monthly flow and the coefficients of variation indicates that the annual fluctuations in monthly flow are much more pronounced on the Suam River than on the Muruny and Wei Wei Rivers. However on all three rivers there is considerable annual fluctuation in monthly flow.

Total monthly outflow and mean monthly flows for the period 1982 - 1983 have been calculated from daily flows (Annex 4.3-3) and have been summarised in Table 4.6. In Table 4.7 the longterm mean monthly flows for the rivers Suam and Muruny are compared with the available monthly flow figures from 1982 and 1983. In general it can be concluded that the 1982 monthly flows were below average, whereas the monthly outflow during 1983 were above average, especially during the second half of the year.



Monthly runoff of Suan-river at Kongolai (2 B 7), Moruny-river at Marich Pass (2 B 9) and Weiwei-river at Sigor (2 B 28) respectively.

Figure 4.4 mean monthly and annual discharge (m^3/s).

Monthly rainfall and evaporation figures have been estimated for each catchment area, and are presented in Table 4.6 together with the monthly runoff depth and the runoff rainfall ratio. The runoff rainfall relationship depends on numerous factors and requires among other proper hydrograph analysis and continuous monitoring of rainfall with automatic rainfall recorders. The presented runoff rainfall ratios were calculated in an attempt to compare the runoff rainfall ratios for different catchment areas. However, on a monthly basis no definite conclusions could be drawn.

Table 4.6 Monthly flow data 1982-1983.

1982	Suam River Catchment at Kongolai RGS 2B7 Catchment Area 1350 Km^2												
	JAN	FEB	MARCH	TOTAL APRIL/ MARCH 82/83	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
Total $x10^6$ m^3	2.62	2.68	2.03		41.03	56.99	21.77	16.47	35.33	14.04	41.22	46.06	16.98
Monthly Mean	1.12	1.11	0.76		15.83	21.28	8.40	6.15	13.19	6.19	15.39	17.77	6.34
Daily Max.	2.63	1.84	25.28		327.67	60.74	30.38	49.21	66.14	72.81	319.04	100.10	95.85
Daily Min.	0.25	0.52	0.40		0.59	0.46	0.82	2.99	8.7	2.90	3.67	3.20	2.04
Rainoff in mm.	1.9	2.0	1.5		30.4	42.2	16.1	12.2	26.2	11.9	30.5	34.1	12.6
Rainfall in mm	-	-	-		200	235	75	125	130	85	145	135	30
Runoff /Rainfall	-	--	-		0.15	0.18	0.21	0.10	0.20	0.14	0.21	0.25	0.42
Evap. in mm.	-	-	-		175	155	125	120	150	170	145	140	160
1983													
Total x 10^6 m^3	4.87	6.63	2.38	303.77	26.46	42.67	17.42	36.07	99.34	61.84	-	-	-
Monthly mean	1.82	2.74	0.89	9.63	10.21	15.93	6.72	13.47	37.09	23.86	37.97	-	-
Daily max.	2.77	7.83	1.72	327.67	357.49	554.91	15.53	454.90	393.54	254.49	59.69	-	-
Daily min.	1.19	1.44	0.48	0.46	0.48	4.18	2.77	0.24	13.71	0.93	1.08	-	-
Rail of mm.	3.6	4.9	1.8	225	19.6	31.6	12.9	26.72	73.59	45.8	34.0	-	-
Rainfall in mm.	15	30	45	1250	150	-	-	-	-	-	-	-	-
Runoff /Rainfall	0.24	0.16	0.04	0.18	0.13	-	-	-	-	-	-	-	-
Evap. in mm	205	185	215	1945	195	160	210	125	175	130	-	-	-

1982	Muruny River Catchment at Marich Pass, RGS 2B31 Catchment Area: 1355 Km^2											
	JAN	FEB.	MARCH	APRIL	MAY	JUNE	TOTAL JUNE-MAY 82 83	JULY	AUG.	SEPT.	OCT.	NOV	DECEMBER
Total x 10^6 m^3	-	-	-	-	-	14.44		14.85	21.57	15.24	14.60	19.80	14.33
Monthly mean	-	-	-	-	-	5.57		5.55	8.32	5.88	5.45	7.64	6.36
Daily max.	-	-	--	-	-	7.31		21.66	32.75	13.66	35.29	54.53	11.09
Daily min.	-	-	-	-	-	4.16		3.97	4.75	4.55	4.36	4.75	4.75
Runoff in mm	-	-	-	-	-	10.66		11.00	15.92	11.20	10.30	14.6	10.95
Rainfall in mm.	-	-	-	205	250	65		95	155	50	90	165	50
Runoff/Rainfall	-	-	-	-	-	0.16		0.12	0.10	0.22	0.12	0.09	0.22
Evap. in mm.	-	-	-	160	165	140		145	155	170	155	170	160
1983													
Total x 10^6 m^3	13.00	12.00	13.09	15.50	21.08	20.89	196.65	21.01	30.94	21.51	21.80	-	-
Monthly mean	4.84	5.04	4.89	5.98	7.87	8.06	6.24	8.11	11.55	8.30	8.14	-	-
Daily max.	5.34	6.52	10.10	23.16	12.47	16.63	54.53	125.05	138.95	152.18	73.69	-	-
Daily min.	4.75	4.55	4.55	4.55	4.55	6.52	3.97	5.73	5.14	4.16	4.16	-	-
Runoff in mm.	96	9.00	9.66	11.1	15.6	15.4	145	15.51	22.83	15.87	16.09	-	-
Rainfall in mm	10	40	15	140	155	(100)	1065	-	205	110	-	-	-
Runoff/Rainfall	0.96	0.23	0.64	0.80	0.10	(0.15)	0.14	-	0.11	0.14	-	-	-
Evap. in mm.	195	155	185	145	110	180	1925	110	140	130	-	-	-

Table 4.7 Comparison of monthly flow data.

	Suam River Catchment U/S Kongolai RGS - B27				Maruny River Catchment U/S Marich Pass RGS - 2B9		RGS - 2B31	
	1956 - 1972		1982	1983	1957 - 1972		1982	1983
	Mean m³/S	Standard deviation	m³/S	m³/S	Mean m³/S	Standard deviation	m³/S	m³/S
January	2.76	2.09	1.12	1.82	2.76	1.40	-	4.84
February	3.56	3.18	1.11	2.74	2.87	1.43	-	5.04
March	7.47	8.24	0.76	0.89	3.27	1.34	-	4.89
April	17.26	18.48	15.83	10.21	4.53	2.69	-	5.98
May	20.41	12.50	21.28	15.93	5.97	1.11	-	7.87
June	11.52	6.44	8.40	6.72	5.09	3.45	5.77	8.06
July	21.73	11.03	6.15	13.47	11.52	11.82	5.55	8.11
August	28.57	13.68	13.19	37.09	9.42	3.84	8.32	11.55
September	15.66	9.13	6.19	23.86	6.16	2.21	5.88	8.30
October	12.22	7.31	15.39	37.97	5.01	1.73	5.45	8.14
November	13.15	12.93	17.77	-	5.57	4.95	7.64	-
December	6.39	5.64	6.34	-	3.94	2.38	6.36	-
Annual mean	13.39	3.08	9.42	(10 month) 15.07	5.51	1.77	-	(10 month) 7.28
June 1982 - May 1983				8.75 m³/S	June 1982 - May 1983			6.12 m³/S
October 1982 - September 1983				12.69 m³/S	October 1982 - Sept. 1983			7.01 m³/S

Annual flows

The Hydrology Section of the MoWD normally presents annual flow data as per calendar year. However, the record of the automatic water level recorder at the Muruny River (June 1982 - October 1983) does not cover a calendar year. For the Suam River the record runs from January 1982 - October 1983. On the other hand rainfall data have been updated from April 1982 - April 1983 for the Suam River catchment and for the Muruny River catchment from June 1982 - May 1983. Therefore annual flows are analysed and presented as per "hydrological year". Because of the rainfall data the "hydrological year" for the Suam River was taken from April, i.e. start of the early rain, till March, i.e. end of the dry season and from the Muruny River from June till May. In Table 4.8 the annual runoff data have been

summarised (Table 4.6) and for the two catchments the runoff-rainfall ratios are calculated. A comparison between the 1982/1983 runoff and rainfall data and the longterm mean figures, shows that rainfall and runoff are not consistent.

Table 4.8 Annual runoff data.

		1982-1983	Longterm mean	"Average" year
RGS - 2B7, Suam River at Kangoloi		April-March	1956-1972	
Total outflow	$m^3 \times 10^6$	303.8	420	285
Mean annual flow	m^3/S	9.6	13.5	9
Runoff depth	mm/Yr.	225	315	210
Rainfall depth	mm/Yr.	1250	1175*)	1175*)
Runoff-rainfall	ratio	0.18	0.27	0.18
Evaporation, Epan	mm/Yr.	1950		
RGS - 2B31, Muruny River at Marich-Pass		June-May	1957-1972	
Total outflow	$m^3/10^6$	196.7	175	220
Mean annual flow	m^3/S	6.2	5.5	6.9
Runoff depth	mm/Yr.	145	130	160
Rainfall depth	mm/Yr.	1065	1150*)	1150*)
Runoff-rainfall	ratio	0.14	0.11	0.14
Evaporation - Epan	mm/Yr.	1925		

*) Estimated from isohyetal map for longterm annual rainfall (Plate 4.2)

The inconsistency could be due to the tentative character of the rating curves applied and the relative unreliable water level and rainfall records. Also the difference between flows calculated from staff gauge readings and automatic water level recorders has to be taken into account.

Assuming that the 1982/1983 runoff and rainfall data are more reliable than the past data 1956-1972, the calculated runoff-rainfall ratios can be considered as a first approximation.

Applying the 1982/1983 runoff-rainfall ratios, the "average" year runoff and runoff depth was calculated from the longterm mean annual rainfall (Plate 4.2). The "average" year figures indicate that for the Suam River catchment, either the mean annual rainfall has been under estimated or the 1956-1972 runoff has been over estimated. Whereas for the Muruny River catchment the rainfall could be over estimated or the 1956-1972 runoff could be under estimated. The latter can be attributed to the difference between daily flows based on staff gauge readings and daily flows calculated from water level recorder charts.

4.7 Water Balance

The components of the water balance generally taken into account are given by the following equations:-

Precipitation = Evaporation + Runoff + Percolation + Change in soil moisture content + Change in surface water retention.

If the water balance is calculated over a one-year period it can be assumed by first approximation that the soil moisture content and the surface water retention at the beginning of the year are equal to the values at the end of the one-year calculation period. Thus both terms become zero, and the equation simplies to:

$$P = E_a + R + G$$

where P = average rainfall in mm

E_a = actual evapotranspiration

R = Surface water runoff

G = Groundwater recharge or percolation

From the annual water balance the percolation can be assessed;

the percolation equals the rainfall minus the surface water runoff and the actual evaporation:

$$G = P - E_a - R$$

However, in practice it becomes very difficult to give a relatively accurate figure for the actual evapotranspiration. This would require additional studies on the vegetation pattern, cover and the consumptive use for each type of vegetation, trees, bushes and crops.

Considering the hydrogeological conditions in West Pokot (Section 5) the annual regional groundwater recharge will be very limited, i.e. in the order of less than 1% of the annual rainfall. Which in fact is negligible in comparison to the

other water balance components. The actual evepotranspiration therefore will be in the order of 900 - 1000 mm per year (Table 4.8). The main source of groundwater recharge of isolated groundwater bodies are the river beds.

4.8 Surface water quality

In the past, surface water samples were collected only at four gauging stations: 2B 7 on the Suam River, 2B 24 and 2B 31 on the Muruny River and 2B 28 on the Wei Wei River. The analyses of these samples, obtained from the MoWD files, are listed in Table 4.9.

During the ASAL Water Survey (November 1983 - February 1984) the surface water was sampled at circa 100 sites. The chemical analyses of selected 22 samples are listed in Table 4.10. These samples represent water from both major rivers and small seasonal streams.

The analyses of all major ions are available only for three samples from Suam River at Kacheliba (2B 7). In all other analyses, the Na + and K+ concentrations were not determined.

Considering the total dissolved solid content (TDS) of water, the three major rivers - Suam, Muruny and Wei Wei - contain low mineralised water with TDS content lower than 150 mg/l.

The TDS content of water samples from 18 minor streams varies from 21 mg/l to 360 mg/l with only 4 samples exceeding 150 mg/l.

The bicarbonate is the major anion in all samples. As for the cations, no values are available for sodium and potassium. The differences between sum anions and sum cations, however indicate, that Na+ and K+ concentrations are lower than those of calcium.

Some of the samples show a relatively high iron content which may be attributed to solution of iron from the lateritic soils.

The fluoride concentration in all samples is below 1 mg/l. Generally speaking, the surface water at all sampling sites is of good anorganic quality when judged by the WHO International Standards for drinking water. Only the iron concentrations exceed the recommended standard.

It must be stressed however that the composition of surface water is subject to rapid changes in time. A single sample can therefore never be considered as a representative one for a long period. A frequent sample collection is necessary to monitor the eventual changes in the water quality.

Table 4.9 Chemical data from MoWD files

SOURCE	DATE OF sampling	pH	EC (µS/cm)	mg/l												Hard. ($CaCO_3$)	TDS (mg/l)
				Na	K	Ca	Mg	Fe	Mn	Cl	HCO_3	SO_4	NO_3	F	SiO_2		
Suam- 2B7	21.03.73	7.6	210	14	4	22	6	0.2	0.2	1	134	1	0.0	0.2	20	76	126
	01.04.75	8.4	180	13	3.9	19	5.3	1.0	0.0	4	120	4	0.0	0.8	-	70	110
	12.06.75	7.8	125	7.5	2.0	11	3.4	0.5	0.3	3	60	10	0.2	0.2	-	42	77
Muruny-2B24	08.07.75	7.0	130	-	-	16	5.8	0.4	0.0	1	-	-	-	0.2	-	64	78
	15.12.81	8.1	125	-	-	23	9.5	2.0	0.1	4	125	-	-	0.2	-	72	75
Muruny-2B31	28.04.83	7.7	140	-	-	18	5.6	-	0.0	1	22	8	-	0.3	-	64	84
Wei Wei-2B28	16.12.81	7.9	110	-	-	10	3.7	0.2	1.3	2	74	-	-	-	-	40	66
	28.04.83	7.4	80	-	-	10	2.8	-	0.0	1	15	0	-	0.1	-	36	48

Table 4.10 Chemical data ASAL Water Survey

ASAL Field no.	Source*	Sampling date	pH	EC (µS/cm)	mg/l								Hard **	TDS (mg/l
					Ca	Mg	Fe	Mn	Cl	HCO_3	SO_4	F		
09	Suam River	15.11.83	8.4	140	14	4.9	9.0	0.0	3	98	2	0.4	56	84
16	Suam River	15.11.83	7.7	150	22	2.0	12	0.0	4	83	1	0.4	60	90
20	Chemayo Stream	22.11.83	8.0	140	18	8.5	1.9	0.0	7	104	2	0.5	81	84
22	Muruny River	22.11.83	7.8	100	16	4.1	2.5	0.0	8	96	2	0.2	57	60
24	Parua River	17.11.83	7.6	100	14	4.9	1.1	0.0	5	68	2	0.2	54	60
44	Kolopot Stream	24.11.83	8.2	225	26	8.3	0.0	0.0	5	166	2	0.3	100	135
49	Saya Stream	22.11.83	8.3	600	63	31	1.0	0.0	35	244	74	0.7	287	360
68	Tirken River	22.11.83	8.1	540	50	20	3.5	0.0	61	243	4	0.3	210	324
71	Ortum River	12.11.83	7.9	195	25	9.2	0.0	0.0	6	100	10	0.2	82	117
83	Iyon River	23.11.83	8.0	195	21	10	2.6	0.0	9	122	2	0.3	92	117
97	Chemorei Stream	23.11.83	8.0	210	21	6.6	2.2	0.0	9	159	2	0.4	95	126
107	Chepnyal Stream	23.11.83	7.8	110	11	8.2	0.8	0.0	4	61	4	0.4	62	66
115	Ptoyo Stream	24.11.83	8.2	600	66	32	0.0	0.0	50	346	43	0.5	294	360
117	Mayaya Stream	24.11.83	8.4	140	14	4.9	9.0	0.0	3	98	2	0.4	56	84
200	Apollo Stream	31.10.84	6.7	70	5.6	2.4	1.4	0.0	6	44	0	0.2	24	42
204	Siya River	01.02.84	7.0	180	14	5.3	1.2	0.0	5	73	2	0.0	58	108
244	Wei Wei River	02.02.84	7.5	170	19	8.3	14	0.0	6	63	3	0.0	82	102
272	Orwa River	02.02.84	7.0	95	8.8	3.9	0.2	0.0	6	54	3	0.1	38	57
309	Kapsai Stream	06.02,84	6.5	36	3.2	2.0	2.0	0.0	4	34	1	0.0	16	21
318	Kunyanga River	31.01.84	7.3	290	35	19	-	-	8	163	5	0.0	164	174
320	Chepkono Stream	06.02.84	6.2	40	3.2	1.0	2.0	0.0	5	46	1	0.0	12	24
343	Matembur Stream	07.02.84	7.1	280	25	12	-	0.2	8	80	1	0.1	108	168

* for location see plate 4.1 ** Tot.hardness in mg $CaCO_3$/ 1 - not determined.

5. HYDROGEOLOGY

5.1 Previous hydrogeological studies

The "Water Resources study for the Kerio Valley Basin" by Sogreah (1981), which includes also the West Pokot District, is the only regional study dealing with the groundwater conditions in this district. The present project area coincides with the hydrogeological unit 5 in Sogreah's report. The general conclusions are as follows:

"There is not a general aquifer, but small local water-bearing formations may exist: alluvial deposits of the Suam, areas of weathered or fractured hard rock forming part of the Basement System. Only a very small number of wells have been identified. Of all the units in the project area, this unit seems to be the least favoured as far as groundwater development potential is concerned".

The geological reports published by the geological survey of Kenya (see section 2.1) give a brief summary on the availability of groundwater for each corresponding map sheet. The hand-dug wells in the river beds are mentioned as the major source of groundwater.

5.2 Available data

5.2.1 Aerial photographs and Landsat data

Aerial photographs on a 1:62000 scale were available for the regional survey. Additionally, scale 1:18000 photographs were used for the detailed investigations. The interpretation of these photographs yielded information on the accessibility of the area, drainage pattern, lithological boundaries and structure. A preliminary structural map, based on the Landsat data interpretation by Geosurvey, was used for the location of the major structures (see section 2.1).

5.2.2 Boreholes

In the fifties, several boreholes were drilled in Kacheliba division (former Karasuk) under the supervision of the Geological Survey of Uganda. Twelve drilling reports could be traced in the files of the Ministry of Water Development. These boreholes with the code "CD" are situated between Kacheliba and Kunyao. Available data of the boreholes are summarized in Table 5.1. Their locations are shown in Plate 5.1.

Table 5.1 Borehole data from MoWD files

BH. NO.	Location	Depth (m)	Completion Date	Struck Level (m)	Rest Level (m)	Yield (m^3/h)
CD 147	Kunyao W	30	19-06-42	22 & 27	14.0	2.5
CD 268	Kunyao W	30	26-10-45	20	12.0	3.0
CD 814	Karameri	55.5	14-12-51	21 & 53	14.5	3.5
CD 825	Karameri	62.5	02-01-52	20 & 55	20.7	0.5
CD 987	Koduch	93	28-04-53	65 & 89	54.9	2.5
CD 989	Kachekelekenei	208.5	01-07-53	107 & 181	80.0	0.2
CD 1012	Kachekelekenei	120	28-07-53	87 & 117	75.5	1.5
CD 1503	Kunyao E	98	08-03-56	35 & 90	18.3	1.8
CD 1521	Koduch S	152	14-04-56	103 & 144	56.7	1.3
CD 1548	Chepulatina	61	30-04-56	52	18.6	2.0
CD 1560	Kachekelekenei	69	12-05-56	60	25.0	1.3
CD 2306	Kacheliba	70.5	01-07-59	56	50.3	1.0
C 2293	Kapenguria	45	16-11-54	?	20.7	3.0
C 4557	Marich Pass	81	21-02-79	42	37.4	6.5

A summary of available borehole data for the whole of West Pokot District (including the northen part of Kacheliba division) is given in Annex 5.4.
More information on existing shallow boreholes will be presented in ASAL Report "Water Survey West Pokot District" (in preparation).

Fifteen boreholes were drilled within the framework of the present WRAP study, sites were selected according to the water demand. Their locations are shown on Plate 5.1. Twelve boreholes were drilled with a rotary rig and three with a percussion rig. The depth of the boreholes varies between 41 and 72 m. Table 5.2 summarizes the drilling data.

Table 5.2 Borehole data from WRAP

Borehole Number	Location	Coordinates X	Coordinates Y	Sheet No.	Surface Elevation (m + msl)	Total depth (m)	Completion date	Water struck level depth (m)	Water struck level elevation (m + msl)	Water rest level depth (m)	Water rest level elevation (m + msl)	Geol. log	Geoph. log	Well test	W. sample	Rock form.
C 5414	Morobus 1	7527	1539	75/2	1620	48	31-10-83	24 42	1596 1578	14.9 17.5	1605 1602	X	X	X	X	B
C 5415	Morobus 2	7529	1541	75/2	1620	47.5	07-11-83	31 43	1599 1577	21.7 14.9	1598 1605	X	X	X	X	B
C 5416	Psurum 1	7461	1543	75/1	1560	68	11-11-83	24	1536	20.9	1539	X	X	X	X	B
C 5428	Psurum 2	7466	1541	75/1	1560	50	22-11-83	24	1536	11.4	1559	X	X	X	X	B
C 5429	Chepkopegh 1	7478	1619	75/1	1500	47	30-11-83	30 42	1470 1458	12.3 12.4	1488 1488	X	X	X	X	B
C 5430	Chesera	7366	1603	75/1	1360	41	16-12-83	12 18	1348 1342	8.5 8.6	1351 1351	X	-	X	X	S
C 5431	Serewa	7225	1476	75/1	1400	36.5	02-04-84	24	1376	17.1	1383	X	-	X	X	S
C 5432	Matembur 1	7273	1503	75/1	1440	61	27-03-84	23	1317	41.1	1399	X	-	-	-	B
C 5488	Kokwomeses 1	7927	1455	76/1	1000	51	14-11-83	38	962	27.8	972	X	-	-	-	S
C 5489	Kokwomeses 2	7926	1455	76/1	1000	72	30-01-84	52	948	26.9	973	X	-	-	X	S
C 5538	Psurum 3	7457	1532	75/1	1580	67	25-01-84	35	1545	19.2	1561	X	X	X	X	B
C 5539	Chepkopegh 2	7478	1609	75/1	1510	64	06-02-84	43	1467	33.3	1477	X	X	-	X	B
C 5540	Chepkopegh 3	7480	1621	75/1	1500	68	27-02-84	18	1482	6.5	1493	X	X	X	X	B
C 5541	Kangalan	7891	1543	76/1	1150	64	28-02-84	dry	-	-	-	X	-	-	-	S
C 5807	Matembur 2	7225	1494	75/1	1420	50	19-04-84	dry	-	-	-	X	-	-	-	B

The geological logs are presented in Annex 5.1. These are based on the samples collected during drilling at one or two meter interval.

5.2.3 Shallow wells

Many hand-dug wells can be found along the major rivers but most of them are not permanent. Sixty six shallow wells with hand-pumps were constructed in West Pokot (including the northern part of Kacheliba division) during an anti-cholera campaign in 1980 and 1981. The data on shallow wells have been collected during the ASAL Water Survey and will be presented in a separate report.

5.2.4 Well test data

Tested yields for the existing boreholes, as listed in Table 5.1 are based only on the capacity of the pump. The drawdowns were not measured and consequently the values for specific capacity and transmissivity could not be calculated. Nine well tests and three bailer tests were carried out in the boreholes drilled in WRAP. Data obtained from the pumping phase were in some cases difficult to interpret because of problems with the pumping rate..

The well test data were analysed using Jacob's method for the pumping phase and Theis's method for the recovery (Kruseman and and de Ridder, 1970). The analysis are shown in Annex 5.2 and the results are summarized in Table 5.3. The transmissivity values (T= hydraulic conductivity times thickness of the aquifer) obtained from the recovery phase are preferred to values obtained from the pumping phase since these latter values are more sensitive to fluctuating pump discharge.

The specific capacity is another parameter derived from the well test. The specific capacity of a well is the yield produced per meter drawdown (Q/s in m^2/day). The specific capacity can be used to estimate the well yield corresponding to a given drawdown. In the last column of Table 5.2, the well yield for a drawdown of 10 m has been calculated for each borehole.

5.2.5 Groundwater levels

The data on water struck level and water rest level are listed in Tables 5.1 and 5.2. The water struck level corresponds with the depth below the surface at which groundwater is encountered during the drilling. The water rest level represents the final level to which groundwater rose or fell. The groundwater level

Table 5.2 Borehole data from WRAP

Borehole Number	Location	Coordinates X	Coordinates Y	Sheet No.	Surface Elevation (m + msl)	Total depth (m)	Completion date	Water struck level depth (m)	Water struck level elevation (m + msl)	Water rest level depth (m)	Water rest level elevation (m + msl)	Geol. log	Geoph. log	Well test	W. sample	Rock form.
C 5414	Morobus 1	7527	1539	75/2	1620	48	31-10-83	24 42	1596 1578	14.9 17.5	1605 1602	X	X	X	X	B
C 5415	Morobus 2	7529	1541	75/2	1620	47.5	07-11-83	31 43	1599 1577	21.7 14.9	1598 1605	X	X	X	X	B
C 5416	Psurum 1	7461	1543	75/1	1560	68	11-11-83	24	1536	20.9	1539	X	X	X	X	B
C 5428	Psurum 2	7466	1541	75/1	1560	50	22-11-83	24	1536	11.4	1559	X	X	X	X	B
C 5429	Chepkopegh 1	7478	1619	75/1	1500	47	30-11-83	30 42	1470 1458	12.3 12.4	1488 1488	X	X	X	X	B
C 5430	Chesera	7366	1603	75/1	1360	41	16-12-83	12 18	1348 1342	8.5 8.6	1351 1351	X	-	X	X	S
C 5431	Serewa	7225	1476	75/1	1400	36.5	02-04-84	24	1376	17.1	1383	X	-	X	X	S
C 5432	Matembur 1	7273	1503	75/1	1440	61	27-03-84	23	1317	41.1	1399	X	-	-	-	B
C 5488	Kokwomeses 1	7927	1455	76/1	1000	51	14-11-83	38	962	27.8	972	X	-	-	-	S
C 5489	Kokwomeses 2	7926	1455	76/1	1000	72	30-01-84	52	948	26.9	973	X	-	-	X	S
C 5538	Psurum 3	7457	1532	75/1	1580	67	25-01-84	35	1545	19.2	1561	X	X	X	X	B
C 5539	Chepkopegh 2	7478	1609	75/1	1510	64	06-02-84	43	1467	33.3	1477	X	X	-	X	B
C 5540	Chepkopegh 3	7480	1621	75/1	1500	68	27-02-84	18	1482	6.5	1493	X	X	X	X	B
C 5541	Kangalan	7891	1543	76/1	1150	64	28-02-84	dry	-	-	-	X	-	-	-	S
C 5807	Matembur 2	7225	1494	75/1	1420	50	19-04-84	dry	-	-	-	X	-	-	-	B

The geological logs are presented in Annex 5.1. These are based on the samples collected during drilling at one or two meter interval.

5.2.3 Shallow wells

Many hand-dug wells can be found along the major rivers but most of them are not permanent. Sixty six shallow wells with hand-pumps were constructed in West Pokot (including the northern part of Kacheliba division) during an anti-cholera campaign in 1980 and 1981. The data on shallow wells have been collected during the ASAL Water Survey and will be presented in a separate report.

5.2.4 Well test data

Tested yields for the existing boreholes, as listed in Table 5.1 are based only on the capacity of the pump. The drawdowns were not measured and consequently the values for specific capacity and transmissivity could not be calculated. Nine well tests and three bailer tests were carried out in the boreholes drilled in WRAP. Data obtained from the pumping phase were in some cases difficult to interpret because of problems with the pumping rate..

The well test data were analysed using Jacob's method for the pumping phase and Theis's method for the recovery (Kruseman and and de Ridder, 1970). The analysis are shown in Annex 5.2 and the results are summarized in Table 5.3. The transmissivity values (T= hydraulic conductivity times thickness of the aquifer) obtained from the recovery phase are preferred to values obtained from the pumping phase since these latter values are more sensitive to fluctuating pump discharge.

The specific capacity is another parameter derived from the well test. The specific capacity of a well is the yield produced per meter drawdown (Q/s in m^2/day). The specific capacity can be used to estimate the well yield corresponding to a given drawdown. In the last column of Table 5.2, the well yield for a drawdown of 10 m has been calculated for each borehole.

5.2.5 Groundwater levels

The data on water struck level and water rest level are listed in Tables 5.1 and 5.2. The water struck level corresponds with the depth below the surface at which groundwater is encountered during the drilling. The water rest level represents the final level to which groundwater rose or fell. The groundwater level

Table 5.3 Well test data

Borehole Number	Location	Depth (m)	Aquifer system*	Test date	Disch. Q (m^3/day)	Drawdown s (m)	Q/s (m^2/day)	T-Pump (m^2/day)	T-Recovery (m^2/day)	Init-rest level (m)	Yield ** (m^3/h)
C 4557	Marich Pass	81	SF	19-02-75	158	2.90	54.5	-	72.3	37.4	23
C 5414	Morobus 1	48	FB	18-01-84	144	18.90	7.6	1.9	2.4	17.3	3
C 5415	Morobus 2	47.5	FB	23-01-84	140	27.70	5.0	3.5	1.2	14.9	2
C 5416	Psurum 1	68	WB	17-02-84	25	37.20	0.7	1.0	1.1	20.1	0.5
C 5428	Psurum 2	50	WB	10-02-84	43	18.30	2.3	-	5.6	11.4	1
C 5429	Chepkopegh 1	47	WB	26-03-84	70	26.0(in 35 minutes)		-	-	13.4	0.5
C 5430	Chesera	41	AS	30-03-84	185	0.77	240	280	280	9.4	100***
C 5431	Serewa	36.5	AS	12-04-84	165	3.81	43	-	38	17.2	18
C 5432	Matembur 1	61	WB	-	borehole almost dry		-	-		41.1	-
C 5488	Kokwemeses 1	51	FS	-	borehole almost dry		-		-	27.8	<0.1
C 5489	Kokwomeses 2	72	FS	06-02-84	Bailer test; borehole empty after 45 min.					26.9	<0.5
C 5538	Psurum 3	67	FB	31-01-84	50	18.40	2.7	2.3	1.5	19.2	1
C 5539	Chepkopegh 2	68	FB	19-03-84	Bailer test; borehole empty after 1 hour					33.3	<0.5
C 5540	Chepkopegh 3	68	WB	15-03-84	70	35 (in 2 hours).		-	-	5.5	<1
C 5541	Kangalan	64	FS	-	dry	-	-	-	-	-	-
C 5807	Matembur 2	50	WB	-	dry	-	-	-	-	-	-

* SF = Scree Fan
FB = Fractured Basement
WB = Weathered Basement
AS = Alluvial Sediment
FS = Floodplain Sediment

** Yield per S = 10m^3/h
*** Uncertain

elevations above mean sea level were estimated from the 1:50000 topographical map. The groundwater level fluctuations were monitored in boreholes CD 147, 825, 1503 and 2306. The readings have been taken once monthly from November 1982 to May 1983. The data are listed in Annex 5.3. No data are available of groundwater fluctuations in newly drilled boreholes because most of the boreholes were completed during the final phase of the project.

5.2.6 Chemical data

Fourteen groundwater samples were collected from 11 boreholes, during well tests. The samples were analysed in the laboratory of the Ministry of Water Development. The analyses are not complete since natrium and potassium concentrations could not be determined. The available data are listed in Table 5.4.

5.3 Groundwater occurrence

The groundwater occurrence is controlled by the available recharge and geological conditions of the area.

As already outlined in Chapter 2, the investigated area is composed mainly of metamorphic Basement rocks. Fresh metamorphic rocks can be considered as impermeable and have no storage capacity. Groundwater in exploitable quantities is only found in weathered and fractured zones in these rocks.

The nonindurated sediments, which are represented by Tertiary grits and Quanternary fluvial and piedmont deposits, store and transmit water. The occurrence of groundwater in these sediments depends on the size and sorting of the grains.

The general aquifer conditions in the Basement rocks and in the sediments are briefly outlined below. The local aquifer conditions are further discussed in Section 5.4 for each of the selected areas.

Table 5.4 Chemical data

Borehole No.	Date of Sampling	pH	EC (µS/cm)	mg/l												Hardness $(CaCO)_3$	TDS (mg/l)
				Na	K	Ca	Mg	Fe	Mn	Cl	HCO_3	SO_4	NO_3	F	SiO_2		
C 5414	18-01-84	8.0	960	-	-	75	78	5.4	0.0	108	373	19	-	0.2	-	420	576
C 5415	23-01-84	8.1	740	-	-	55	47	0.3	0.0	15	515	57	-	0.6	-	328	444
C 5415	24-01-84	7.9	760	-	-	36	58	0.6	0.0	14	312	88	-	0.6	-	326	456
C 5416	17-02-84	7.8	1330	-	-	111	18	1.2	0.0	34	237	370	-	0.6	-	386	810
C 5416	18-02-84	8.0	1440	-	-	119	19	0.0	0.0	43	278	374	-	0.5	-	412	840
C 5428	11-02-84	7.8	290	-	-	29	9	2.2	0.0	5	151	5	-	0.2	-	110	174
C 5429	26-03-84	8.2	660	-	-	54	54	0.1	0.0	15	365	5	-	1.0	-	266	396
C 5430	30-03-84	7.7	440	-	-	35	15	0.2	0.0	7	224	13	-	0.6	-	146	264
C 5431	02-05-84	7.8	300	-	-	24	12	1.7	-	8	192	2	-	0.4	-	110	180
C 5489	02-02-84	7.7	2100	-	-	53	55	15.0	0.0	368	624	30	-	0.5	-	358	1260
C 5538	31-01-84	8.0	1500	-	-	134	72	1.0	0.0	41	312	512	-	0.5	-	630	900
C 5539	19-03-84	8.0	3200	-	-	282	139	0.0	-	370	405	576	-	0.5	-	1272	1920
C 5540	13-03-84	7.8	495	-	-	37	26	0.1	0.0	9	180	24	-	1.1	-	200	294
C 5540	13-03-84	7.9	730	-	-	70	31	0.1	0.0	12	207	132	-	1.0	-	300	438

- not determined

5.3.1 Aquifer conditions in the Basement rocks

The results of the hydrogeological studies carried out in various areas of the African Basement Complex (Clark, 1982) indicate that there are no regional aquifers. The aquifer properties vary strongly over the studied areas. They are related to the structural and climatological history of the areas involved. The groundwater occurrence in the basement areas of West Pokot is a function of:

- available recharge
- degree of weathering
- width and length of the fissures and fractures
- interconnection between the fractures

5.3.2 Aquifer conditions in nonindurated sediments

Small patches of alluvial deposits occur in and along lower courses of all major streams. These sediments mainly consist of sand and gravel. These alluvial aquifers are usually recharged from influent rivers, where hydraulic continuity exists between sediments and rivers.

Extensive floodplain sediments developed only along the river Suam, Wei Wei and Kerio. The clayey character of these floodplain sediments prevents vertical recharge. Results from the investigation in the Kerio Valley (MoWD, 1984) showed that floodplain sediments form poor aquifers, except in the places where they are interbedded with layers of coarse sediments.

Torrent-wash deposits are generally coarser than floodplain sediments and may locally form good aquifers.

The hydrogeological characteristics of the Turkana grits are not known.

5.4 Detailed investigations

The main purpose of the detailed investigations was to indicate suitable sites for new boreholes in areas with a high water demand. These drilling sites were determined by geological methods and surface geophysical methods.

The geological methods included remote sensing techniques and ground reconnaissance surveying. As for the remote sensing, the interpretation of Landsat data by Geosurvey International (see section 2.5) was used to determine the major linear structures. In addition to the Landsat data, aerial-photo interpretation was carried out for each area. The photographs (on 1:18000 scale) gave a more detailed information on the drainage pattern, vegetation and presence of faults and dykes. In some cases, however, the regional linear structures, obtained from Landsat data, were not obvious on photographs as these cover only small areas. The geological survey was concentrating mainly on the lithology of the outcropping formation.

The geophysical investigation consisted of both a resistivity method and a seismic survey. The short description of the geophysical methods is given in chapter 3.

5.4.1 Morobus (Boreholes C 5414 and C 5415)

Geology

The area is composed of partly weathered biotite gneisses with pegmatite veins. The main strike of the rocks is 170°S with a dip of 45°. Thin cover of alluvial sediments developed near the river.

Three major lineaments were located, running in the south-north direction.

Drilling sites

Two sites were selected in the lineaments on the both sides of the river. Borehole C 5414 was drilled on the southern side, about 10 m from the river. Borehole C 5415 on the northern side is situated at 20 m from the river. The total depth of the boreholes is 48 and 47.5 m respectively.

Aquifer conditions

The geological logs (Annex 5.1) confirmed the presence of weathered zones which were predicted by geophysical measurements. These zones are characterized by a clayey upper layer (probably including alluvial sediments) and partly or completely decomposed gneisses. At a depth of about 20 m, fresh gneisses were found. The weathered pegmatite veins and the fractures in the fresh gneisses form a major waterbearing system as indicated by the reported water struck levels (Table 5.1).

In borehole C 5414 groundwater was struck at 24 and 42 m below surface. Also in borehole C 5415 groundwater was struck below the upper weathered zone, at 31 and 43 m. The final rest levels in the boreholes, 17.5 and 14.9 m respectively, indicate confined conditions in both aquifers.

Transmissivity and yields

The well tests (Table 5.3) gave transmissivity values of 2 m^2/h and 1 m^2/day for C 5414 and C 5415 respectively. The yields of 3 m^3/h and 2 m^3/h, calculated for a drawdown of 10 m, are considered as moderate in the Basement rocks.

Groundwater quality

The analysis of groundwater samples (Table 5.3) show a clear difference in the chemical composition of water from the two boreholes. The sample from C 5414 contains moderately high mineralized water with higher Mg, Fe and Ca and Cl concentrations when compared with the water from borehole C 5415. The later borehole contains less mineralized water with a relative high HCO_3 and SO_4 concentrations. These differences are an indication that these groundwater types probably come from different sources.

The groundwater in both boreholes has a low fluoride content From anorganic point of view it is suitable as drinking water.

5.4.2 Psurum (Boreholes C 5416, 5428 and 5538)

Geology

The Basement rocks are mainly represented by the hornblende gneisses. The strike of the rocks, outropping in the river Iyon is south-north. Along the river Iyon thin alluvial deposits occur.

No clear lineaments were observed on the aerial photographs. The geophysical measurements, though, indicated several anomalous zones which may indicate weathering and fracturing.

Drilling sites

Three boreholes were drilled in this area. Two sites (C 5416 and C 5428) were selected in a possibly fractured zone near the village centre. The third borehole (C 5538) was drilled south of Psurum, into rocks which, according to the geophysical survey, constituted a deep weathered zone. The depth of boreholes varied from 50 to 68 m.

Aquifer conditions

According to the geological logs, all three boreholes penetrate weathered and fractured zones. The thickest zone of completely weathered rocks, which appears in the logs as clayey material, is found in borehole C 5538. It is likely that this zone prevents vertical recharge to the aquifer. Below the clayey zone partly weathered gneisses occur. In borehole C 5416 this zone continues to about 60 m below surface where fresh gneisses were struck. In the other two boreholes fresh rock is found at 40 m (C 5428) and 25 m (C 5538) respectively. The presence of thin layers of loose material within the fresh rock may indicate either open fractures or weathered pegmatite - or quartz-veins.

From the reported water struck levels (Table 5.1) it seems that boreholes C 5416 and 5428 abstract water from the weathered zone while borehole C 5538 draws from the fractures. The differences between water struck levels and water rest levels indicate confined conditions in all three aquifers. The rest levels vary from 11 m in C 5428 to 21 m in C 5416.

Transmissivity and yields

The transmissivity values are low being 1.0, 5.5 and 1.5 m^2/ day for respectively C 5416, C 5428 and 5538. The corresponding yields are respectively 0.5, 1 and 1 m^3/hours. The yield difference between the first two boreholes which are situated in the same weathered zone may be attributed to the available recharge. The borehole C 5428 is situated near the river Iyon where the aquifer is at least partly recharged by infiltrating river water.

Two different groundwater types were identified. The samples from C 5416 and C 5538 contain high mineralized water with very high sulphate content. Both the TDS and sulphate content exceed the recommended WHO-limit for drinking water. The sample from C.5428 on the other hand contains low mineralized water and is suitable as drinking water.

5.4.3 Chepkopegh (Boreholes C 5429, C 5539 and C 5540)

Geology

The bedrock in the surroundings of Chepkopegh consists of biotite-gneisses and amphibolities. Several pagmatite veins running in southeast-northwest direction were encountered in and along the river Chepkopegh. Thin alluvial deposits occur locally in the river bed. Two lineaments were observed on the aerial photographs and confirmed by the geophysical measurements.

Drilling sites

Three drilling sites were selected. The first borehole (C 5429) was drilled in the village centre on a small resistivity anomaly. The second borehole (5539) is situated southwest of the school on one of the lineaments. The third site (C 5540), indicated by geophysics as the most promising one, was selected near the river Chepkopegh in a potentially fractured zone. The total depth of the boreholes amounts to 47, 64 and 68 m respectively.

Aquifer conditions

Unlike the previous areas, the soil cover is almost lacking. Only in the geological log of C 5429 a thin layer of clayey material covering hard rock is found. The thickness of partly weathered gneisses is at all sites approximately 30 m. In borehole C 5429 and C 5540 groundwater was struck in this layer . In C 5539, though, the groundwater is found beneath a zone of slightly fractured fresh rock. The water rest levels vary from 6.5 m below surface in C 5540 to 33 m below surface in C 5539.

Transmissivity and yields

The rapid drawdown in all three boreholes indicates very low transmissivities. Consequently all yields are below 1 m^3/h. These low yields are disappointing, especially for borehole C 5540 where river water was expected to recharge the fractured zone.

Groundwater quality

In borehole C 5429 and C 5540 moderately mineralized water of good anorganic quality was found. Borehole C 5539, on the other hand, contains saline water with high Ca, Mg, Cl and SO_4 concentrations.

5.4.4 Chesera (Borehole C 5430)

Geology

The area is dominated by the Chesera River. A relatively broad belt of alluvium was deposited along the river. These clays , sands and gravels cover the gneisses and amphibolites of the Basement System. No lineaments were observed on the aerial photographs. Two fractured zones, running in west-east and northwest-southeast directions were identified by geophysics.

Drilling site

Borehole C 5428 was drilled circa 150 m southwest of the school. Its location took into account the short distance to the river and the relatively great depth of the bedrock. The total depth of the borehole amounts to 41 m.

Aquifer conditions

The geological log of borehole C 5430 shows four lithological zones. The clayey upperpart of 12 m represents the recent flood plain sediments.

Coarse sand and gravel below it is 14 m thick. This zone may represent an old river channel. The zone of weathered gneisses, which underlay the sediments is around 14 m thick. The fresh Basement rocks were encountered at 40 m below surface. The groundwater was struck in the gravel and sand zone at 12 and 18 m below surface. The clayey sediments above this zone are responsible for the confined conditions in the aquifer.

Transmissivity and yield

The transmissivity value of 280 m^2/day is the highest value found in West Pokot. The coarse sediments and possible recharge from the river creates unique aquifer conditions which are not encountered in the weathered and fractured Basement rocks. The theoretical yield, calculated for a drawdown of 10 m amounts to 100 m^3/hour. However, the recommended yield should not exceed 50 m^3/hour, because it is difficult to estimate the groundwater recharge, especially during dry periods.

Groundwater quality

Groundwater found in Chesera borehole has a moderately high total dissolved solids content and a low fluoride concentration. The water is of a good anorganic quality.

5.4.5 Serewa (Borehole C 5431)

Geology

The outcrops of Basement rocks in the valley of the Kunyanga river consist of biotite gneisses. At some places along the river alluvial sand deposits occur.

According to the Landsat data interpretation, two lineaments, in respectively southeast - northwest and southsoutheast - northnorthwest direction, cross the area. These lineaments, however, could not be traced on the aerial photographs. The geophysical investigations indicated several fractured zones, running in south-north direction.

Drilling site

Borehole C 5431 was drilled circa 60 m west of the village church to 36.5 m depth.

Aquifer conditions

An existing shallow well, dug near the river, has water throughout the year. The shallow groundwater table indicate an alluvial aquifer which is most likely fed by river water. The alluvial cover near the river is 10 m thick as appears from a geophysical profile (Annex 3.1). Further from the river a clay layer of about 20 m thickness has been identified by geophysics. Whether this clay represents floodplain sediments or completely decomposed gneisses is not known. In borehole C 5431 a layer of clayey material was found up to a depth of 24 m. Immediately below it, the main aquifer was struck the water rose to 17 m below surface. The material of this zone is described as gravel on top of weathered metamorphic rock. It is possible that this 2 m thick gravel layer represents an old meander of river Kunyanga.

Transmissivity and yield

A transmissivity value of 40 m^2/day was obtained from the well test analysis. This relative high value for Basement rock has to be attributed to the gravel layer. It is moreover possible that this aquifer is directly recharged by river water through a buried meander. The yield of the borehole amounts to 18 m^3/hour.

Water quality

Analyses of a water sample indicates a low mineralised groundwater of good anorganic quality.

5.4.6 Matembur (Borehole C 5432 and C 5807)

Geology

The bedrock in the surroundings of Matembur consists of biotite gneisses. No outcrops, however, were observed near the village. Alluvial deposits developed along a stream which crosses the Matembur - Serewa road 2.5 km southwest of the village. No lineaments were observed on the aerial photographs. The Landsat interpretation showed a southeast - northwest running lineament along the stream that crosses the Matembur - Serewa road. Geophysical measurements indicated clearly a fault at this site. Another, smaller, anomally was found 500 m west of the village.

Drilling sites

Two sites were selected. The first borehole, C 5432, was drilled at the anomally near the village and the second one, C 5807, is located in the fault zone near the river crossing. Total depth of the boreholes amounts to 61 and 50 m respectively.

Aquifer conditions

The geological log of borehole C 5432 shows a 5 m thick clay layer on the top of almost complete decomposed biotite gneiss. From 18 m to 57 m below surface partly to highly weathered and fractured gneisses were found. This zone includes several pegmatite veins. Fresh rock occurs in the last 4 m of the log.

The borehole was reported as almost dry. A little amount of perched water was struck at 23 m. The borehole C 5432, drilled at the second,more promising site, was completely dry.

The failure to struck groundwater in Matembur may be attributed to a high clay and mica content in the weathered zone and to a lack of interconnected fractures.

5.4.7 Kokwomeses and Kangalan (Boreholes C 5488, C 5541 and C 5541

Geology

Geological conditions of these locations differ from those previously described. Both locations are situated in the area of Quarternary sediments which borders on the Basement rocks of the Cherangani Hills. These sediments belong to floodplain deposits which fill the Kerio Valley Basin. Depth to the Basement rocks, beneath these deposits, exceeds at some places 100m as appears from the geophysical measurements. The great depth of Basement rocks is related to a displacement on the Lomut Fault, which is the major structural feature in the area.

Drilling Site

Two sites were selected at Kokwomeses and one site at Kangalan. Boreholes C 5488 and C 5489 were drilled on both sides of the Chesegon - Lomut road. Borehole C 5541 at Kangalan is drilled on the western side of the same road. All boreholes are situated on the downthrow side of the Lomut Fault. The depth of boreholes amounts to 51, 72 and 64m respectively.

Aquifer conditions

The entire geological section of boreholes C 5541 is composed of predominantly clayey material with some layers of sand and gravel. At the base of boreholes C 5488 and C 5489 weathered gneisses were found at 44 and 70 m respectively. No groundwater was struck in the Kangalan borehole C 5541. Little water was struck in boreholes C 5488 and C 5489 in sandy layers. Groundwater rose in both boreholes to circa 27m below surface. The aquifer conditions in Kokwomeses and Kangalan are similar to those in floodplain sediments in the Kerio River. The clayey character of these sediment prevents vertical recharge and groundwater is found only in layers of coarse material.

Transmissivity and yields

The bailer test, carried out in borehole C 5489, indicates a very low transmissivity. The borehole was empty after 45 minutes of bailing. The yield of this borehole is estimated at less than 0.5 m^3/hour. Borehole C 5488 was reported as almost dry and borehole C 5541 as completely dry.

Groundwater quality

Groundwater samples collected during the bailer test in borehole C 5489 contained slightly saline water with high chloride and iron concentration.

5.5 Regional groundwater conditions

As outlined in section 5.3, the groundwater in West Pokot occurs either in weathered/fractured metamorphic rocks or in fluviatile sediments.

5.5.1 Basement areas

In general, there are no regional aquifers in Basement rocks. The detailed investigations, carried out in six areas, showed great variations in depth to groundwater, transmissivity of aquifer and groundwater quality. These variations, occuring even over short distances in the same geological unit, highly complicate the systematic search of potential aquifers as the transfer of exploration techniques which proved to be successful at one site usually fail to produce tangible results elsewhere. Nevertheless, the best prospects for finding groundwater are offered by zones underlain by weathered and fractured rocks provided that they are sufficiently recharged.

The weathering profile of Basement rocks, as observed in the borehole logs and geophysical measurements, shows a similar sequence in all investigated areas: clayey (lateritic) layer on the top grades progressively or sometimes sharply into partly decomposed rock and finally into fresh rock. The thickness of clayey top layer varies from less than 1 meter in Chepkopegh to more than 10 m in Morobus. The fresh Basement rocks were found at depths between 20 (Morobus) and 60 m (Psurum).

Permeability of the weathered zone depends on the degree of decomposition of parent rocks. The weathering products of semi-pelitic gneisses, which are the main Basement rocks at all drilling sites, have generally a high clay and mica content. Pegmatite veins within the gneisses may weather into coarser material.

The yields of boreholes which abstract water from the weathered zone do not exceed 1 m^3/hour.

The permeability of unweathered Basement rocks depends on the presence of fractures, their geometry and interconnection. The observation at surface can give only a rough indication on the fracture pattern of deeper layers. The major structures, which appear on the aerial photographs, presumably continue to greater depths. The minor fractures can be located only with geophysical methods. Four boreholes penetrate the fractured gneisses in Morobus (2), Psurum and Chepkopegh. The yields of the latter two are low. The values are in the same order of magnitude as is nearby wells which tap the weathered zones. The two Morobus boreholes have higher yields (2 and 3 m^3/hour). Whether this should be attributed to a more developed fracture-system or to an additional recharge from nearby river is not clear. The groundwater rest level in both boreholes is lower than the riverbed, hence the infiltration of (seasonal) river water into aquifers is possible. On the other hand, the different chemical composition of groundwater in two boreholes suggests that at least one of the aquifers is recharged by another source than the river.

Available recharge is in fact the determining factor for the amount of abstractable groundwater. In the semi-arid parts of West Pokot, the recharge probably does not exceed 1% of total precipitation. A thick clay layer which developed on the top of weathered zone prevents infiltration of rain water. The Basement aquifers are recharged mainly through the open fractures or partly weathered rock surfaces. Infiltration of river water will considerably increase the amount of recharge, assuming there is a hydraulic connection between the river and aquifer. This may be the case in one of the Morobus boreholes (see above). On the other hand, boreholes at Chepkopegh and Matembur, drilled near the rivers, were reported as a low yield-borehole and a dry borehole respectively. Drilling near a river therefore does not always guarantee a successful well. However, there are two other aspects, which stress the importance of a river course in the Basement areas: Firstly, the course may be determined by a tectonic structure along which open fractures may have developed. Secondly, along the rivers, coarse sediments might have been developed with a considerably higher permeability than underlaying Basement rocks.

Several shallow wells draw water from alluvial aquifers along the rivers. Moreover, burried river channels may contain a large amount of groundwater as shown in the boreholes in Chesera and Serewa.

A schematic representation of hydrogeological conditions in a Basement area is shown in Figure 5.1 (Clark, 1982).

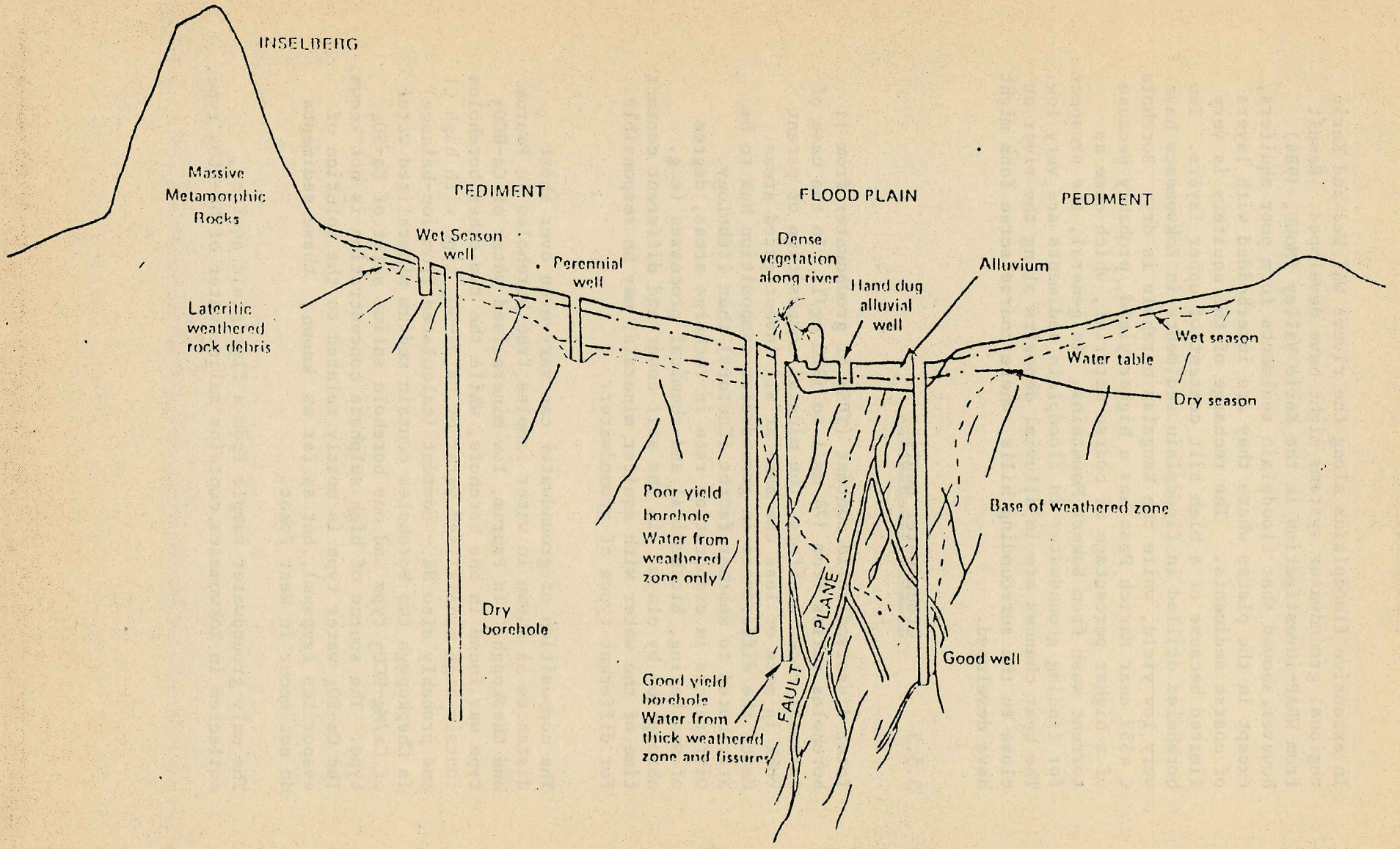


Figure 5.1 Diagrammatic basement complex hydrogeology (Clark, 1982)

5.5.2 Flood plains

In extensive floodplains along the rivers Wei Wei and Kerio regional groundwater systems might have developed. Result from WRAP-investigation in the Kerio Valley (MoWD, 1984) however, showed that floodplain sediments form poor aquifers, except in the places where they are interbedded with layers of coarse sediments. The recharge of the aquifers is very limited because of a high silt content of upper layers. Two boreholes drilled in floodplain sediments in Kokwomeses have very low yield, while the Kangalan borehole is dry. Borehole C 4557 near Marich Pass has a higher yield, probably because of a higher percentage of coarse material, which came as torrent wash from Sekerr Mountains. In general, the prospect for finding groundwater in floodplain sediments are very low. The best chances are in alluvial deposits along the river or close to the surrounding hills, where coarse scree fans might have developed.

5.5.3 Groundwater quality

Total dissolved solid content (TDS) of groundwater from 11 boreholes varies from 174 mg/l to 1920 mg/l. In the case of Basement rocks aquifers, the mineral composition of parent rock is more or less the same at all investigated areas. Hence the differences in groundwater composition has to be attributed to another factor (factors) than lithology. Differences in evaporation rate in recharge areas, degree of weathering, biochemical and chemical processes (e.g. absorption by clay) in the soil cover and different contact time of the water with aquifer minerals, may be responsible for different types of groundwater.

The composition of groundwater can vary even over short distances as shown in water samples from boreholes in Psurum and Chepkopgh. In Psurum, low mineralised water of $Ca-HCO_3$ type was found in one borehole, while the two other boreholes contain high mineralised water of $Ca/Na-SO_4$ type with high Cl and probably also Na - content (calculated from ion-balance) In Chepkopegh two boreholes contain medium mineralised water of $Ca/Mg-HCO_3$ type and one borehole saline water of $Ca-SO_4$ type. The source of high sulphate concentration is not known. The $Ca-SO_4$ water type is mostly related to the solution of evaporites (gypsum), but as far as known, these sediments do not occur in West Pokot.

The only groundwater sample from a floodplain aquifer, collected in Kokwomeses, contains saline water of $Na-HCO_3$ type.

No general conclusion as to the regional hydrochemical pattern can be drawn. Similar to the water quantity also the water quality is unique for each site.

Considering the use of groundwater as drinking water, the WHO-recommended limit of 500 mg/l for the total dissolved solid is exceeded in 5 boreholes (see table 5.3). The fluoride content in all samples is within the limit.

The water from all boreholes can be used for cattle watering, although a high sulphate content is undesirable for stock use. The Chesera and Serewa boreholes, the only ones to be considered for irrigation, contain good quality water for this purpose.

6. WATER RESOURCES ASSESSMENT

6.1 General

The previous chapters of this report deal specifically with the hydrogeological investigations aimed at the assessment of water resources in part of West Pokot District. This chapter summarises the results in the context of water availability for planning purposes at district level and local developments. Other studies directed by the Ministry of Water Development and the Kerio Valley Development Authority through Norconsult (1979, 1983) and Sogreah (1981), studied the possibilities for surface water development with emphasis on large scale irrigated agriculture and reservoirs for domestic use and hydropower. These developments being beyond the scope of this project, have not been studied in detail. Therefore the project's recommendations are mainly dealing with small scale developments, such as hand-pumped wells and the use of surface water for cattle watering.

In cooperation with the Water Resources Assessment Project a survey of water supply systems in West Pokot District was carried out through the ASAL Development programme. The results of this survey will be presented in the District Atlas West Pokot (MoF and P, forthcoming in 1985). The present and future total water demand has been established on basis of the 1979 population data.

6.2 Water supplies

6.2.1 Domestic water supplies

The number of operating water supplies in West Pokot District is limited(Figure 6.1). Surface water is the major source, being abstracted from rivers and springs, either by gravity or by pumping, while groundwater is obtained from approximately fifty hand-pump operated boreholes. During the anti-cholera campaign between 1980 and 1981 the Ministry of Health constructed sixty six shallow wells equiped with Afro-Implex hand-pumps in West Pokot. The majority of these pumps are located in the Kacheliba and Kapenguria Divisions. At present, however, none of these pumps is in operational condition and it is doubtful whether they can be rehabilitated. Experience has learned that this type of pump is unsuitable under the given circumstances. Groundwater is also obtained from hand-dug shallow wells in the river beds during the dry seasons. Most water supplies are operated and maintained by the Ministry of Water Development, whereas some water supplies are under the control of church organisations. The existing improved water supplies and the water supplies presently under construction or in the design phase are listed in Table 6.1 and plotted on Figure 6.1. The following locations for possible groundwater development were proposed by the District Water Officer:

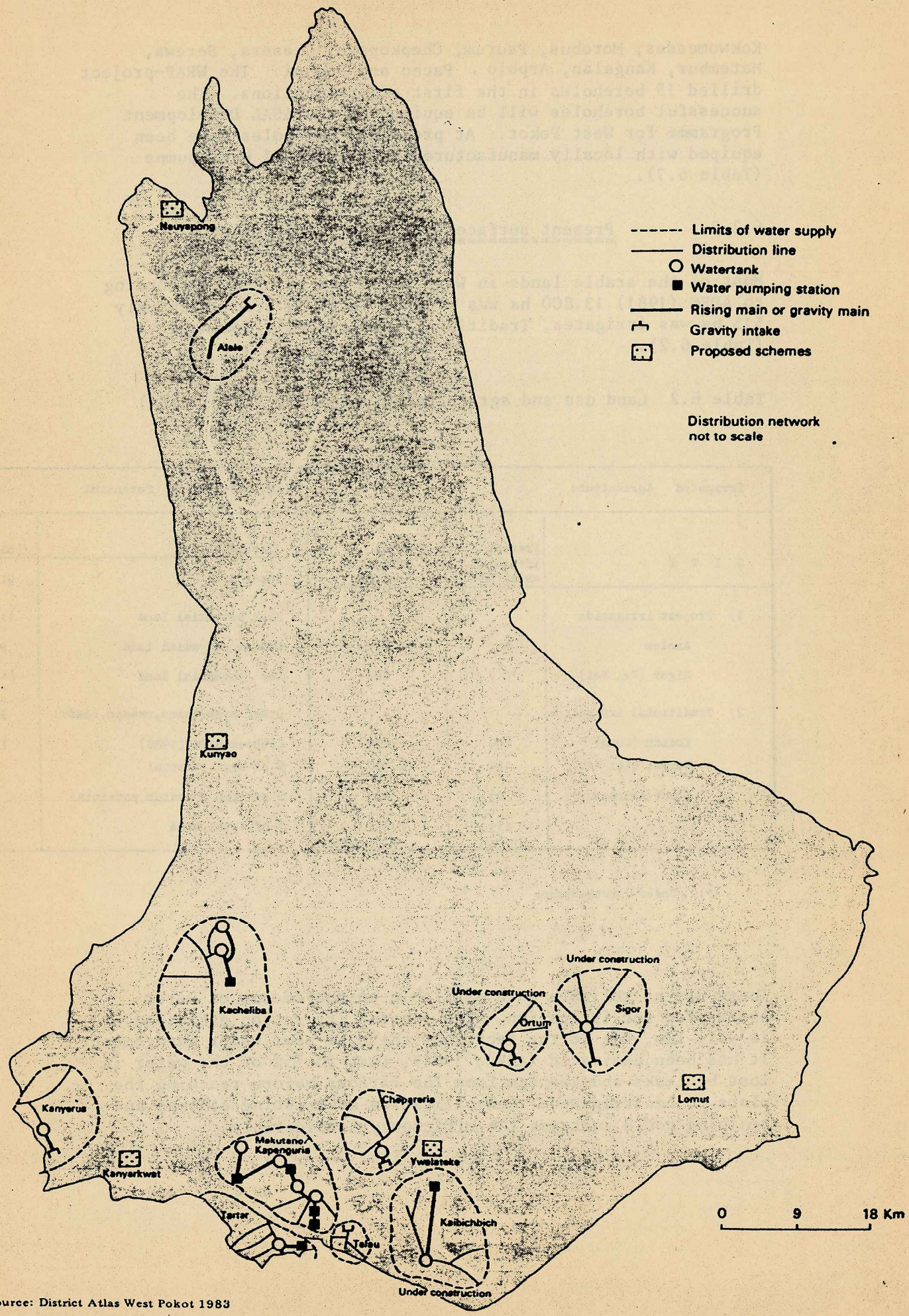
Table 6.1 Water supplies in West Pokot

Name of supply, Division and year commissioned			Source	Technical data: System pumped/ Gravity	Yield m³/ day	Number of metered Con.	Number of Kiosk/ W.P.	Population	Area Km²	Piping Km	Storage m³	Treatment	Responsible agent	REMARKS
1. Kapenguria	Kap	1952	River	pump	312	290	-	3.000	16	10	200	Full	M.O.W.D.	Over utilized, to be augmented
2. Makutano	Kap	1972	River	pump	400	220	1	2.500	10	9	180	Full	M.O.W.D.	To be extended
3. Tartar-Keringet	Kap	1979	River	pump	80	70	-	1.000	50	15	180	Full	M.O.W.D.	Under utilized, should be extended
4. Kwanza Centre*)	-	1973	Spring/ dam	pump	100	35	-	1.200	10	8	45	Nil	M.O.W.D.	Self help, due for rehabilitation
5. Kanyarkwat	Kap	1975	Sub-dam	Hand pump	-	-	-	-	-	-	-	Nil	M.O.W.D.	Not working, Handpump brokedown, source not adequate
6. Kacheliba	Ka	1982	well/ river	pump	90	35	-	2.000	9	8	270	Cl	M.O.W.D.	Yield of well not sufficeint
7. Talau	Kap	1982	Spring	Gravity	45	-	15W/P	1.000	6	4	-	Nil	M.O.A.	Small inexpensive system, meeting people's demand.
8. Kabichbich	Kap	1983	Stream	pump	110	-	10W/P	1.500	19	12	135	Nil	M.O.W.D	-
9. Cheperaria	Che	1981	Stream	Gravity	400	50	3W/P	2.000	36	30	90	Nil	M.O.W.D.	(Care-Kenya, D.D.C.)
10. Sigor	Si	1972	River	Pump	30	25	-	1 200	4	3	20	Nil	M.O.W.D./ C.C.	New gravity system of much greater capacity-under construction.
11. Ortum	Che	1975	Stream	Gravity	190	30	-	2.000	8	10	135	Cl	M.O.W.D.	(Mission, D.D.C.) New system under construction
12. Alale	Ka	1980	Spring	Gravity	?	2	3	200	-	-	-	Nil	A.I.C.	Needs to be extended
13. Karas	Kap	1979	Stream	Pump	100	35	-	1.000	9	15	135	Nil	M.O.W.D.	Lines to be extended, treatment works and standby unit to be provided.
14. Kanyerus	Ka	1980	Spring	Gravity	20	-	-	400	2	2	45	Nil	M.O.H.	-
15. Chesta	Si	1975	Stream	Gravity	?	-	-	-	-	-	-	Cl	CHURCH	-
16. Lomut	Si	1979	Stream	Gravity	-	-	-	-	-	-	-	Nil	M.O.H.	Abandoned due to funds
17. Marich Pass	Si	1979	BHC4557	Pump	100	-	-	800	-	-	45	Nil	M.O.W.D.	Borehole drilled for construction Lodwar road
Boreholes: 2	Kap		-	-	20	-	2	800				Nil	M.O.W.D.	Including one WRAP bore-hole
7	Che		-	-	50	-	7	2.000				Nil	M.O.W.D.	W R A P - bore holes
-	Si		-	-	-	-	-	-				-	-	
50	Ka		-	-	200	-	50	12.000				-	M.O.W.D./ CHURCH A.C.C.K.	

*) Outside West Pokot

(Source of data: ASAL development Programme)

Piped watersupplies in West Pokot District, 1983 - Figure 6.1



Source: District Atlas West Pokot 1983

Kokwomesses, Morobus, Psurum, Chepkopegh, Chesera, Serewa, Matembur, Kangalan, Arpolo , Pacho and Poghoi. The WRAP-project drilled 15 boreholes in the first eight locations. The successful boreholes will be equiped by the ASAL Development Programme for West Pokot. At present 8 boreholes have been equiped with locally manufactured India Mark II hand-pumps (Table 6.7).

6.2.2 Present surface water use for irrigation

Most of the arable lands in West Pokot are rainfed. According to ADEC (1981) 13.800 ha was cropped in 1980, from which only 515 ha was irrigates. Traditional irrigation is dominant (Table 6.2).

Table 6.2 Land use and agricultural potential (ADEC, 1981)

Irrigated Agriculture			Agricultural Potential	
S I T E	Present irrigated area (ha)	Total irrigible area (ha)	Classification	ha
			Total area	910.000
1) Project irrigation			High potential land	111.400
Amolem	85	235	Medium potential land	94.900
Sigor (Wei Wei)	0*)	200	Low potential land	612.900
2) Traditional irrigation	-	-	Other area(lakes,swamps,roads)	91.000
Kodich (Suam)	200	200	Cropped area (1980)	13.000
Sangat (Wei Wei)	150	2.000	% of high potental	12%
Lomut (Akiriamut)	80	200	% of high & medium potential	6%
	515	2.835	% of total area	1.5%

*) Under Construction.

There are no reliable data available on the amount of water abstracted for irrigation. The present irrigation efficiency is very low, due to the fact that there is poor water management. It has been estimated (ADEC, 1981), that 50-75% of the water is lost by leaks and seepage from the farrows before reaching the plots to be irrigated. Rehabilitation of existing schemes and training could increase the efficiency considerably.

At present new irrigation schemes are being developed near Kodich (Suam River) and Sigor (Wei Wei River). Sogreah (1981) proposed some major irrigation schemes.

a) between Marich Pass and the confluence of the Muruny and Wei Wei River 2600 - 3200 ha.

b) Sigor - Wei Wei River 1000 - 1500 ha.

c) Kangolai - Suam River 1000 - 1400 ha.

For further details reference is made to the appropriate reports.

6.3 Water demand

To calculate the average daily demand for West Pokot District a consumption per capita is assumed as described in the Design Manual of the M.o.W.D. (may 1979).

The demand is specified for rural areas as:

- 25 litres per head per day when served by communal water points (Wp, Kiosks).
- 50 litres per head per day when served by individual connection.
- 75 litres per day per livestock unit (LSK), i.e. 2.5 cows, 20 goats or sheep or 1.25 camels. ADEC, 1981).

In Table 6.3 the population figures are given for 1984, estimated from the population census data (1979) and projected for the year 2000, growth rates as assumed by District Developing Committee (M.o.F and P, 1983).

Table 6.3 Population data 1979, 1984 and estimate for the year 2000.

Location	Population 1979 (Census data)	Growth rate %	Population 1984	Population 2000
Kapenguria Division				
Mnagei	35.186	6	47.000	120.000
Riwoa	9.619	6	13.000	33.000
Lelan	11.149	6	15.000	38.000
Total	55.954	6	75.000	191.000
Chepararia Division				
Kipkomo	14.628	4	18.000	33.000
Sook	9.325	2	10.000	14.000
Batei	11.136	6	15.000	38.000
Total	35.089	4	43.000	85.000
Sigor Division				
Wei Wei	5.515	5	7.000	13.000
Lomut	6.687	5	8.000	15.000
Sekerr	7.154	3	8.000	13.000
Mwino	7.157	3	8.000	12.000
Masol	3.474	2	4.000	5.000
Cheptukel	4.238	3	5.000	6.000
Total	34.225	3	40.000	64.000
Kara Pokot Division				
Suam	7.513	4	9.000	16.000
Kapchok	7.452	4	9.000	16.000
Alale	13.542	3	16.000	23.000
Kasei	4.877	2	5.000	7.000
Total	33.384	3	39.000	62.000
Total West Pokot	158.652	4.3	197.000	402.000

Between 1969 and 1979 the annual population growth rate for Kenya and West Pokot amounted to 3.9 and 6.8% respectively. These figures have been used as a base to estimate the growth rate per location.

The livestock in West Pokot mainly consists of cattle, sheep, goats and camels. The livestock population data are presented in Table 6.4.

Table 6.4 Livestock population data (ADEC, 1981).

Type of livestock	1980 / 1981	L S U 1980	Estimated growth rate(%)	L S U 1984	L S U 2000 *) projection
Cattle	189,553	75,800	3	85,300	91,300
Sheep	88,300	4,200	3	4,700	5,000
Goats	280,000	14,000	4	16,400	19,900
Camels	14,516	11,600	0.5	11,800	12,800
Total L S U		105,600	3	118,200	129,000

*) Constrained L S U projection according to ADEC (1981)

ADEC (1981) has calculated the maximum potential carrying capacity of livestock in West Pokot at 121.500 LSU. which figure will be reached before the year 2000.

By taking the following assumption into account the estimated figures for the present water demand and the forecast for the year 2000 are given in Table 6.5.

- demand per capital per day and per livestock unit as specified by the Design Manual (MoWD, May 1979).

- percentage of population having access to individual connection (metered connection):

a) in 1984 - 2.5% (Tams, 1979; Sogreah, 1981)

b) in 2000 - 5% (Tams, 1979; Sogreah, 1981)

- because data per division and location are lacking, livestock was assumed to be evenly distributed over the district. Except for camel, which are concentrated in Alale (50%), Kasei (25%) and Masol (25%) locations.

The number of livestock units per square kilometer, excluding camels are;

a) in 1984 -(118.200 - 11.800)/8989 = 11.8 LSU/km²

b) in 2000 -(121.500*- 12.800)/8989 = 12.1 LSU/km²

* maximum potential carrying capacity.

Table 6.5 Water demand 1984 - 2000.

DIVISION		DEMAND IN 1984				DEMAND IN 2000			
NAME	**) Area (Km^2)	Demand per Capita - L S U 25 l/d	50 l/d	75 l/d	Total 10^6 m^3/year	Demand per Capita - L S U 25 l/d	50 l/d	75 l/d	Total 10^6 m^3/year
Kapenguria	1.638	0.67	0.03	0.53	1.23	1.66	0.17	0.54	2.37
Chepareria	1.358	0.38	0.02	0.44	0.84	0.74	0.08	0.45	1.27
Sigor	1.980	0.36	0.02	0.72*)	1.10	0.55	0.06	0.74*)	1.35
Kara Pokot	4.013	0.35	0.02	1.54*)	1.91	0.54	0.06	1.59*)	2.19
Total West-Pokot	(8989) 9.090	1.76	0.09	3.23*)	5.08	3.49	0.37	3.32*)	7.18

*) Including Camel.

**) Data from 1979 census (not consistent)

The total water demand will increase from 5.1 x 10^6 m^3/year in 1984 to approximately 7.5 x 10^6 m^3/year in the year 2000. The demand for livestock remains constant at 3.3 x 10^6 m^3/year, which amounts to respectively 63% and 44% of the total water demand in 1984 and 2000.

In Table 6.6 the present demand and domestic use from the existing improved water supplies are compared for each division. In order to meet the present standards of water requirement the total annual water production in West Pokot should be more than tripled, in Sigor and Kara Pokot Division the total annual water production is only 10% of the present requirements.

6.4 Water resources availability

The term "availability of water" as such is meaningless if not related to the specific purpose for which the water will be used. In this respect the following possibilities for water use in West Pokot can be distinguished:

- domestic use
- cattle watering
- irrigated agriculture: small scale
  large scale
- hydropower

From the hydrogeological conditions it was concluded in Chapter 5, that there are no regional aquifers in Basement areas. Groundwater occurs in isolated bodies. The quantity of abstractable water, stored in these local aquifers is difficult to estimate because nor the extent of aquifers nor the amount of recharge is known.

Results of the present study indicate that, at least, one borehole with a yield of 1 m^3/hour can be successfully drilled in an area of 5 km^2. The total area covered with the Basement rocks amounts approximately to 4000 km^2. This means that circa 800 boreholes can be drilled and equiped with a handpump. To allow an average abstraction of 10 m^3/day per handpump, the annual recharge must equal to minimal 3 x 10^6 m^3. This amount corresponds to approximately 0.1 % of the average total annual rainfall (800 mm), which is reasonable.

Distribution of coarse alluvial deposit along the major rivers is rather irregular, varying in width from zero to 100 m and in thickness from zero to 20 m. Total length of alluvial system is approximately 150 km. In order to obtain a minimum estimate of the total storage of groundwater in this system it is assumed that the effective porosity is only 10% and that only 30% of the system is suitable for exploitation.

Table 6.6 Present demand and domestic use from improved supplies in 1984

Division	Present demand - 1984			Domestic use 1984							
					Distribution		Population Served				Average
	Population	Demand m^3/ year $x10^6$	Consumption l/c/d	Yield m^3/ year $x10^6$	Kiosk,W/P	Individual	Kiosk,WP	Individual	Total	l/c/d	Consumption l/c/d
Kapenguria	75.000	0.67	25.4	0.39	28	615	4.650	6150	10.800	100	10
Chepareria	43.000	0.38	25.4	0.23	10	80	5.200	800	6.000	107	15
Sigor	40.000	0.36	25.4	0.05*)	1	25	1.750	250	2.000*)	70	3
Kacheliba	39.000	0.35	25.4	0.11	53	37	14.230	370	14.600	21	8
Total West Pokot	197.000	1.76	25.4	0.78*)	92	757	25.830	7.570	34.400**)	64	11
% of Population							13%	3.8%	17%		

*) Including BH C-4557, estimated population served: 800

**) 75 - 80 % human domestic use.
25 - 20 % Livestock use.

Furthermore, it is estimated that average width and thickness of the exploitable parts of the alluvial system are 50 and 10 m respectively. In this way a total storage of 2.2 x 10^6 m^3 groundwater is estimated. Assuming that 50% of this volume can be annually recovered, sustained yield of the alluvial system amounts to circa 1 x 10^6 m^3 / year. This figure should be considered as an indication of the order of magnitude only. Updated estimates can be made after a large part of the aquifer system is being exploited.

The total amount of available groundwater in studied part of the West Pokot District is estimated at 4 x 10^6 m^3/year.

The total domestic water demand amounts to approximately 1.9 x 10^6 m^3/year, increasing to circa 4.3 x 10^6 m^3/year in the year 2000.
This demand can be met for the greater part of the area by groundwater development. Locally, shortages will occure in silty flood plain areas.

A high salt content is the major limiting factor when considering the use of groundwater for drinking water. However, water with TDS of 1500 mg/l seems to be acceptable as drinking water in the areas without any other alternative.

From the available analyses it apears that there is no fluoride hazard. No bacteriological analyses are available. The groundwater can be used for cattle watering, although an undesirable high sulphate content occurs at same places.

On an annual basis surface water is abundantly available. The actual availability of surface water depends however, on the topographical conditions and is unevenly distributed in time and space. In the higher elevated and more populated parts of the District, surface water supplies are usually sufficient.

The total combined annual surface water outflow from the Suam river at Kongolai and from the Muruny river at Marich pass amounts to 300-500 x 10^6 m^3.

In general the surface water quality proved to be good. The total disolved solid content is low and no high fluoride concentration was found. Only the iron concentrations exceed the WHO - standard. Bacteriological analyses have not been carried out, thus no recommendation for treatment requirements can be given.

The use of surface water for the various purposes, including domestic supplies, highly depends on the minimum flows from permanent streams, the duration of the dry spell in between two consecutive periods of river flow for non-permanent streams and suitable sites for intake structures and small or large reservoirs. Because most of the engineering aspects are beyond the scope of the project, no detailed assessment of the surface water availability for the various applications can be made.

A water availability map (Plate 6.1) has been prepared to indcate the regional distribution of the different water resources. The following categories of water availability are distinguished:

I. High potential area

Groundwater	-	Scree fans
	-	Coarse alluvial sediments near the main rivers
	-	Yield: > 5 m^3/h, at 10 m drawdown
Surface water	-	Areas at higher altitudes with abundant rainfall (approximately above the 1100 mm/yr isohyet and with low evaporation, less than 1800 mm/yr). In areas with major permanent streams. The minimum base flow at the end of the dry season should not be less than 100 l/s.

II. Medium potential areas

Ground water	-	Fractured Basement rocks + weathered zones.
	-	Sandy flood-plain sediments
	-	Yield: 1-5 m^3/hr, at 10 m drawdown
Surface water	-	Areas with intermediate rainfall (approx.between 1100 and 950 mm/yr)
	-	Near major streams with base flow at the end of the dry season between 10 - 1000 l/s. Near intermittent streams carrying water for at least 9 months. Topography allows construction of small reservoirs.

III. Low potential area

Groundwater	-	Clayey flood-plainsediments
	-	Decomposed Basement rocks
	-	Fresh Basement rocks
	-	Yield: < 1m^3/h, at 10 m drawdown
Surface water	-	Areas with no permanent streams or intermittent streamscarrying water less than 9 months.

6.5 Water development opportunities

Water development opportunities in West Pokot are considered to be fairly good and in fact much better than anticipated before the start of the study.

Groundwater development opportunities are in general restricted to handpump wells. Assuming an annual production of 2000 m^3 per handpump, the estimated amount of available groundwater is sufficient for 2000 handpumps. However, the available groundwater is not evenly distributed.

In the first phase of exploitation the construction of several tens of shallow wells in the alluvial deposits near the major rivers should be considered. The cost of one dug well amounts to approximately K.Shs. 20,000/=. In addition, few medium deep boreholes(Circa 50 m) should be drilled in the scree fans along the hill scarps. Each borehole will cost approximately K.Shs. 50,000/=. The purpose of these wells is not only the water production but also further reconnaissance.

The exploitation of Basement aquifers requiers a detailed geophysical and hydrogeological investigation for each proposed drilling site.

The results of the present study however indicate that at least one borehole with a yield of 1 m^3/h can be successfully drilled in an area of 5 Km^2. An average depth of 60 m will probably be sufficient to struck a waterbearing zone. Drilling of deep borehole is in most cases superfluous since the major weathered and fractured zones occur within 100 m.

The cost of a borehole equiped with a handpump will be in average K.Shs. 70,000/=. Each handpump could supply approximately 300 people.

The use of handpumps seems to be best solution for the abstraction of groundwater if the relatively shallow depths to groundwater, the low yield of boreholes and the availability of low-cost equipment are taken into account. Although some experimental solar pump installations can be found in West Pokot, the present cost level is still prohibitive for a large scale use. The installation and maintenance of any pump must be realized with the active partipation of the local authorities and the members of the community involved.

Eight boreholes,drilled by W R A P, have already been equiped with an India Mark II handpump. The equiped boreholes are listed in Table 6.7.

Table 6.7 Equiped W R A P Boreholes.

Location	M.o.W.D. No.	Depth (m)	w.r.l. (m)
Morobus I	C 5414	48	18
Morobus 2	C 5415	47.5	15
Psurum I	C 5416	68	21
Psurum 3	C 5538	67	19
Serewa	C 5431	36.5	17
Chepkopegh I	C 5429	47	12
Chepkopegh 3	C 5540	68	7
Chesera	C 5430	41	9

Ample opportunities are present for the development of surface water for domestic use and cattle watering, even for small and large scale irrigated agriculture and hydropower. However, the latter two being beyond the scope of this study, have not been taken into consideration by the project.

Less costly opportunities for the development of surface water should be developed first, such as small reservoirs for cattle watering at the valley bottoms and sand dams with shallow wells in the riverbeds of intermittent streams.

The topographical and soil conditions permit the construction of small reservoirs for cattle watering and cattle dips. With a natural gradient varying between 0.2 and 0.06 and dam hight of 4-5 metres a rectangular resevoirs, 50 metres wide and 150 metres long in the direction of the slope could store between 25 000 - 8 000 m^3. To bridge the four months dry spell between November and April rainfall for cattle watering only, a total storage capacity of 0.02 x 10^6 m^3 would be required in West Pokot.

Taking into account that the total evaporation minus the average rainfall during that period would result in approximately 700 mm evaporation losses, the net storage capacity of the reservoirs would reduce to between 18 000 and 6 000 m^3. Assuming a daily water demand of 9000 m^3 for 121,500 LSU (Table 6.4), cattle watering thus could be guaranted by 90-100 small reservoirs, roughly costing between K.Shs. 100,000/=, 200,000/= per reservoir.

Depending on the topographical conditions these reservoirs can either be filled by directed runoff or by diverting the flow from intermittend streams. Properly constructed and dimensioned spillways are required to prevent over-topping of the embankment and to by-pass excessive floods.

As these reservoirs can develop into a breeding place for harmful insects and could become a health hazard when used for human consumption, a considerable distance to nearby settlements should be enforced. Another drawback of relatively shallow reservoirs (dams) is siltation which, if not carefully controlled, may make a reservoir useless within a few years.

The possibilities for the construction of sand dams predominantly depends on the topographical conditions such as slopes and width of the river bed, as well as the impermeability of the underground. No price indication can be given for the sand dams themselves, they vary from site to site. During a recent construction programme of sand dams in Machakos District the average cost per unit amounted to K.Shs. 80,000/=. The sanddam reservoir thus created can be exploited by means of a dug well and a handpump. Depending on the depth, a shallow well including the hand pump, will cost between K.Shs. 20,000 - 30,000.

To guarantee domestic water supply and the supply for small scale irrigation from surface water, site specific investigations are required to study the various possibilities. In most of the area the required amount of surface water is available, but a cost-benefit analysis is always required to study the most feasible solution to divert water to a specific location.

7. REFERENCES

ADEC, 1981.

General development plan for Kerio Valley Basin. Vol.1 & 2, Kerio Valley Development Authority, Nairobi.

Chow, V.T., 1964.

Handbook of applied hydrology. Mc.Grawhill, New York; London.

Clark, L., 1982.

Groundwater abstraction from Basement complex areas of Africa. African water and sewerage conference, paper 7, Nairobi, 25p.

Dietz, T. and A. Van Haastrecht, 1982.

Market integration in Elgeyo Marakwet and West Pokot. Comparing households and locations. Working paper no. 384. Institute for Development Studies, Univ. of Nairobi.

EAGRU, 1978 .

Geological map of the Tiati area. Sheet no. 26 NE, Bedford College, London.

Geosurvey International Ltd., 1982.

Preliminary structural map Kapenguria-sheet, Scale 1:250,000, Nairobi (unpublished).

Kenya Meteorological Department, 1975.

Summary of rainfall in Kenya for the year 1959 - 1974.

Kenya Soil Survey, 1976.

Reconnaissance soil map of the Kapenguria area.

Kipkorior, B.E., R.C. Soper, and J.W. Ssennyonga, 1983.

Kerio Valley : Past, present and future. Institute of African Studies, Nairobi 196p.

Kruseman, G.P. and N.A. de Ridder, 1979.

Analysis and evaluation of pumping test data. Bull, Il, ILRI. Wageningen, 200p.

Mason, P. and A.B. Gibson, 1957.

Geology of the Kalossia - Tiati area. Geol. Survey of Kenya report no.31, 34p.

McCall, G.J.H., 1964.

Geology of the Sekerr area. Geol. Survey of Kenya report no.65, 84p.

Miller, J.M., 1956.

Geology of the Kitale - Cherangani Hills area. Geol. Survey of Kenya report no.35, 34p.

Ministry of Economic Planning and Development, 1980.

West Pokot District Development Plan 1979 - 1983, Nairobi.

Ministry of Economic Planning and Development, 1981.

Kenya population census 1979, Nairobi, 326p.

Ministry of Finance and Planning, 1983.

West Pokot Development Plan, 1984 - 1988, Nairobi, 66p.

Ministry of Finance and Planning, (Fourthcoming 1985 a).

District atlas West Pokot, Kapenguria.

Ministry of Finance and Planning, (Forthcoming 1985 b).

Survey of water points in West Pokot District. ASAL-Development programme, Kapenguria.

Ministry of Water Development, 1978.

Design manual, Nairobi.

Ministry of Water Development, 1984 a.

Water resources assessment study for the Kerio Valley. Main report, WRAP, Nairobi.

Ministry of Water Development, 1984 b.

Water resources assessment study for West Pokot District, Progress report, Water resources assessment project, Nairobi.

Ministry of Water Development, 1984 c.

Geophysical investigation in West Pokot, Water resources assessment project, Nairobi, (in preparation).

Ministry of Water Development, 1984 d.

West Pokot hydrological report, Water resources assessment project, Nairobi, (in preparation).

Norconsult, 1975.

West Kenya water supply project - Kongolai/Kacheliba. Ministry of Water Development, Nairobi, 31 p.

Norconsult, 1979.

Turkwel Gorge multipurpose project, Feasibility Study - Investigations. Ministry of Water Development, Nairobi.

Norconsult, 1983.

Turkwel Gorge multipurpose project, Hydrological Survey, Ministry of Water Development, Nairobi.

Ojany, F.F. and R.B. Ogendo, 1981.

Kenya: A study in physical and human geography. Longman, Nairobi,. 228 p.

Searle, D.L., 1952.

Geology of the area north-west of Kitale township. Geol. Survey of Kenya report no. 19, 80p.

SOGREAH, 1981.

Water resources study for the Kerio Valley Basin. Sectional report, Part one and Two, Kerio Valley Development Authority, 195p.

TAMS, 1980.

National Master Water Plan, stage 1, Ministry of Water Development, Nairobi.

Tollenaar, P., 1975.

Turkwel - basin hydrological survey. Interim report UNDP/FAO, 40p.

VIAK/NORPLAN, 1976.

Turkwel dam and reservoir reconnaissance survey. Ministry of Water Development, Nairobi.

Walsh, J., 1966.

Geology of the Karasuk area. Geol. Survey of Kenya report no. 72, 34p.

Webb, P.K. 1971.

Geology of the Tiati Hills, Rift Valley Province, Kenya. unpub. Ph. D. Thesis, Univ. of London.

Woodhead, T. 1968.

Studies of potential evaporation in Kenya, East Africa Agricultural Forestry Research Organization, Nairobi.

ANNEXES

LIST OF ANNEXES

1.1 W R A P project staff involved in West Pokot investigation

1.2 Population figures for West Pokot (1979- census)

2.1 Lithology of the major Basement rocks

4.1 Rainfall data

-1 Raingauge station (5" standard raingauge)

-2 1982 - 1983 monthly rainfall data

4.2 Evaporation data

-1 Evaporation station (Class A-Pass)

-2 1982 - 1983 monthly evaporation

4.3 Runoff data

-1 Rating curve, Suam river RGS 2B7

-2 Rating curve, Muruny river RGS 2B31

-3 Daily flow data 1982 - 1983

,a Suam River

,b Muruny River

-4 Monthly and annual flow data

a Suam River

b Muruny River

c Wei Wei River

5.1 Geological well logs

5.2 Analysis of well test data

5.3 Groundwater level fluctuations

5.4 Borehole data West Pokot District

Annex 1 INTRODUCTION

1.1 WRAP project staff involved in West Pokot investigation

1.2 Population figures for West Pokot (1979 census)

Annex 1.1 - Personnel involved in field and office work:

Kenyan team

Project Co-Manager	A.M. Nzioki
Geophysicists	F.I. Majanga
	F.K. Karanga
	J.M. Kinya
Hydrologist	L.M. Nyongesa
Geologists	C.K. Mbugua
	N. Gathuru
	C.B. Wanyama
Groundwater Inspectors	D.W. Mwangi
	P.K. Mengich
	E.G. Githiora
	E.M. Okemwa
	G.A. Ikunda
Assistant Hydrologists	C.G. Gitonga
	E. Mucheru
	J.C. Payeni
	P.A. Okumo
Hydrological Assistant	F.K. Mbuvi
Drilling Inspectors	A.M. Abdallah
	C.K. Macharia
	C.K. Wakahiu
Groundwater Technicians	D.W. Migwi
	C.M. Kinyua
Drillers	G. Baraza
	J.S. Wamalika
	F. Ngunjiri
Mechanic	M. Mwaniki

Drivers	T. Mainga
	J.O. Ohanya
	A.O. Ohanya
	J.K. Kirubi
	J. Karumba
	P.N. Kamau
	J. Maina
	H. Wanyonyi
	S. Waweru
	S. Mwai
	G. Njagi
Draughtsmen	W. Mbala
	A. Annam
Typist	G. Munyiri
Messengers	J.O. Onyach
	M.N. Musyoka

Netherlands team

Residents

Project Co-Manager	P.G. Van Dongen
Hydrologist	J.P. Heederik
Hydrogeologist	L. Vasak
Assistant Geophysicist	J. Reckman

Short missions

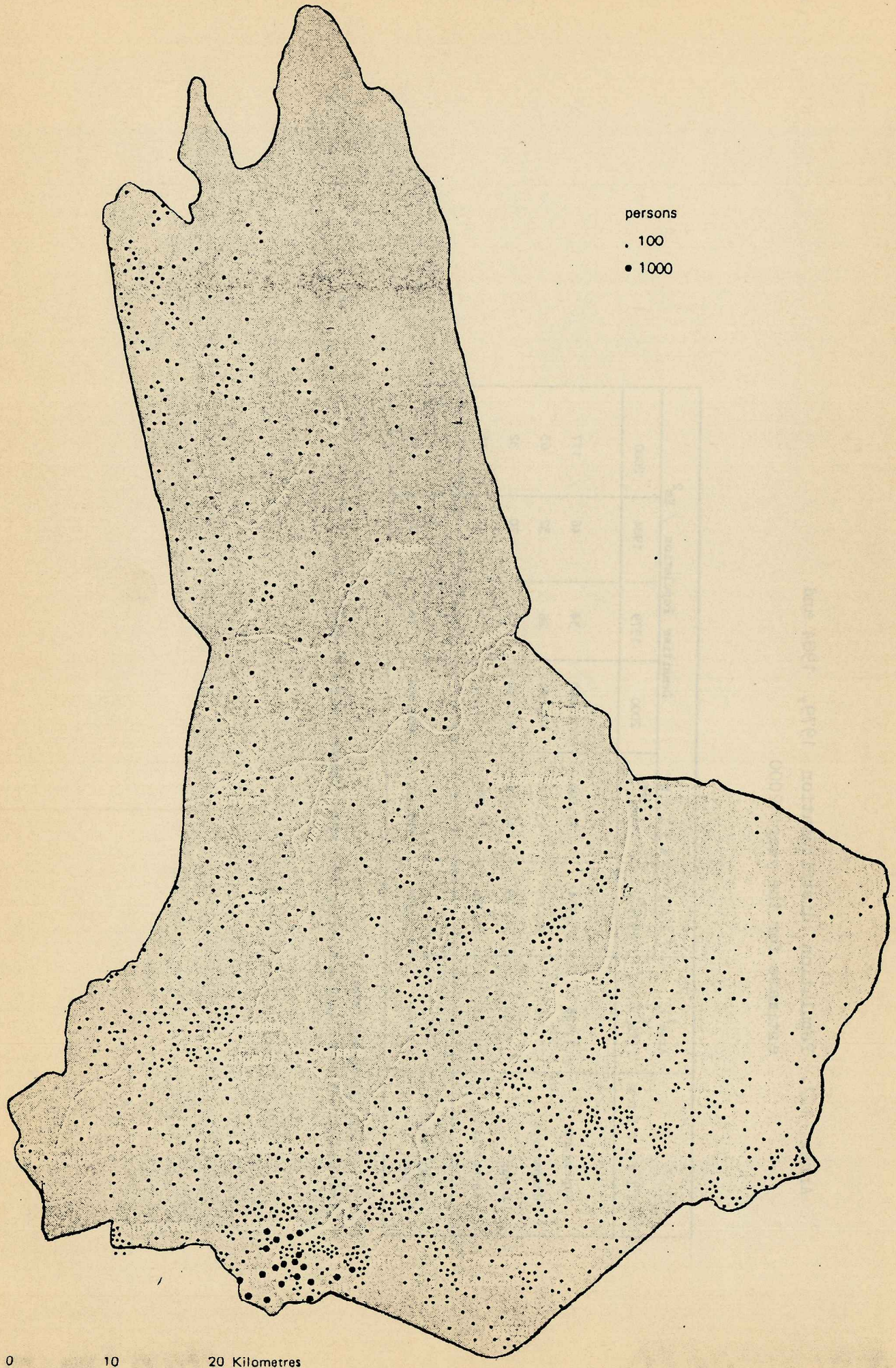
Project Supervisor	G.P. Kruseman
Geophysicist	I.L. Ritsema

Annex 1.2. Population distributation 1979, 1984 and estimate for the year 2000

DIVISION	Area*) (Km^2)	POPULATION			Densities Population / Km^2		
		1979*	1984**)	2000	1979	1984	2000
Kapenguria	1,688	55,954	75,000	191,000	34	46	117
Chapareria	1,358	35,089	43,000	85,000	26	32	63
Sigor	1,980	34,225	40,000	64,000	17	20	32
Kacheliba	4,013	33,384	39,000	62,000	8	10	15
Total West-Pokot	8,989	158,652	197,000	402,000	18	22	45

*) Population Census 1979

**) Growth rates as assumed by District Development Committee (MoF & P,1983)



Source: District Atlas West Pokot 1983

Annex 2 GEOLOGY

2.1 Lithology of the major Basement rocks

Annex 2.1 Lithology of major Basement rocks.

The Precambrian rocks of the Basement System are considered to be the oldest rocks in Kenya. Isotope age determination, however, indicated that rocks of Nyanzian and Kavirondian System in Western Kenya are older. A term "Mozambique Belt" has been proposed instead of the Basement System (e.g. Ojany and Ogendo, 1981), but the latter is still widely used in the geological literature.

The rocks of Basement System in the project area can be divided into 3 groups, according to their origin:

- Metasediments
- Metavolcanics
- Intrusions

(i) Metasediments

The metasediments include various metamorphic rocks, which originally developed from semi-pelitic, psammitic and calcareous sediments.

Semi-Peliticgneisses are the most common rock within the metasedimentary group. They are mainly represented by the biotite-gneisses. Muscovite, hornblende, garnet and epidote-gneisses also occur in the area, but are not widespread. The semi-pelitic gneisses developed from argillaceous sandstones and calcareous sandy shales. All semi-peliticgneisses are strongly foliated. The semi-pelitic gneisses occupy the greater part of the project area.

Psammitic metasediments include quartzites and quarts muscovite gneisses which developed from quartz-rich sandstones. The quartzites are mostly dirty-white in colour and contain muscovite. They occur in a broad belt East of Kapenguria. Further to the north west, the quartzite belts become narrower. Quartzites occur also south east of Sigor and in the Cherangani Hills.

Calcareous metasediments include marbles, calcareous schists and calc-silicate granulites. The marbles which represent metamorphic limestones are mostly white in colour and contain coarse crystals of dolomitic composition. Blue-white and pink variations occur locally. Narrow bands of marble are found all over the area. They are most abundant in the area round Sebit, northwest of Ptoyo and east of Marich Pass. A large outcrop of calc-silicate granulites has been mapped by Miller (1957) in the surroundings of Kiptaburr. The granulites are

greenish-black in colour, spotted with red garnet. The granulites developed from the calcareous sediments and were affected by migmatization. The calcareous schists of sedimentary origin outcrop south west of Wyisa. The schists are cream in colour and contain carbonate feldspar, quartz and epidote.

(ii) Metavolcanics

The term metavolcanics refers to the metamorphic rocks which originally developed from volcanic rocks. According to McCall (1964), the metavolcanic rocks in the Sekerr area have been derived from "Ophiolitic" (basic and ultrabasic) volcanic rocks. They are found now as plagioclase amphibolites and amphibolite schists. The plagioclase amphibolites are composed of green hornblende and plagioclase. They cover a large area north of Tamough River.

The amphibolite schists is fine textured, deep green rock composed dominantly of actinolite. The schists occur in a broad belt between Marich Pass and Turkwel Gorge. The extension of amphibolite schists south of Marich Pass is not clear from the geological map. Miller (1957) included the amphibolite schists in a complex together with hornblende gneiss of semi-pelitic origin which occur in two belts in the Cherangani Hills areas. One belt comprising Kipkomo and the upper Muruny and Moiben valleys, and the other the lower Muruny and upper Arror valleys. North of Kipkomo, diorite-like rocks (charnockite) have been described by Miller. He suggested that these rocks represent metarmorphosed basic lava flows. However, the charnockite are lacking on the geological map of the Sekerr area.

(iii) Intrusions into Basement System

The intrusive rocks in the project area include acid, basic and ultrabasic rocks, which have been partly affected by metamorphism.

The acid intrusions are represented by foliated granites (with or without pegmatite dykes) and granitoid orthogneisses. The granites occur south and north of Marich Pass, in the surrounding of Sarmach, south of Ptoyo and at Turkwel Gorge. Small dykes of pegmatite and veins of quartz are numerous throughout the area.

The basic intrusions include gabbros, chlorite and amphibolite schists and metagabbro orthogneisses. The only significant outcrop of gabbro has been mapped by Miller (1956) in the northeast of Ortum. The gabbros are melanocratic granular rocks containing mostly hypersthene and olivine. The chloritic schists, associated with ultrabasic talc schists form a long narrow belt northwest of Marich Pass. Several small belts occur also in the metavolcanic complex of the Sekerr area. The metagabbro orthogneisses represent syn-orogenic intrusions which have been metamorphised. They occur in three major belts in the Sekerr area. (See Plate 2.1). The orthogneisses are either of biotite-hornblende or hornblende - plagioclase type.

The ultrabasic intrusions includes peridotites, pyroxenites, serpentinites and talc-schists. The peridotites are found only in very small outcrops. The largest outcrop of dark pyroxenites occurs along the Suam River, north of Nakujit. The serpentinites are found in the area round Wyisa.

Annex 4 HYDROLOGY

4.1 Rainfall data

4.2 Evaporation data

4.3 Runoff data

Annex 4.1-1 Raingauge Stations (5" Standard raingauge)

KMD NO	NAME	GRID REFERENCE SHEETS:36-12/8 SCALE:1.250.000 X	Y	ELEVATION M.A.S.L.	PERIOD OF RECORD	REMARKS
87.34.011	* Atumatak	684	247	1500	1959-74	
87.35.005	* Kaputir	776	233	701	1971-80	
88.34.001	* Mt. Elgon F.S.	695	127	2225	1930-	
.012	* Endebess	707	119	1859	1925-78	
.071	Kanyarkwet	712	140	1800	1969-	3
88.35.004	* Kapenguria D.O.	736	139	2134	1931-	2
.016	* Mlimani	722	138	1920	1939-70	
.017	* Lomut	787	156	975	1953-	
.018	* Tamkal	775	153	1219	1939-	
.021	* Kitale met.stn.	722	111	1890	1950-	1
.026	* Kongolai	723	165	1311	1952-	1,5
.027	* Sebit	761	155	1311	1952-	5
.028	* Chepareria	747	145	1524	1952-	5
.029	* Sigor	775	165	1067	1952	2,5
.031	* Kabichbich	755	133	2743	1963-	3
.032	* Chebunyal	755	178	2377	1952	
.035	* Labot	771	122	2987	1957.58	
.056	Kodich	726	180	1372	1980-	
.096	Suam Forest Stn.	695	142	2088	1974-	
MOWD. NO						
615	Kanyao	729	198	1067	1982-	5
625	Chepkopegh	749	161	725	1978-	3
632	Kapsangar	769	133	3048	1975-	2,3
670	* Amolem	771	201	766	1976-	2
697	Turkwel	761	212	726	1978-	2
732	Serewa	722	149	1372	1982-	6
734	Nakujit	727	182	366	1982-	6
736	Kaptalamwa	771	133	2896	1982-	4

NOTES:-
1. Full meteorological station
2. Station with Evaporation plan
3. Project rehabilitated stations
4. Project installed stations
5. Station rehabilitated by Norconsult AS.
6. Station installed by Norconsult AS

* Station used in analysis

Annex 4.1 -2[a] Monthly rainfall data 1982

Suam and Muruny Catchment

Registration Number		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
KMD-NO.	88.34.071	5.8	16.8	33.6	210.8	206.0	110.3	99.8	158.7	97.5	-	-	-	-
	88.35.004	-	-	-	-	-	111.5	110.5	179.3	105.0	141.1	201.5	48.7	
	018	11.6	62.9	75.6	126.8	343.1	30.1	146.0	241.1	82.0	-	-	-	-
	026	-	-	-	133.8	192	58.4	148.0	-	-	-	214.2	16.8	-
	027	-	—	-	221.3	203.6	46.5	61.2	132.1	48.3	92.5	155.3	71.5	-
	028	0.8	2.0	28.7	192.7	254.3	51.7	143.8	137	59.9	129.9	220.7	59.5	-
	029	-	-	-	301.1	247.3	31.6	20.8	166.5	44.5	83.1	162.9	54.8	-
	031	8.1	18.8	65.5	324.1	342.1	159	127.8	256.1	82.4	152.9	257.7	55.8	-
	032	13.6	0	11.1	161.3	86.3	54.0	156	192.7	41.7	-	63.2	48.3	-
	056	4.8	18.0	127.0	153.5	267.0	57.5	150.0	20.4	30.7	50.6	129.1	0	-
	096	57.0	9.3	82.8	220.2	194.7	99.0	135.1	135.1	107.1	147.1	106.4	25.3	-
MOWD-NO	625	-	-	34.5	111.2	99.2	322.6	26.0	14.0	29.2	-	-	-	-
	632	-	-	-	262	616.9	121.5	117.7	219.3	55.5	71.2	-	95.6	-
	732	-	-	-	204.0	308.0	43.7	95.9	145.3	67.7	109.4	229.3	43.6	-
	734	-	-	53.5	151.5	178.6	43.6	79.4	95.6	63.9	82.4	163.8	0	-
	736	-	-	-	154.4	-	59.9	93.6	199.1	70.4	127.2	124.0	370	-

Annex 4.1 - 2[b] Monthly rainfall data 1983

Suam and Muruny Catchment

Registration Number	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
KMD-NO. 88.34.071	14.9	39.6	16.0	147.8	141.2	103.4	175.7	-	-	-	-	-	-
88.35.004	12.5	69.8	23.9	189.7	206.0	184.5	317.4	391.7	156.3	181.0	-	-	-
018	0	33.8	0	-	-	-	-	-	-	-	-	-	-
026	12.9	19.5	3.1	135.0	125.9	115.0	64.6	153.3	69.6	101.9	-	-	-
027	8.0	32.1	2.9	183.6	128.7	116.1	66.3	147.5	37.6	96.1	-	-	-
028	0	51.3	44.2	114.5	178.9	82.6	70.8	391.6	124.9	-	-		-
029	10.2	40.3	5.7	80.2	60.8	112.2	121.4	274.9	73.0	139.3	-	-	-
031	15.7	93.5	-	-	-	-	-	-	-	-	-	-	-
032	-	-	16.2	-	-	-	-	-	-	-	-	-	-
056	0	42.9	2.6	104.3	62.8	142.0	124	133.2	41.2	-	-	-	-
096	18.7	19.1	32.5	-	-	-	-	-	-	-	-	-	-
625	0	27.9	2.8	206.5	266.7	157.5	34.3	161.0	-	-	-	-	-
632	17.9	3.8	119.2	197.9	197.9	-	-	220.4	134.2	-	-	-	-
732	6.0	57.2	7.2	93.4	172.6	125.3	99.2	245.5	138.8	110.0	-	-	-
734	-	-	17.0	102.3	79.5	88.1	81.1	133.5	87.3	79.7	-	-	-
736	39.2	40.3	20.4	144.4	113.4	127.8	-	-	-	-	-	-	-

Annex 4.2 - 1 Evaporation Stations (Class A-Pan)

Registration Number	Station Name	Location Coordinates *		Elevation m.s.l.	Record Period	Remarks
		X	Y			
KMD-NO 87.34.011**	Atamatak	684	247	1500	1957-74	1
88.35.026	Kongolai	723	165	1310	1982-	2
029	Sigor	775	165	1070	1966-	2
034	Cherengoni	757	114	2200	1966-	-
KMD-NO 632	Kapsangar	769	133	3050	1982-	3
636	Kapenguria	736	139	2135	1982-	1,3
670	Amolem	771	201	765	1976-	-
697	Turkwel gorge	761	212	725	1978-	2

1. Woodhead (1968), Potential evaporation station, MOWD no. 636 = KMD no. 88.35.004
2. Norconsult A.S. installed evaporation pan
3. WRAP installed evaporation pan

Annex 4.2 - $2^{a,b}$ Monthly evaporation data 1982 and 1983
Suam and Muruny catchment

Annex 4.2 - 2^{a} Monthly evaporation for 1982 in mm

Registration Number	JAN.	FEB.	MARCH	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT	NOV.	DEC.	TOTAL
KMD.NO. 88.35.026	-	-	-	182	162	130	125	157	160	168	155	164	-
029	-	-	-	170*	203*	158*	185	172*	206	180	203	152	-
034	140	135	195	85	90	80	120	75	145	115	125*	170	1475
M.O.W.D. NO. 632	-	-	-	135	114	125	115	135	105	140	159	180	-
636	-	-	-	165*	145*	120	110	140*	185	122	125*	157	-

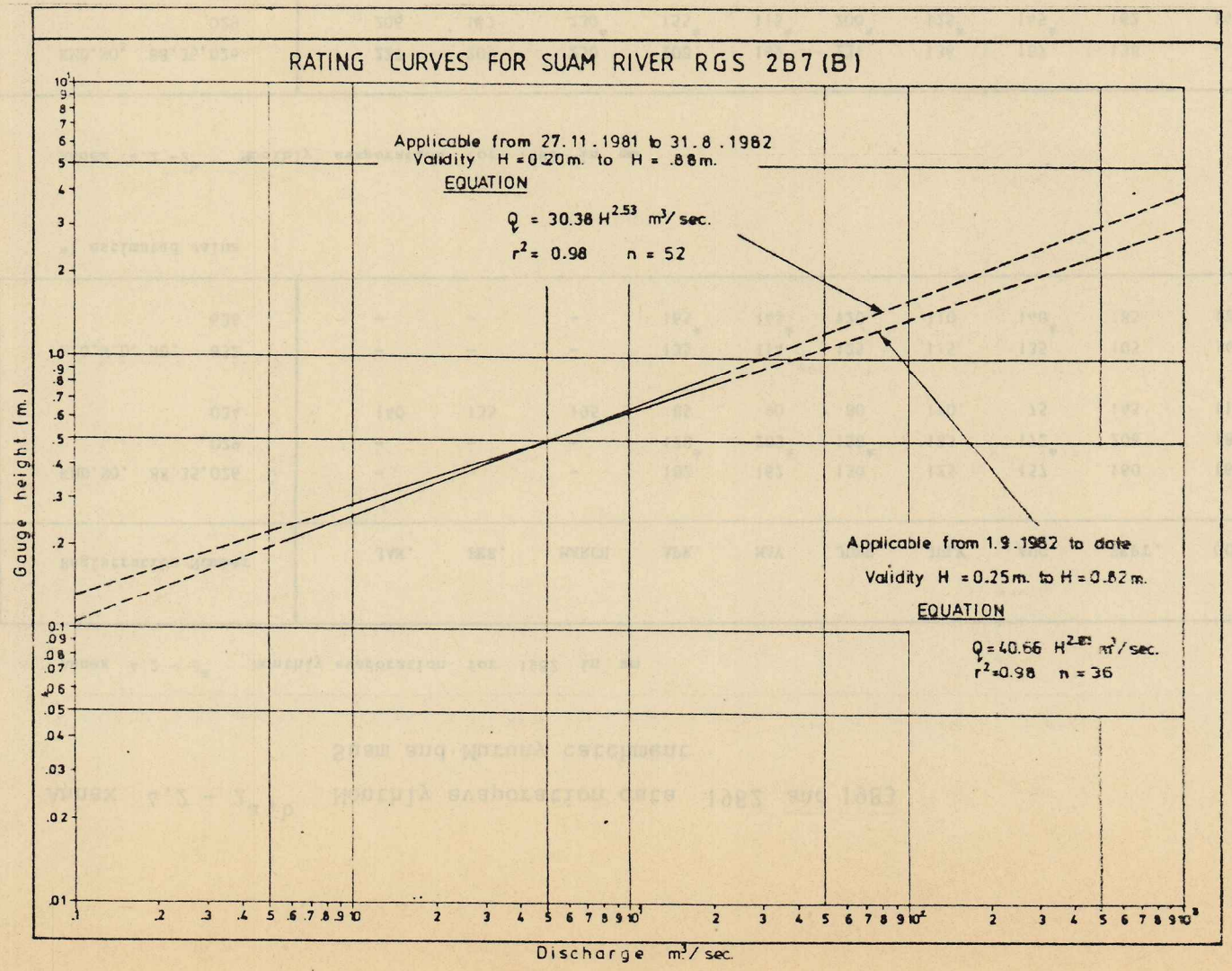
*) estimated value

Annex 4.2 -2^{b} Monthly evaporation for 1983 in mm

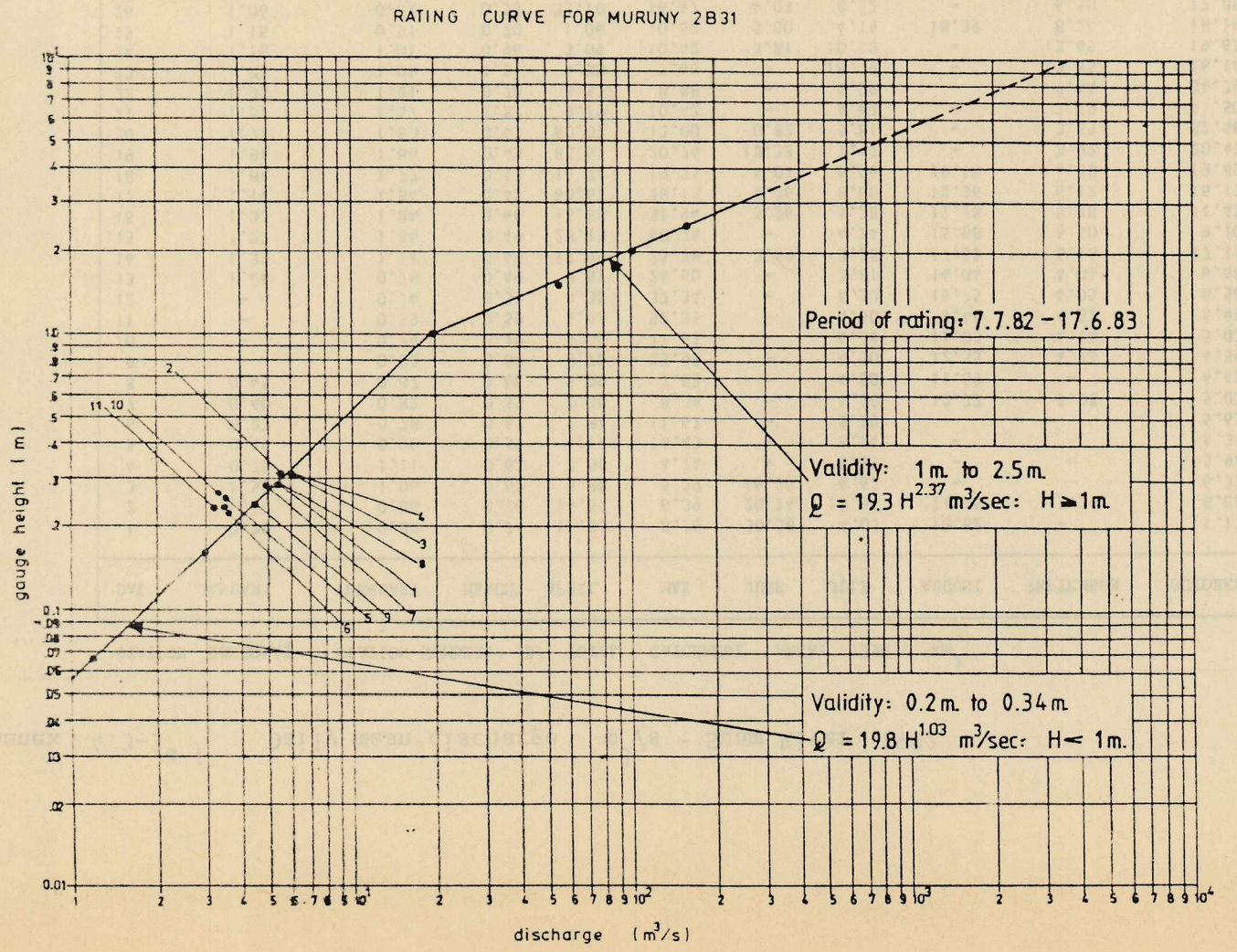
KMD.NO. 88.35.026	227	209	250	208	169	231	136	187	138	-	-	-	-
029	206	187	230*	155*	115*	200*	125*	145*	162	140*	-	-	-
034	-	-	-	-	-	-	-	-	-	-	-	-	-
M.O.W.D.NO. 632	177	115	125*	110	80	140*	85*	120*	95	100	85	-	-
636	183	157	172	178	145	190*	115	160	117	N.A.	116	-	-

*) estimated value

Annex 4.3-1 Rating curve, Suam River - RGS 2B7



Annex 4.3-2 Rating curve, Muruny River - RGS 2B 31



Annex 4.3-3[a-1] Daily mean discharge m^3/s - Suam River 1982

STATION KANGOLAT STATION NUMBER: 2B7 TOTAL CATCHMENT AREA: 1350 Km^2

DAY	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1	0.70	0.82	0.74	11.03	8.70	30.38	4.03	10.62	-	11.17	11.00	15.81
2	1.44	0.96	0.70	14.67	6.39	20.14	18.96	11.45	5.34	8.66	14.08	11.42
3	1.55	1.06	0.62	8.88	5.39	16.20	4.62	-	-	6.33	17.16	20.23
4	0.78	1.11	0.62	8.00	4.74	-	6.69	-	-	5.98	29.47	11.92
5	0.49	0.96	0.59	4.14	14.43	-	6.24	-	-	5.34	24.40	8.66
6	0.27	0.78	0.62	2.81	11.67	-	5.39	-	-	5.65	29.86	9.10
7	0.40	0.82	0.55	3.38	8.34	-	4.38	12.77	5.98	5.03	23.97	7.05
8	0.45	0.87	0.66	5.00	7.83	-	4.50	11.69	-	4.45	-	8.04
9	-	0.82	0.82	8.70	25.98	-	4.50	12.55	4.73	4.59	40.66	7.05
10	-	0.74	0.70	5.00	11.67	-	4.38	11.03	4.18	5.03	35.53	6.16
11	-	0.59	0.59	5.98	52.35	-	4.50	9.44	4.31	5.49	29.86	5.65
12	-	0.74	0.59	4.35	37.34	-	4.50	16.75	4.05	6.50	23.97	5.82
13	1.44	0.78	0.49	8.61	24.60	-	3.81	14.04	4.05	6.68	17.85	6.50
14	1.39	1.11	0.49	12.99	25.28	3.59	3.28	17.65	6.16	17.11	14.60	6.33
15	1.27	1.84	0.49	28.13	60.74	-	4.14	15.68	6.50	9.10	15.22	5.65
16	1.33	1.84	0.66	15.68	31.94	5.26	4.38	12.18	8.88	11.43	14.00	5.34
17	1.11	1.84	0.43	60.61	28.13	4.26	8.00	12.36	6.12	16.17	10.50	5.34
18	1.84	1.77	0.43	14.71	19.25	4.03	6.06	19.19	4.88	19.89	8.88	5.03
19	1.91	1.84	0.43	83.67	20.74	12.32	7.42	-	3.92	20.41	8.04	4.88
20	1.77	1.63	0.43	60.07	13.00	0.82	5.81	-	3.55	82.46	7.05	4.88
21	1.57	1.57	1.57	9.19	10.42	-	4.62	-	3.79	41.50	6.33	4.59
22	1.33	1.21	0.78	5.53	8.88	-	5.29	-	9.04	34.79	6.50	3.79
23	1.21	1.06	1.21	4.38	7.66	-	16.79	-	13.55	26.14	6.33	3.67
24	1.16	1.01	0.96	3.09	10.42	3.81	10.18	-	13.65	19.63	7.44	3.43
25	1.16	0.91	0.70	1.06	10.62	5.00	4.14	18.39	8.24	18.19	9.10	3.79
26	1.06	0.82	0.55	33.10	16.47	4.03	8.52	-	6.50	17.85	5.98	3.20
27	0.96	0.82	0.52	6.72	59.00	-	5.53	10.22	5.82	12.30	4.73	2.98
28	0.91	0.82	0.49	15.86	28.50	3.81	4.38	-	4.73	8.24	42.47	2.88
29	0.91	-	3.18	27.59	30.38	7.33	3.92	-	5.18	14.60	34.75	2.58
30	0.96	-	0.74	2.07	30.38	5.00	5.67	8.34	5.34	14.30	15.53	2.39
31	0.91	-	1.21	-	28.50	-	6.01	-	-	12.03	-	2.30
Total $X10^6$ m^3	2.62	2.68	2.03	41.03	56.99	21.77	16.47	35.33	14.04	41.22	46.06	16.98
Monthly Mean	1.12	1.11	0.76	15.83	21.28	8.40	6.15	13.19	6.19	15.39	17.77	6.34
Daily Max.	2.63	1.84	25.28	327.67	60.74	30.38	49.21	66.14	72.81	319.04	100.10	95.85
Daily Min.	0.25	0.52	0.40	0.59	0.46	0.82	2.99	8.70	2.98	3.67	3.20	2.04
Runoff in mm.	1.94	1.99	1.5	30.4	42.2	16.1	12.2	26.2	11.9	30.5	34.1	12.6
Rainfall in mm.	-	-	-	200	235	75	125	130	85	145	135	30
Rainfall/Runoff	-	-	-	0.15	0.18	0.21	0.10	0.20	0.14	0.21	0.25	0.42
Evap. in mm.	-	-	-	175	155	125	120	150	170	145	140	160

Annex 4.3 -3^{a-2} Daily mean discharge m^3/s - Suam River 1983

STATION KANGOLAI STATION NUMBER 2B7 TOTAL CATCHMENT AREA: 1350 Km^2

DAY	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1	2.21	1.72	1.44	0.88	9.07	15.22	13.52	20.76	22.33	11.51	-	-
2	2.12	2.94	0.98	1.08	19.37	13.13	17.90	16.83	21.54	12.58	-	-
3	2.12	2.88	0.98	0.83	9.10	12.30	11.00	14.60	209.54	12.58	-	-
4	1.96	2.30	0.88	0.70	6.68	10.75	8.50	31.42	0.03	10.75	-	-
5	1.96	2.21	0.93	0.66	6.16	10.50	6.88	27.49	33.67	33.94	-	-
6	1.96	2.04	0.79	2.12	43.80	9.10	5.82	23.14	18.91	55.20	-	-
7	2.39	1.88	0.83	9.93	13.26	7.63	5.49	22.73	11.51	55.20	-	-
8	2.04	1.80	0.98	9.87	14.19	6.50	5.33	22.73	15.53	55.20	-	-
9	2.30	1.65	0.88	7.63	35.59	5.82	4.88	29.95	9.10	55.20	-	-
10	2.04	1.58	0.88	12.96	20.00	5.34	4.19	25.69	14.41	55.20	-	-
11	1.72	1.51	0.88	8.24	18.19	4.88	4.18	31.28	18.49	55.20	-	-
12	1.65	1.51	0.83	8.87	15.96	4.59	3.55	31.33	12.03	40.66	-	-
13	1.58	1.96	0.79	6.68	15.85	3.67	3.43	27.96	8.88	39.48	-	-
14	1.58	2.39	0.70	4.45	16.83	3.55	3.43	26.14	7.63	38.90	-	-
15	1.58	1.80	1.14	9.10	16.17	3.43	4.31	33.92	6.87	-	-	-
16	1.51	5.25	1.38	6.50	10.26	3.55	4.76	72.81	12.67	-	-	-
17	1.58	744	0.79	6.16	8.04	3.43	5.33	85.50	18.19	-	-	-
18	1.44	4.59	1.08	6.33	6.33	3.20	5.33	50.86	18.19	-	-	-
19	1.80	4.03	1.44	4.73	8.45	4.73	10.50	35.53	22.73	-	-	-
20	1.38	.17	1.44	3.43	12.30	5.34	70.31	49.41	48.26	-	-	-
21	1.38	4.18	0.70	3.79	14.91	5.34	29.08	37.19	26.83	-	-	-
22	1.25	3.67	0.70	58.93	9.10	4.88	12.25	34.99	20.38	-	-	-
23	1.31	2.88	1.03	18.19	8.45	3.31	12.50	36.80	18.19	-	-	-
24	1.31	2.39	0.58	14.91	10.50	3.09	10.87	40.07	17.16	-	-	-
25	1.31	2.04	0.58	14.60	28.43	8.24	12.58	49.27	16.50	--	-	-
26	2.77	1.88	0.79	25.26	23.14	5.03	9.33	75.42	18.04	-	-	-
27	2.39	1.65	0.74	25.69	27.96	10.75	29.32	29.90	23.94	-	-	-
28	1.96	1.51	0.66	16.17	20.00	5.34	18.51	31.47	19.42	-	-	-
29	2.04	-	0.58	10.50	14.00	7.63	15.85	67.69	13.75	-	-	-
30	1.96	-	0.62	7.24	12.85	11.25	37.02	41.86	10.50	-	-	-
31	1.88	-	0.58	-	18.91	-	31.57	25.26	-	-	-	-
Total $X10^6$ m^3	4.87	6.63	2.38	26.46	42.67	17.42	36.07	99.34	61.84	(45.93)	-	-
Monthly mean	1.82	2.74	0.89	10.21	15.93	6.72	13.47	37.09	23.86	37.97	-	-
Daily max.	2.77	7.83	1.72	357.49	554.91	15.53	454.90	393.54	254.49	59.69		
Daily min.	1.19	1.44	0.48	0.48	4.18	2.77	8.24	13.71	0.03	1.08	-	-
Runoff in mm.	3.6	4.9	1.8	19.6	31.6	12.9	26.72	73.59	45.8	34.0	-	-
Rainfall in mm	15	30	45	150	-	-	-	-	-	-	-	-
Rainfall/Runoff	0.24	0.16	0.04	0.13	-	-	-	-	-	-	-	-
Evaporation in mm.	205	185	215	195	160	210	125	175	130	-	-	-

Annex 4.3 - 3^{b-1} Daily mean discharge m^3/s - Muruny River 1982

STATION: MARICH PASS STATION NUMBER: 2B31 TOTAL CATCHMENT AREA: 1355 Km^2

DAY	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1	-	-	-	-	-	7.61	5.14	6.32	6.32	5.14	5.14	6.52
2	-	-	-	-	-	6.32	4.75	5.93	6.12	5.73	4.75	8.71
3	-	-	-	-	-	6.02	5.14	7.71	5.73	5.34	7.31	7.51
4	-	-	-	-	-	5.63	10.49	10.10	6.52	5.14	6.12	7.80
5	-	-	-	-	-	5.24	6.72	12.47	6.72	5.14	7.31	-
6	-	-	-	-	-	5.34	5.53	10.69	6.72	4.94	16.12	6.22
7	-	-	-	-	-	4.87	4.75	8.12	6.12	4.94	11.88	8.90
8	-	-	-	-	-	4.75	4.55	7.11	5.73	5.14	12.08	10.20
9	-	-	-	-	-	4.85	4.16	6.72	5.53	5.14	9.31	8.30
10	-	-	-	-	-	4.94	3.97	6.12	5.34	5.53	10.30	7.61
11	-	-	-	-	-	4.85	6.72	6.32	5.34	5.73	13.27	7.21
12	-	-	-	-	-	4.46	4.36	6.52	5.73	5.53	8.51	-
13	-	-	-	-	-	5.14	4.36	7.11	5.53	5.53	7.31	6.32
14	-	-	-	-	-	4.85	4.36	11.09	5.93	12.47	6.72	6.42
15	-	-	-	-	-	5.34	4.55	12.47	6.91	4.75	6.12	6.02
16	-	-	-	-	-	5.14	4.36	9.70	9.31	4.73	5.93	5.73
17	-	-	-	-	-	5.53	4.75*	9.31	6.52	5.53	5.73	5.63
18	-	-	-	-	-	5.53	4.85*	5.73	5.73	5.14	5.34	5.43
19	-	-	-	-	-	5.93	7.21*	5.34	5.34	5.34	5.34	-
20	-	-	-	-	-	5.53	6.12	5.14	5.14	5.73	4.94	5.43
21	-	-	-	-	-	5.14	5.34	9.20	5.14	5.73	4.94	5.34
22	-	-	-	-	-	7.31	5.34	-	5.14	5.14	4.94	5.83
23	-	-	-	-	-	6.52	6.72	9.90	5.93	4.75	4.75	5.53
24	-	-	-	-	-	6.52	11.88	14.02	6.12	4.55	5.14	5.24
25	-	-	-	-	-	6.32	6.72	10.6	5.53	4.36	9.70	5.04
26	-	-	-	-	-	5.73	5.53	8.20	5.34	4.36	7.11	-
27	-	-	-	-	-	5.53	4.94	8.90	5.34	4.75	6.32	5.14
28	-	-	-	-	-	5.34	4.55	7.71	5.14	4.75	9.11	4.94
29	-	-	-	-	-	5.14	4.36	7.51	5.14	6.52	7.92	4.94
30	-	-	-	-	-	5.73	4.36	6.91	5.14	5.93	7.11	4.94
31	-	-	-	-	-	-	5.34	6.72	-	5.34	-	4.73
Total $X10^6 m^3$	-	-	-	-	-	14.44	14.85	21.57	15.24	14.60	19.80	14.83
Montly mean	-	-	-	-	-	5.57	5.55	8.32	5.88	5.45	7.64	6.34
Daily max.	-	-	-	-	-	7.31	21.66*	32.75*	13.66	35.29*	54.53*	11.09
Daily min.	-	-	-	-	-	4.16	3.97	4.75	4.55	4.36	4.75	4.73
Runoff in mm.	-	-	-	-	-	10.66	11.00	15.92	11.2	10.8	14.6	10.95
Rainfall in mm.	-	-	-	205	250	65	95	155	50	90	165	50
Rainfall/Runoff	-	-	-	-	-	0.16	0.12	0.10	0.22	0.12	0.09	0.22
Evaporation in mm.	-	-	-	160	165	140	145	155	170	155	170	160

* Estimated value

Annex 4.3 - 3^{b-2} Daily mean discharge m^3/s - Murumy River 1983

STATION MARICH PASS STATION NUMBER: 2B31 TOTAL CATCHMENT AREA: 1355 Km^2

DAY	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTBER	NOVEMBER	DECEMBER
1	4.75	5.14	4.75	4.75	5.93	8.91	12.47	7.92	32.27*	8.12	-	-
2	4.75	5.14	4.55	4.75	5.34	8.12	8.71	7.71	6.12	8.12	-	-
3	4.55	4.75	4.55	4.55	4.94	7.71	7.51	7.31	7.71	8.12	-	-
4	4.55	4.75	4.55	4.55	4.75	7.51	7.01	7.31	-	7.92		
5	4.55	4.75	4.55	4.55	4.55	7.51	6.52	6.91	7.81	7.31	-	-
6	4.94	4.75	4.55	7.51	9.31	7.92	6.32	8.12	7.11	5.14	-	-
7	5.34	4.75	4.55	7.71	9.50	7.51	5.83	9.11	7.71	7.51	-	-
8	5.34	4.55	4.55	6.12	10.49	7.51	5.63	8.32	7.31	15.05	-	-
9	5.14	4.55	4.55	7.51	9.70	7.51	5.33	15.25	7.11	17.03	-	-
10	4.94	4.55	4.55	6.12	8.91	7.31	-	8.12	7.71	6.32	-	-
11	4.94	4.55	4.55	5.53	8.12	7.31	5.73	8.71	-	4.55	-	-
12	4.94	5.34	4.75	5.34	7.71	7.51	5.53	12.87	7.51	4.36	-	-
13	4.55	5.34	4.75	5.14	7.51	9.90	5.73	8.91	7.11	4.75	-	-
14	4.55	5.14	4.94	5.14	7.51	7.51	5.73	-	7.31	5.14	-	-
15	4.55	4.94	4.94	5.14	7.31	7.11	5.73	9.50	7.51	5.34	-	-
16	4.55	4.94	5.34	5.14	7.31	6.72	5.73	9.70	7.92	7.31	-	-
17	4.55	5.34	6.91	5.14	7.11	6.52	6.32	11.09	10.49	7.51	-	-
18	4.55	5.14	5.53	5.14	7.51	6.52	7.11	19.21	4.75	7.51	-	-
19	4.75	5.53	5.34	4.94	7.51	6.72	8.12	67.88*	5.93	7.71	-	-
20	4.75	5.32	5.14	4.94	9.31	10.69	9.11	12.87	4.55	7.71	-	-
21	4.75	5.12	4.94	4.94	8.12	9.90	10.69	9.70	5.34	7.71	-	-
22	4.75	5.34	4.94	5.93	7.71	6.91	8.12	9.11	11.29	12.08	-	-
23	4.75	5.34	4.94	7.31	7.51	6.91	9.31	10.10	5.34	22.16*	-	-
24	4.94	5.14	4.74	5.93	8.12	6.72	12.67	11.09	6.72	10.69	-	-
25	5.14	4.75	4.85	5.53	8.51	6.91	7.51	13.66	7.51	6.91	-	-
26	5.34	4.75	4.74	7.92	8.91	7.11	6.72	8.12	8.12	6.12	-	-
27	5.14	4.75	4.85	13.66	9.90	10.10	9.11	8.12	6.32	6.12	-	-
28	5.14	4.75	4.94	6.72	8.91	10.69	8.71	10.30	9.70	6.32	-	-
29	5.14	-	4.94	-	8.51	10.10	14.45	6.12	5.93	6.32	-	-
30	5.14	-	4.75	5.75	8.71	12.47	17.03	5.73	7.71	-	-	-
31	5.14	-	4.94	-	8.71	-	8.71	7.71	-	7.11	-	-
Total X 10^6 m^3	13.00	12.20	13.09	15.50	21.08	20.89	21.01	30.94	21.51	21.80	-	-
Monthly mean	4.84	5.04	4.89	5.98	7.87	8.06	8.11	11.55	8.30	8.14	-	-
Daily max.	5.34	6.52	10.10	23.16	12.47	16.63	125.05*	138.95*	152.18*	73.69*	-	-
Daily min.	4.75	4.55	4.55	4.55	4.55	6.52	5.73	5.14	4.16	4.16	-	-
Runoff in mm	9.6	9.00	9.66	11.1	15.6	15.4	15.51	22.83	15.87	16.09	-	-
Rainfall in mm	10	40	15	140	155	-	-	205	110	-	-	-
Rainfall/Runoff	0.96	0.23	0.64	0.08	0.10	-	-	0.11	0.14	-	-	-
Evap. in mm	195	155	185	145	110	180	110	140	130	-	-	-

* Estimated values

Annex 4.3- 4[a] Mean monthly and annual discharge (m^3/s) 1956 - 1972

Suam River, RGS 2B7 at Kongolai

Catchment area: 1350 Km^2

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL m^3/s	MEAN depth mm
1956	0.462	1.699	36.631	83.110	4.621	3.571	4.859	32.848	6.156	2.489	1.44	2.226	15.009	351.6
1957	1.579	1.155	2.527	11.081	30.271	13.405	7.697	14.249	4.112	1.436	7.464	4.466	8.287	193.6
1958	0.855	4.603	0.888	10.808	21.728	19.171	24.276	24.104	16.622	17.693	1.220	11.446	12.701	296.7
1959	1.057	2.584	5.693	10.729	28.855	7.102	23.957	16.821	14.045	15.914	10.293	5.975	11.919	278.4
1960	0.787	2.200	9.786	18.701	31.107	3.279	34.284	33.188	10.424	5.236	10.605	2.226	13.485	315.9
1961	0.838	.934	1.84	15.784	17.160	14.014	38.568	44.062	13.677	28.346	55.587	21.493	21.025	491.1
1962	7.940	1.872	6.386	1.495	15.716	7.957	18.095	38.147	25.939	9.231	5.774	4.007	11.047	258.0
1963	4.842	3.367	5.074	20.179	28.659	6.683	6.683	20.219	8.608	4.021	12.998	18.689	11.690	273.1
1964	3.710	2.237	8.099	10.619	4.729	16.594	31.121	29.308	24.183	17.415	4.559	3.681	13.021	305.1
1965	3.540	1.594	3.738	8.665	6.40	8.183	8.183	3.908	2.197	13.762	11.950	2.526	6.206	145.0
1966	1.416	12.035	8.184	34.037	6.711	5.182	18.548	22.201	17.359	12.007	17.415	2.549	13.137	306.9
1967	1.391	1.532	2.515	14.037	47.063	22.654	36.160	39.333	10.619	18.236	27.751	5.947	18.937	442.4
1968	2.379	9.543	10.364	13.677	15.376	8.325	11.384	22.824	4.106	4.616	6.683	5.635	9.576	224.3
1969	3.868	7.062	9.005	2.288	16.594	5.040	24.410	18.378	25.372	7.759	6.796	2.860	10.786	252.0
1970	6.040	1.960	11.525	10.902	20.785	17.245	25.061	55.389	23.394	13.394	10.308	3.426	16.642	388.8
1971	2.634	1.388	1.416	17.387	40.300	22.003	21.918	54.228	40.975	18.293	10.109	6.060	19.726	460.8
1972	3.511	4.757	3.256	9.911	10.846	15.376	34.236	26.476	18.095	17.982	22.569	5.380	14.366	336.5
MEAN	2.756	3.560	7.466	17.259	20.407	11.522	21.732	28.570	15.657	12.225	13.148	6.388	13.391	313.0
N(YEARS)	17	17	17	17	17	17	17	17	17	17	17	17	17	
SDEV	2.090	3.175	8.239	18.475	12.505	6.445	11.028	13.685	9.133	7.308	12.934	5.642	3.981	
CV	0.758	0.892	1.104	1.070	0.613	0.559	0.507	0.478	0.583	0.598	0.984	0.883	0.297.	

Annex 4.3 - 4[b] Mean monthly and annual discharge (m^3/s) 1957 - 1972

Muruny River, RGS 2B9 at Marich Pass

Catchment area: 1355 Km^2

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL m^3/s	MEAN depth mm
														mm
1957	1.841*	1.691	2.720	5.239	6.221	16.651	2.914	7.079	2.939	1.705	2.331	2.056	4.448	103.5
1958	1.574	2.268	2.064	1.682	3.055	4.681	17.315	9.345	5.239	5.012	2.333	2.832	4.775	111.1
1959	1.613*	2.376	1.688	2.047	5.547	2.843	5.437	5.239	6.241	4.112	2.648	1.883	3.473	80.8
1960	1.478	1.365	5.720	2.478	6.711	2.464	9.550*	7.343*	5.422*	4.715*	2.900	2.668	4.401	102.7
1961	1.481	1.320	1.399	3.500*	7.000*	3.300*	53.563	16.393	5.123*	5.527	22.936	10.848	11.032	258.8
1962	6.154	4.095	4.129	4.403	7.065	4.137	12.406	11.738	8.192	5.312	4.621	3.600*	6.371	148.3
1963	2.831	3.290	2.467	4.765	5.654*	3.888*	6.609	8.145*	4.282	2.840	3.712	8.158	4.721	109.9
1964	3.030	2.404	3.387	4.760	4.089	3.497	10.316	17.868	10.112	7.697	4.910	4.194	6.355	148.3
1965	3.633	2.880	3.248	4.015	4.995	3.341	3.763	3.888	3.036	3.899	4.828	2.843	3.696	86.2
1966	1.639	4.502	2.588	3.000*	5.75	3.259	6.320	7.060	8.043*	4.112	3.092	2.093	4.288	99.8
1967	1.580	1.540	2.307*	2.429*	6.464*	5.179*	13.422	9.458	6.230	6.570	7.306	5.097	5.632	131.1
1968	3.426	5.210	5.579	7.844	6.740	4.559	6.060	7.079	3.738	4.304	5.465	4.046	5.332	124.6
1969	2.741	3.205	4.305	5.409	6.513	2.869	9.062	7.844	9.969	4.361	6.655	2.546	5.466	127.2
1970	4.225	2.509	5.095	12.840*	6.840*	6.999*	8.832*	14.159	7.360*	4.471*	3.413*	3.426	6.678	155.4
1971	3.172	2.690	2.435	3.568	6.213*	5.692	7.306	9.486	5.383*	7.663*	3.861*	3.336*	5.067	117.9
1972	3.142	4.515	3.201	4.475	6.614	8.062	11.460	8.456	7.337	7.869	8.107	3.384	6.380	148.9
MEAN	2.760	2.866	3.270	4.526	5.967	5.089	11.521	9.411	6.165	5.011	5.570	3.938	5.508	123.3
SDEV	1.395	1.431	1.342	2.688	1.112	3.448	11.816	3.845	2.210	1.732	4.953	2.383	1.766	
CV	0.505	0.499	0.41	0.594	0.186	0.678	1.026	0.409	0.358	0.346	0.889	0.605	0.321	
N	16	16	16	16	16	16	16	16	16	16	16	16	16	

* estimated

Annex 4.3-4[c] Mean monthly and annual discharge (m^3/s) 1957 - 1976

Wei Wei River, RGS 2B28[*)], d/s of Tamkal (Sigor)

Catchment area: 170 Km^2

* 2 B 8 1955 - 1962

12 1962 - 1969

15 1969 - 1977

28 1978 - date

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL MEAN m^3/s	ANNUAL MEAN depth mm
1957	1.845	1.742	0.858	4.350	5.170	4.180	3.545	3.112	2.348	1.872	2.894	3.231	2.929	475
58	1.679	2.551	1.911	2.132	5.097	2.466	6.646	5.848	4.242	3.928	2.331	2.730	3.463	560
59	1.713	1.974	2.628	3.223	6.439	2.693	4.154	3.341	2.939	3.163	2.591	2.591	3.113	505
1960	1.475	1.170	2.551	3.826	6.301	2.798	4.426	3.774	3.381	4.024	2.678	2.843	3.268	530
61	1.557	1.147	0.909	3.682	7.000	2.885	5.040	9.458	3.191	4.818	31.409	9.626	6.727	1090
62	4.993	3.011	3.987	4.282	6.343	3.823	4.446	4.984	4.389	3.936	3.681	3.531	4.284	690
63	2.134	2.835	2.251	4.735	5.777	2.968	2.684	4.250	2.999	2.189	4.188	7.759	3.731	605
64	3.330	2.441	3.033	4.242	3.596	3.322	3.293	6.598	5.748	3.426	2.415	2.430	3.656	595
65	1.807	1.450	2.396	2.959	4.177	2.205	1.957	1.781	1.482	2.294	2.392	2.523	2.535	410
66	1.354	3.381	2.880	3.270	6.196	1.962	3.265	3.412	5.043	3.452	3.004	1.478	3.225	520
67	2.047	1.730	1.810	2.631	7.391	4.100	8.495	6.541	3.460	6.983	10.109	5.324	5.052	815
68	2.718	3.115	4.446	7.136	9.373	4.757	3.738	6.230	2.945	4.174	9.314	4.559	5.209	840
69	2.948	3.574	4.092	5.258	6.685	2.646	4.551	4.434	5.781	3.608	5.324	3.974	4.406	715
1970	4.160	3.173	7.197	11.976	8.140	5.697	4.001	8.271	4.610	3.442	2.803	2.007	5.467	885
71	2.071	1.339	1.196	5.060	6.891	3.711	3.306	4.533	3.356	4.637	3.694	3.236	3.600	580
72	2.125	3.165	1.843	3.709	5.789	5.147	7.927	4.632	5.238	13.228	11.714	3.169	5.645	915
73	2.395	1.730	1.437	1.835	3.254	2.960	2.087	5.271	3.483	2.242	4.082	2.053	2.741	445
74	1.700	1.519	2.234	2.968	4.111	3.683	4.851	5.721	4.720	2.652	2.307	1.558	3.180	515
75	1.294	1.258	1.580	2.561	4.787	2.642	5.273	8.050	4.181	2.841	2.127	1.718	3.213	520
76	1.336	1.322	0.955	1.716	4.992	2.003	5.070	3.780	4.616	1.843	2.389	1.670	2.649	430
MEAN	2.234	2.181	2.510	4.078	5.875	3.332	4.438	5.200	3.908	3.904	5.751	3.401	3.905	630
SDEV.	0.975	0.845	1.517	2.267	1.532	1.039	1.708	1.924	1.136	2.513	6.646	2.091	1.158	-
CV.	0.436	0.387	0.604	0.556	0.261	0.312	0.385	0.370	0.291	0.644	1.156	0.615	0.297	-
N.	20	20	20	20	20	20	20	20	20	20	20	20	20	-

Annex 5 HYDROGEOLOGY

5.1 Geological well logs

5.2 Analysis of well test data

5.3 Groundwater level fluctuations

5.4 Borehole data West Pokot District

Annex 5.1 Geological Well Logs

LEGEND TO THE LOGS


unknown


clay


loam


clayey


fine sand


medium sand


coarse sand


sandy


gravel


tuff


volcanic ash


volcanic agglomerate


lava (P=phonolite, T=trachyte)



diatomite



weathered



marble



gneiss



quartzite



pegmatite



schist


chert, chalcedony

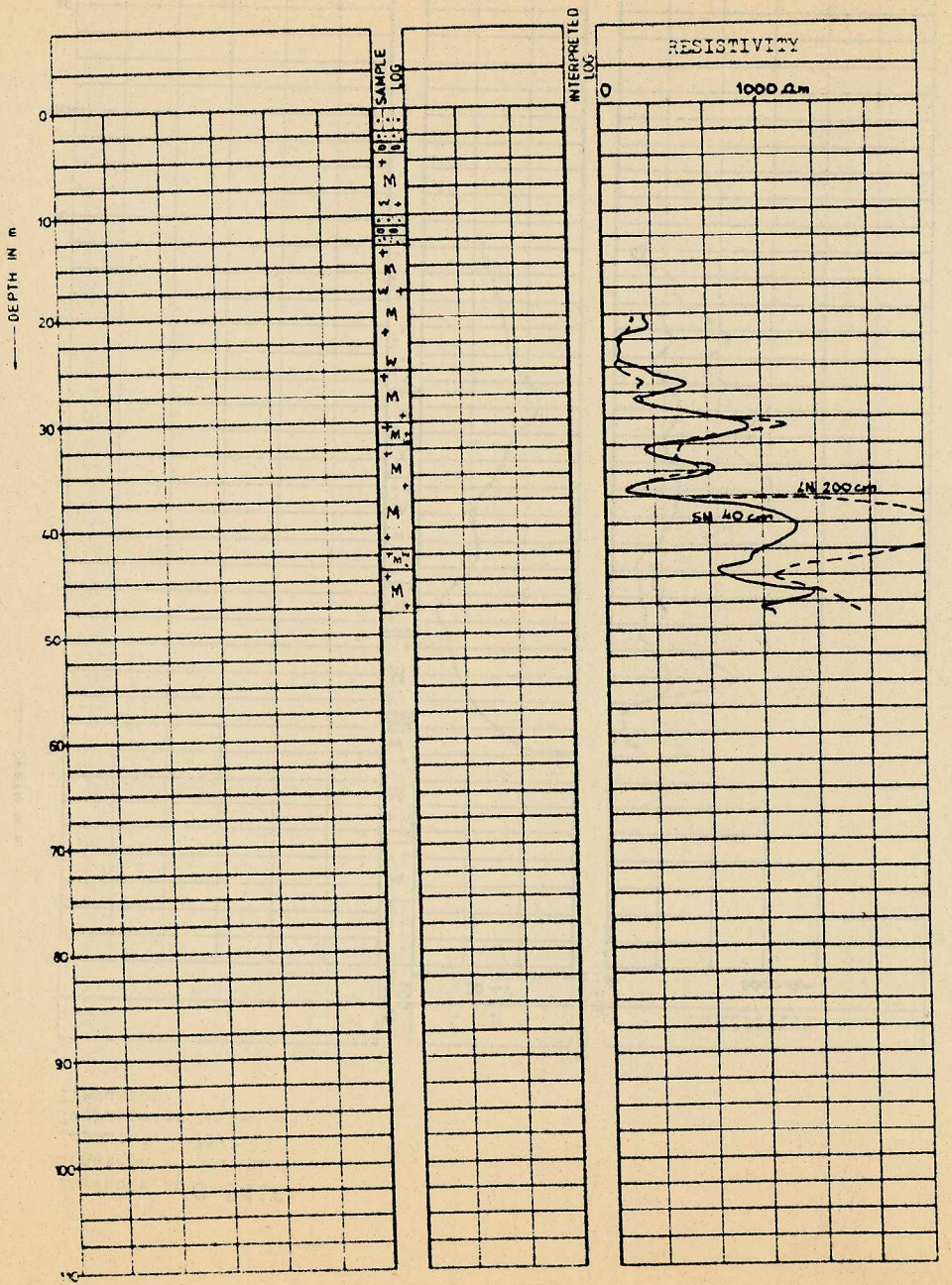


consolidated

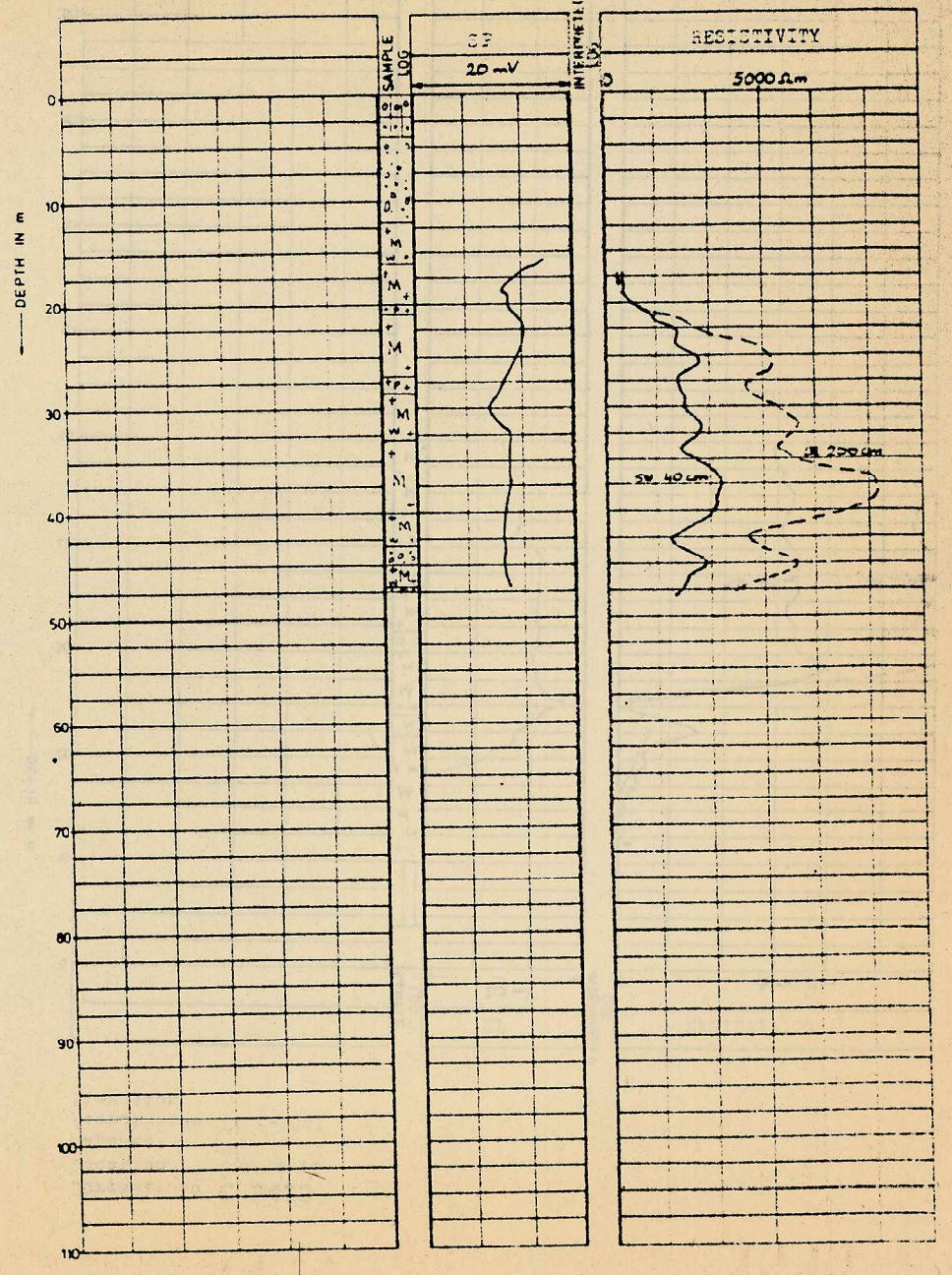


metamorphic

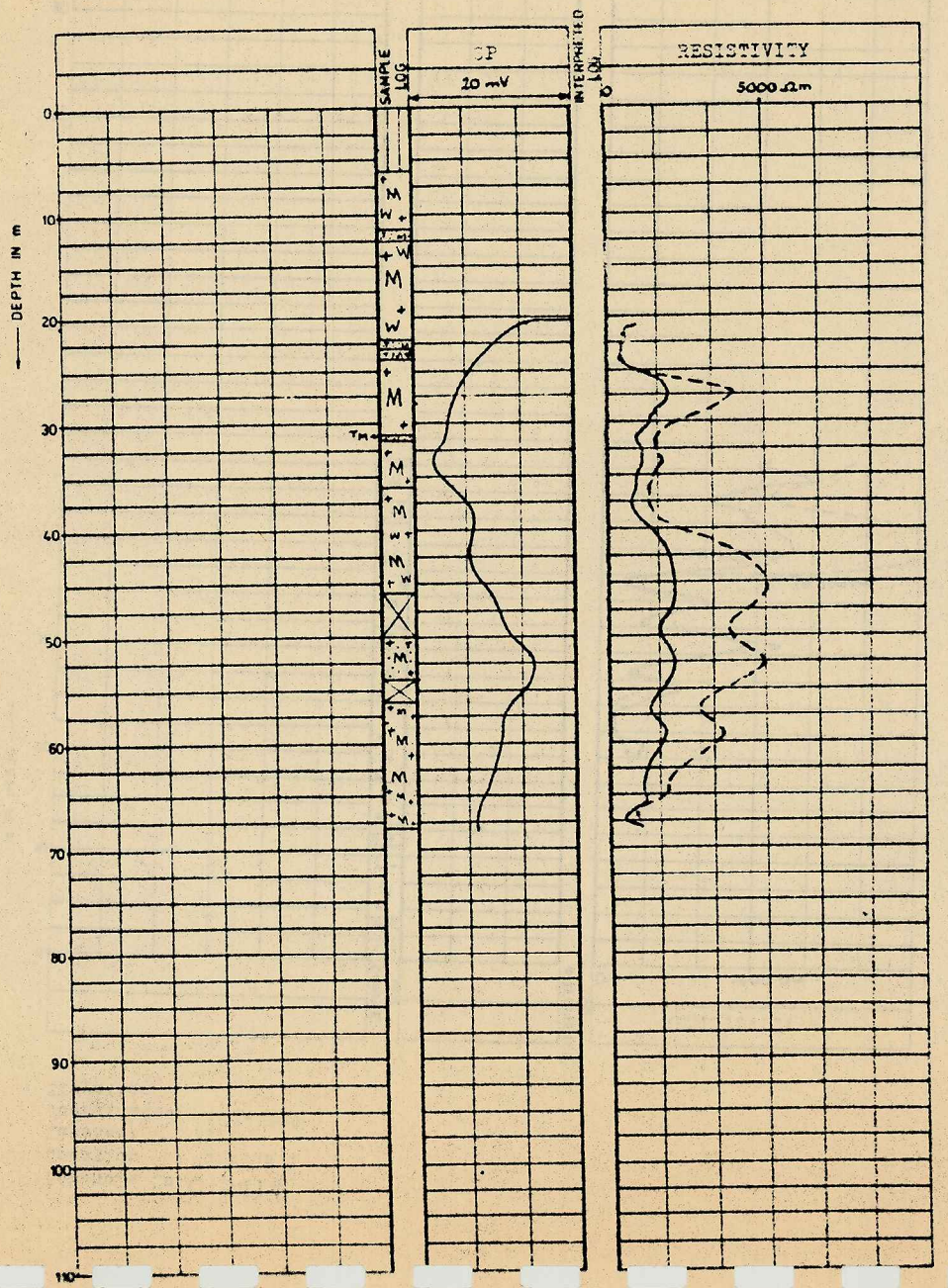
Borehole No C 5414
Location Boreous I
Mapsheet 75/2
Coordinates 7527-1539
Elevation



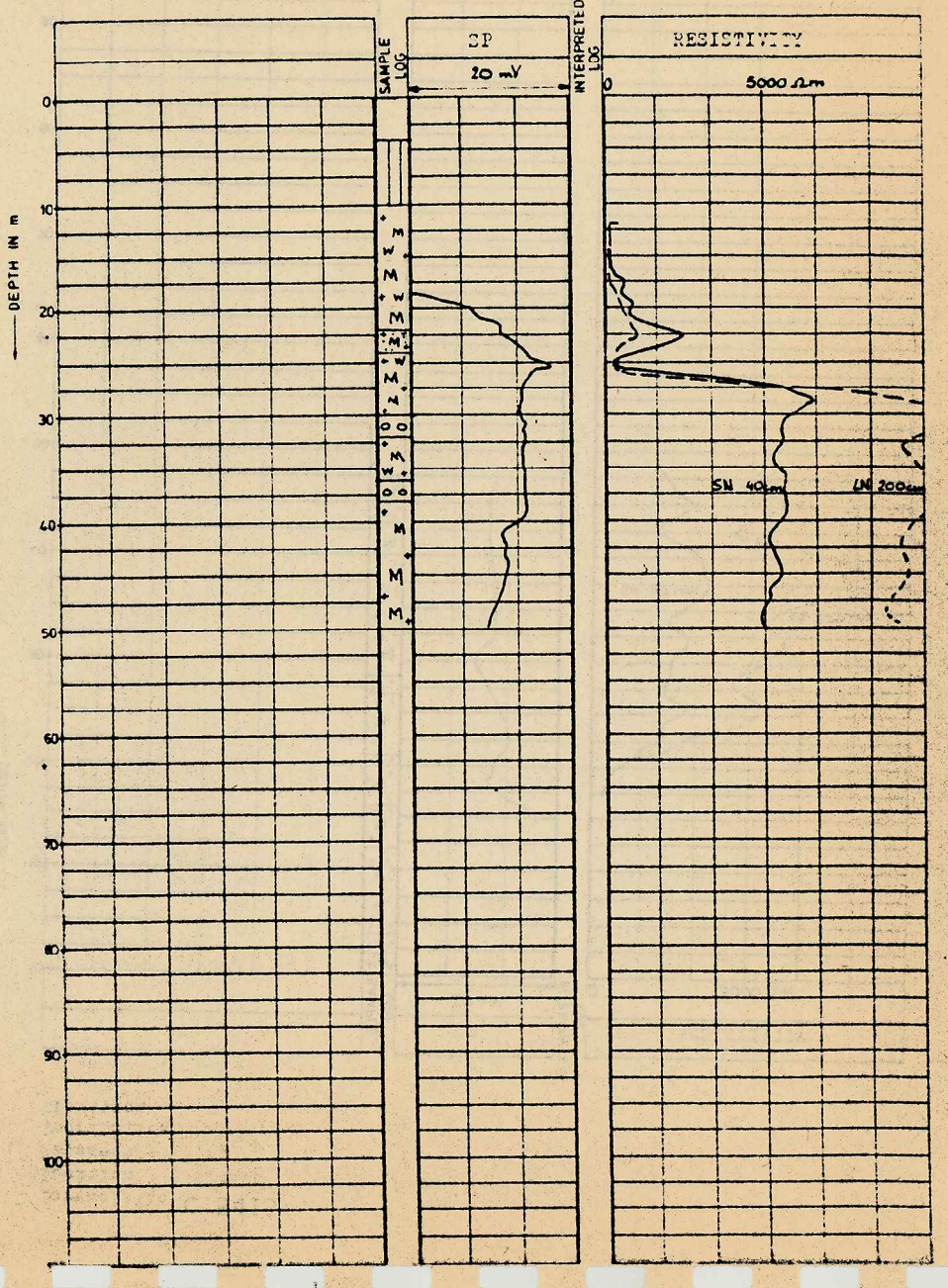
Borehole No C 5415
Location Boreous II
Mapsheet 75/2
Coordinates 7529-1541
Elevation



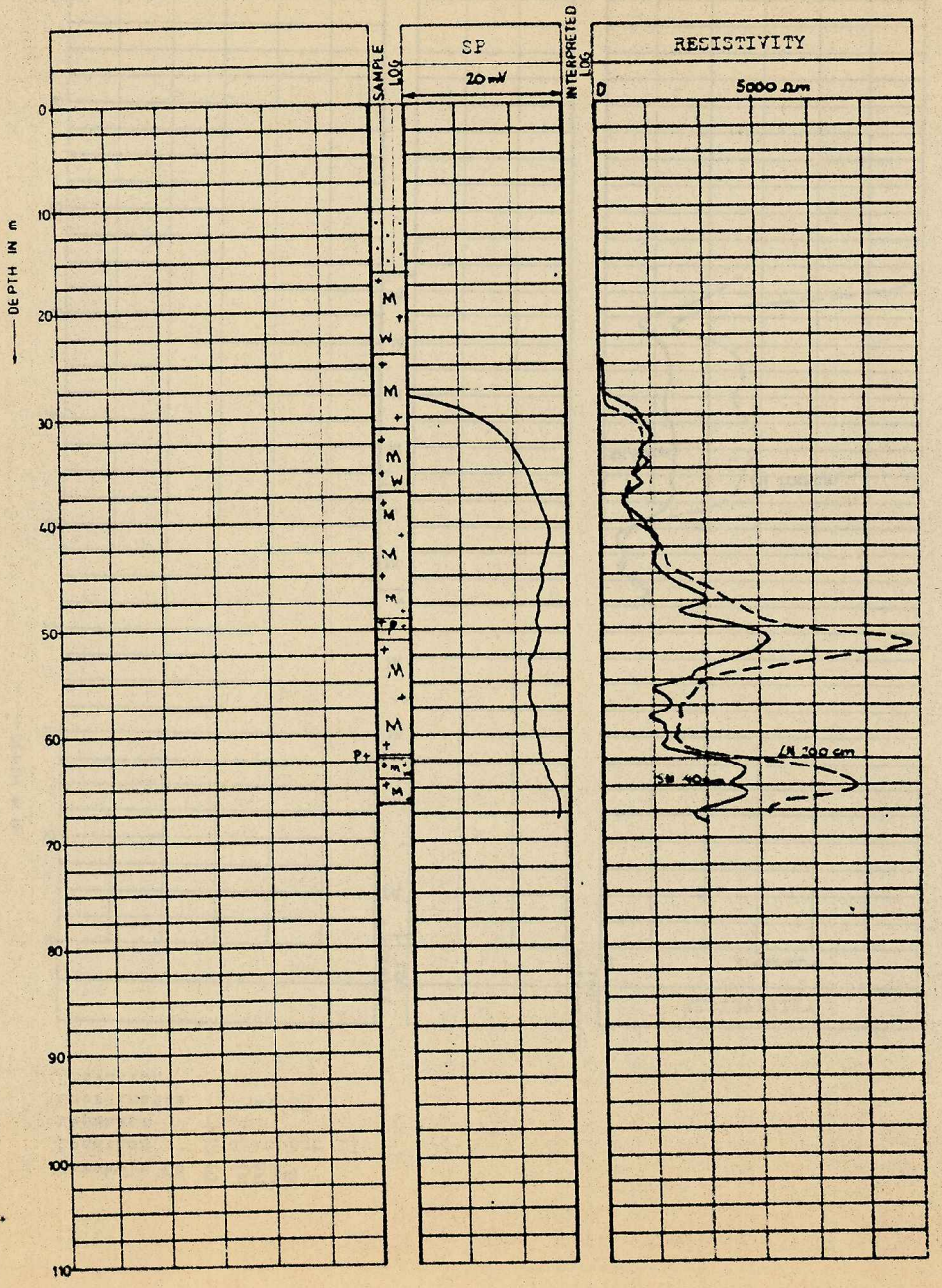
Borehole No C 5416
Location Puurum I
Mapsheet 75/1
Coordinates 7461-1543
Elevation



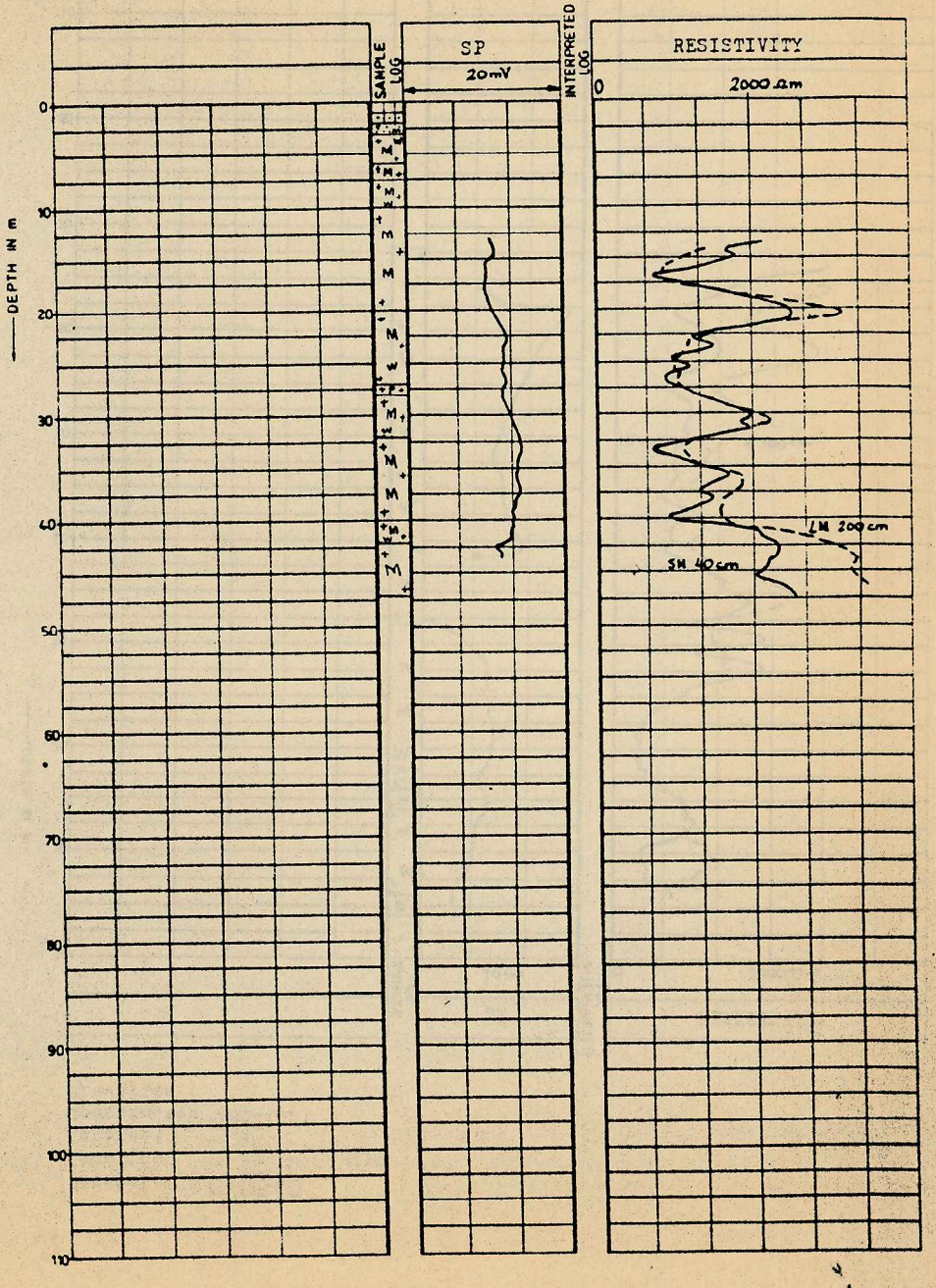
Borehole No C 5428
Location Puurum II
Mapsheet 75/1
Coordinates 7466-1541
Elevation



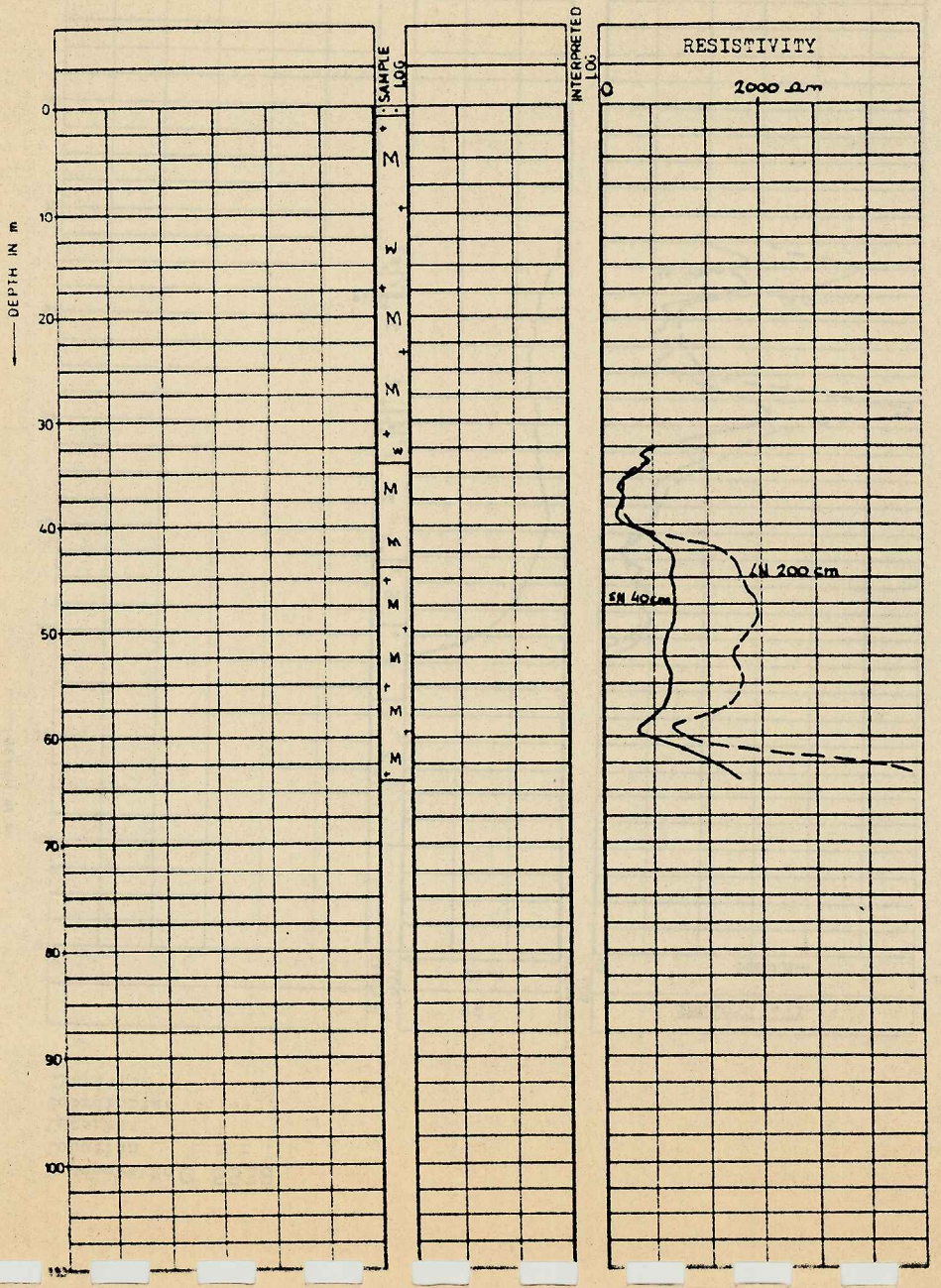
Borehole No C 5538
Location Pourim III
Mapsheet 75/1
Coordinates 7457-1532
Elevation



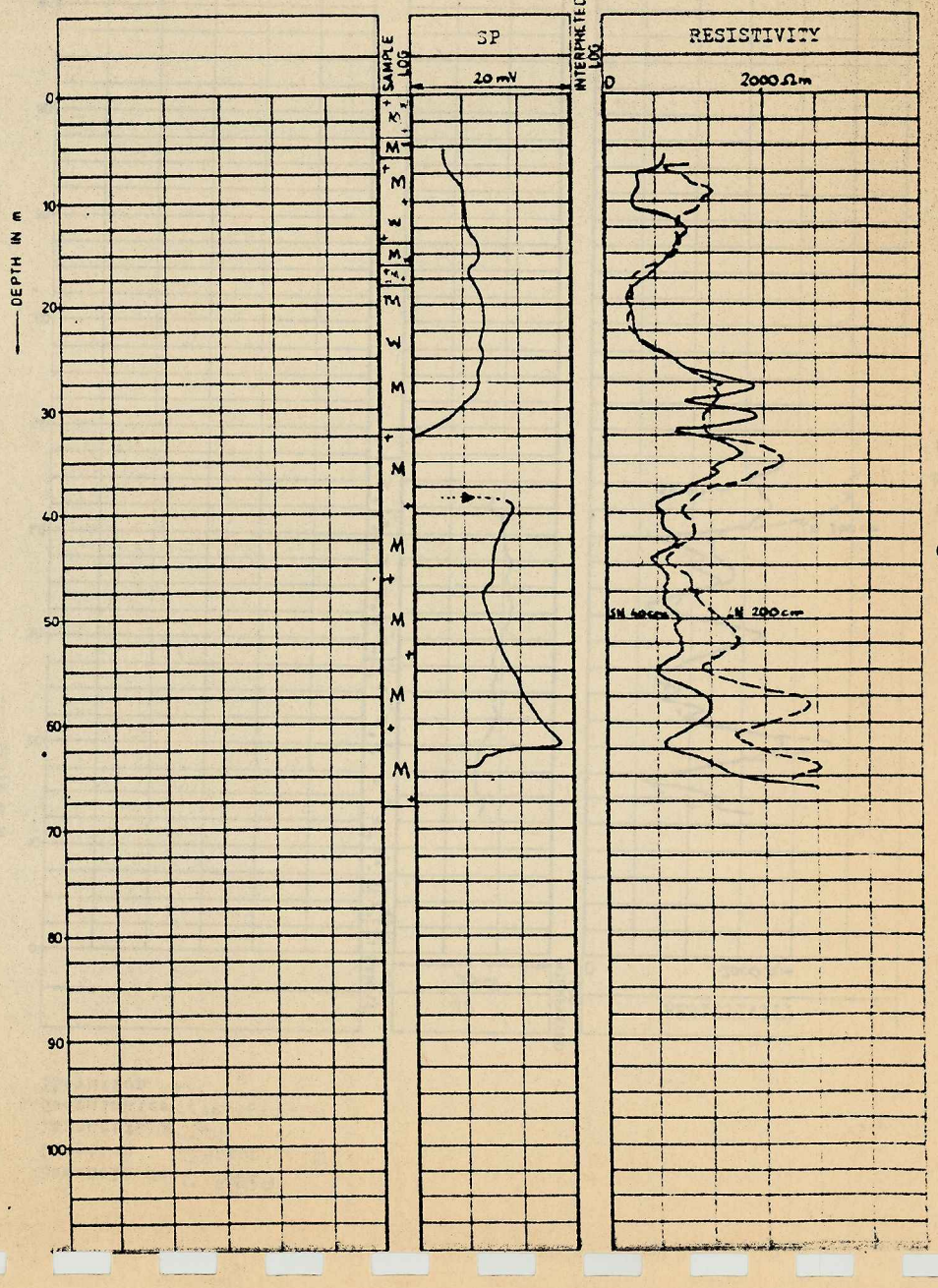
Borehole No C 5429
Location Chepkopegn I
Mapsheet 75/1
Coordinates 7478-1619
Elevation

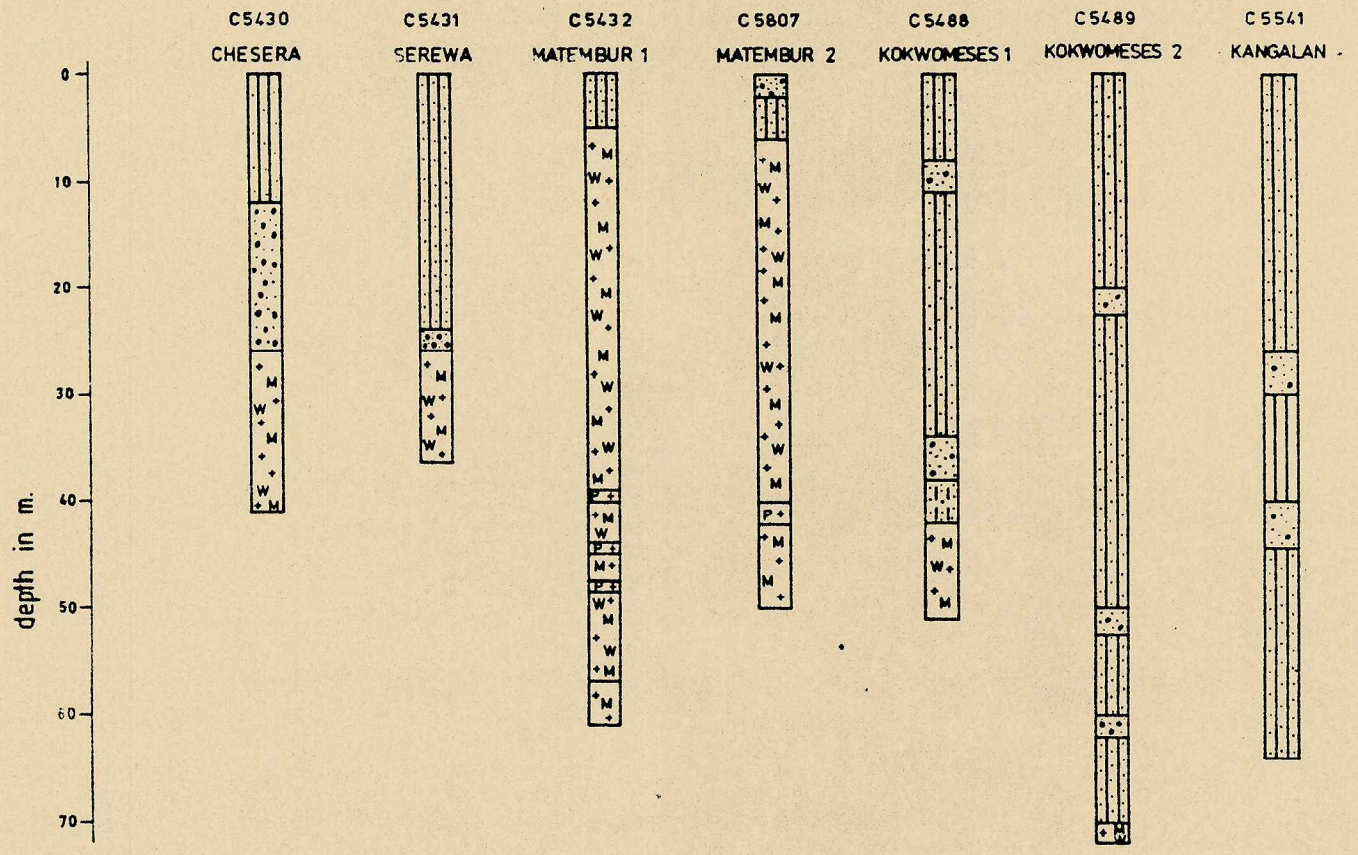


Borehole No C 5539
Location Cherkopegh II
Mapsheet 75/1
Coordinates 7478-1609
Elevation

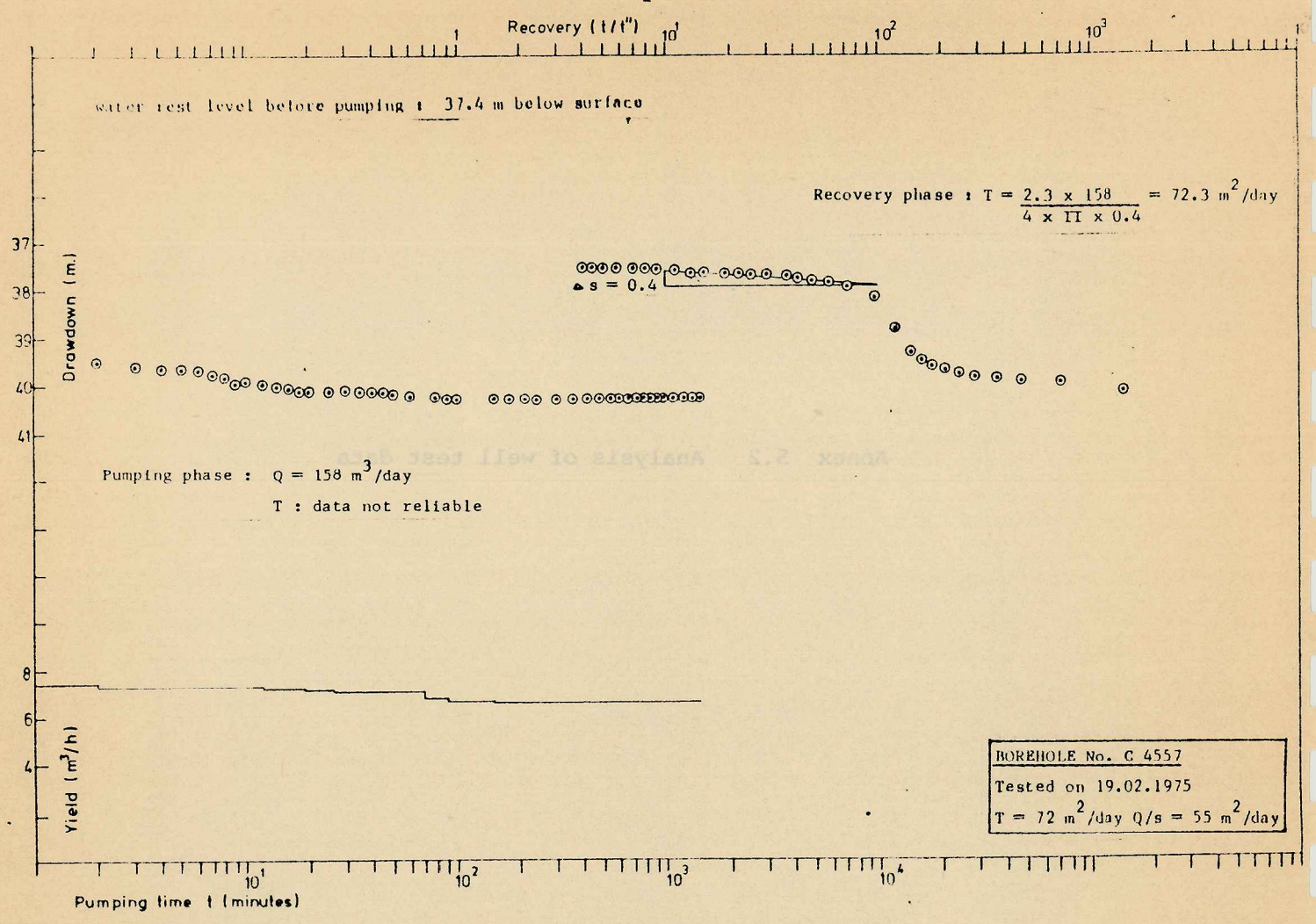


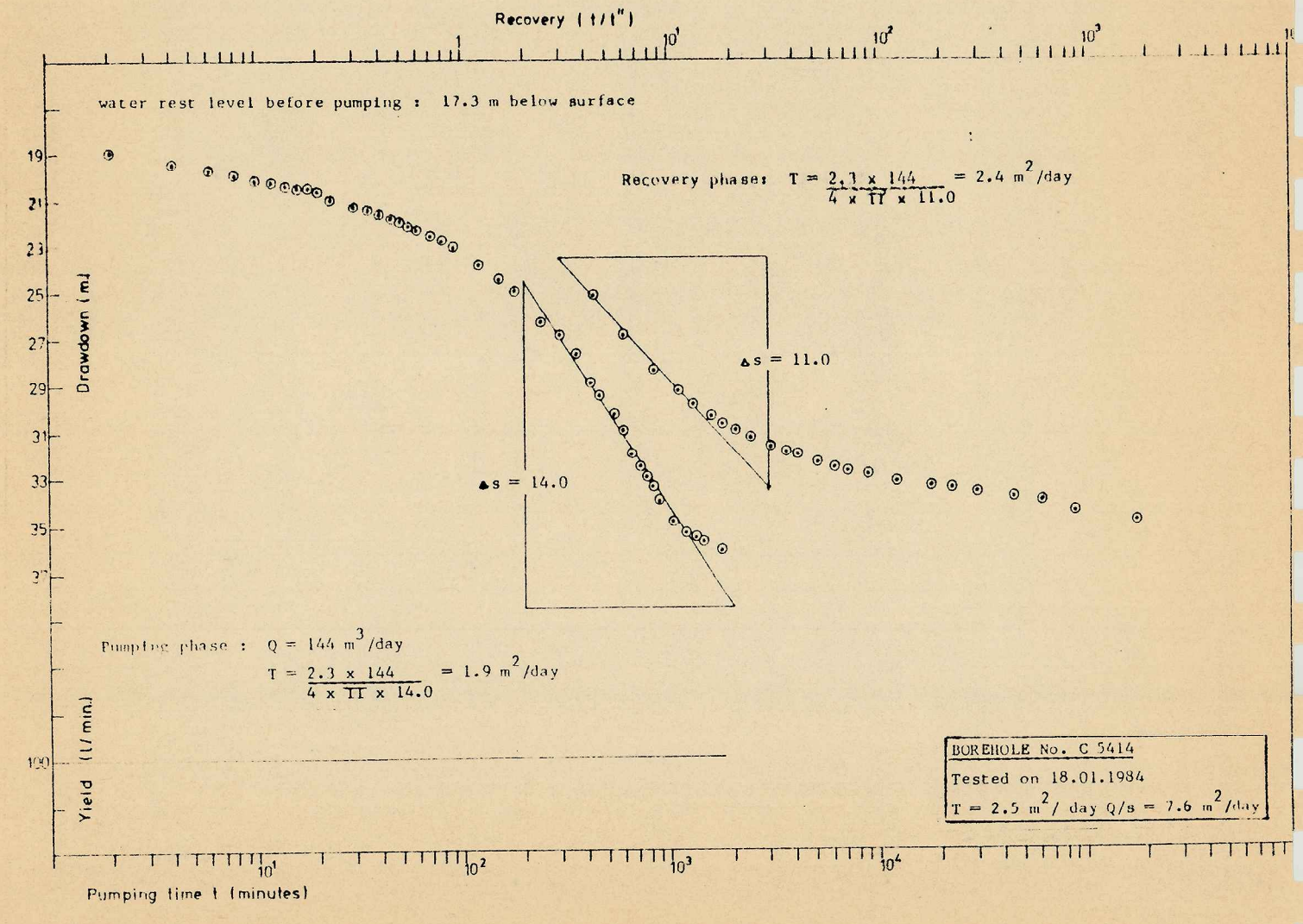
Borehole No C 5540
Location Cherkopegh III
Mapsheet 75/1
Coordinates 7480-1621
Elevation

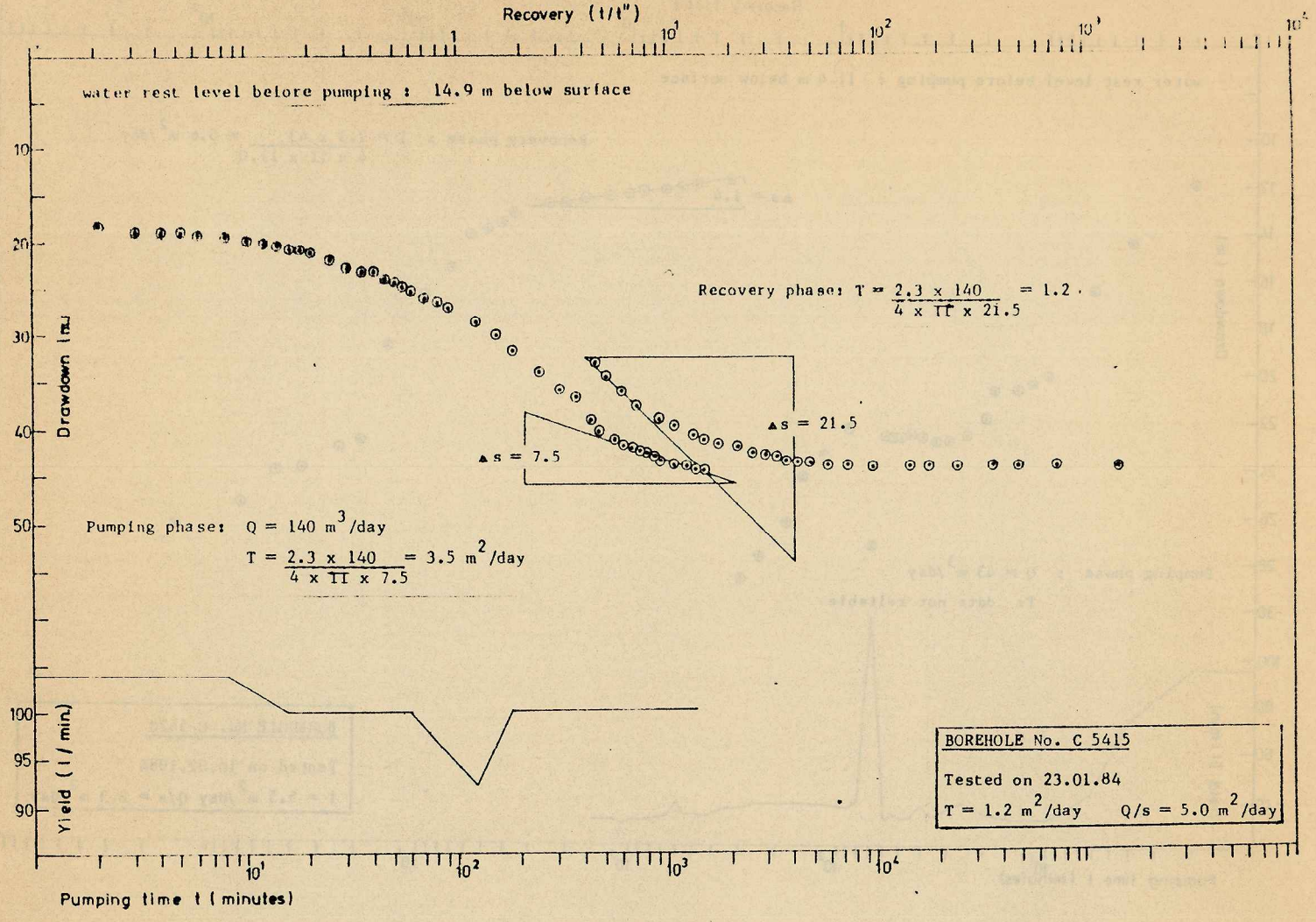


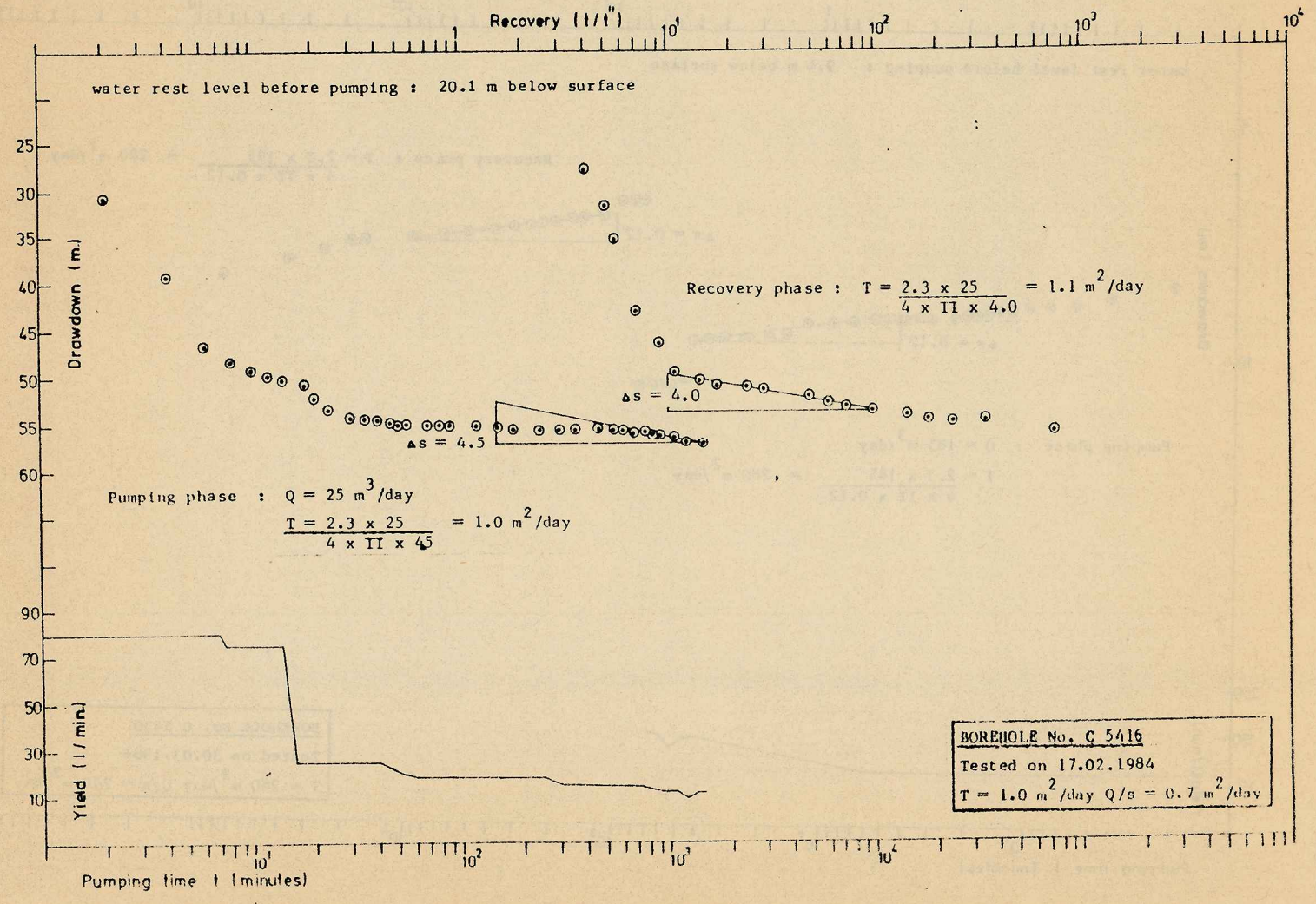

C5430
CHESERA
C5431
SEREWA
C5432
MATEMBUR 1
C5807
MATEMBUR 2
C5488
KOKWOMESES 1
C5489
KOKWOMESES 2
C5541
KANGALAN
depth in m.
0
10
20
30
40
50
60
70

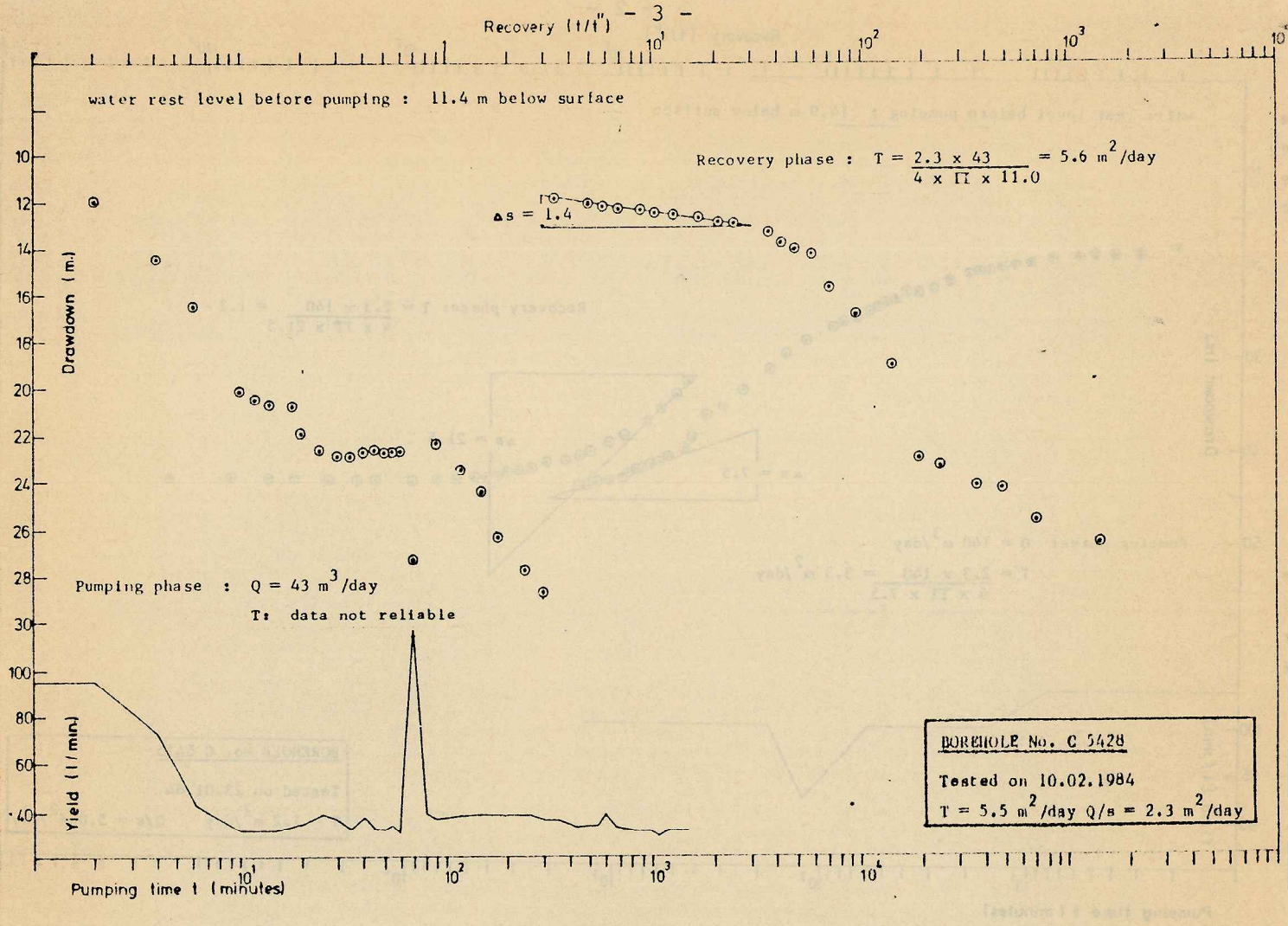
Annex 5.2 Analysis of well test data

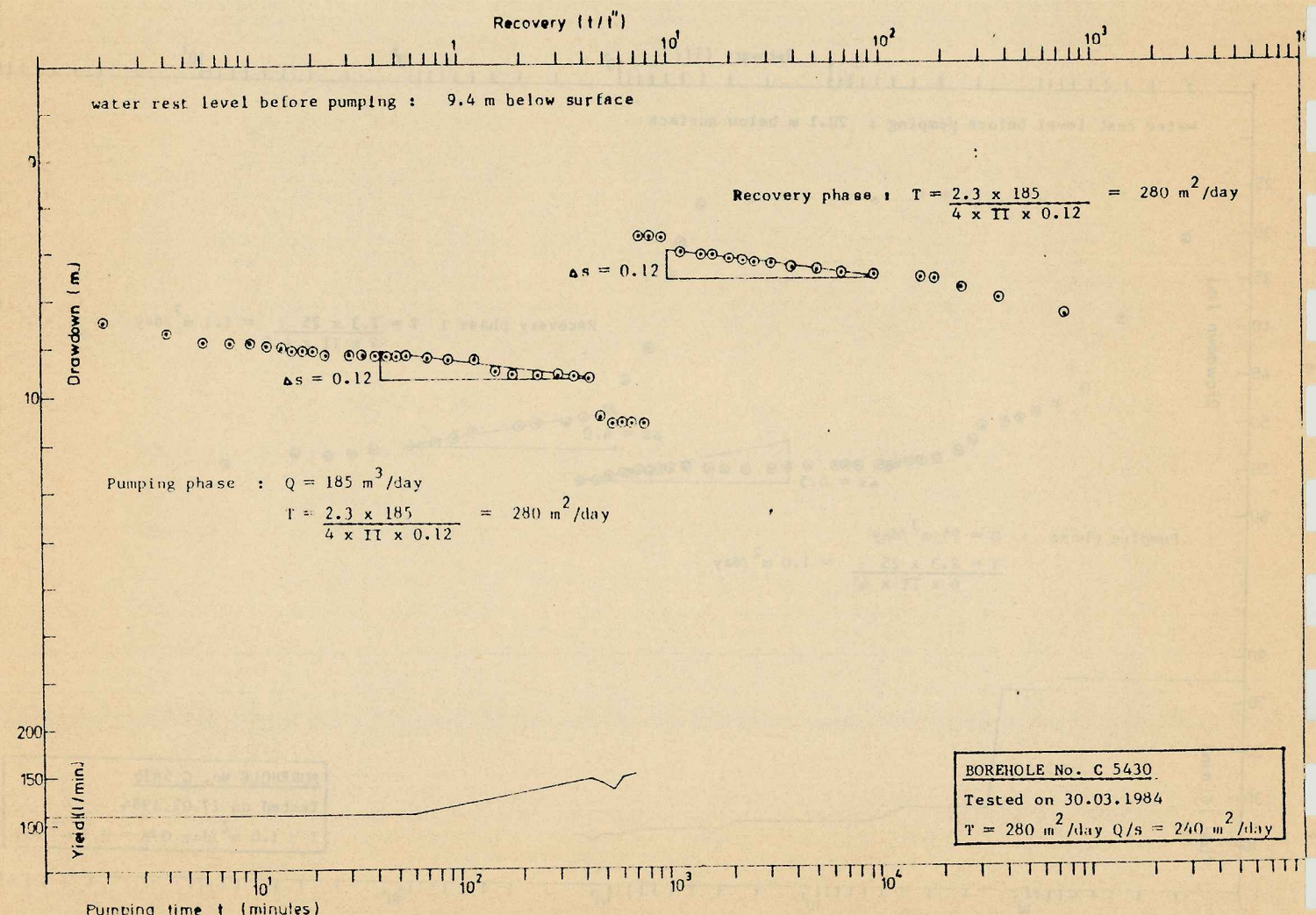

Recovery (t/t')
1
10¹
10²
10³
water rest level before pumping : 37.4 m below surface
Recovery phase : T = 2.3 x 158 / 4 x Π x 0.4 = 72.3 m²/day
Drawdown (m.)
37
38
39
40
41
Δs = 0.4
Pumping phase : Q = 158 m³/day
T : data not reliable
8
6
4
Yield (m³/h)
BOREHOLE No. C 4557
Tested on 19.02.1975
T = 72 m²/day Q/s = 55 m²/day
10¹
10²
10³
10⁴
Pumping time t (minutes)

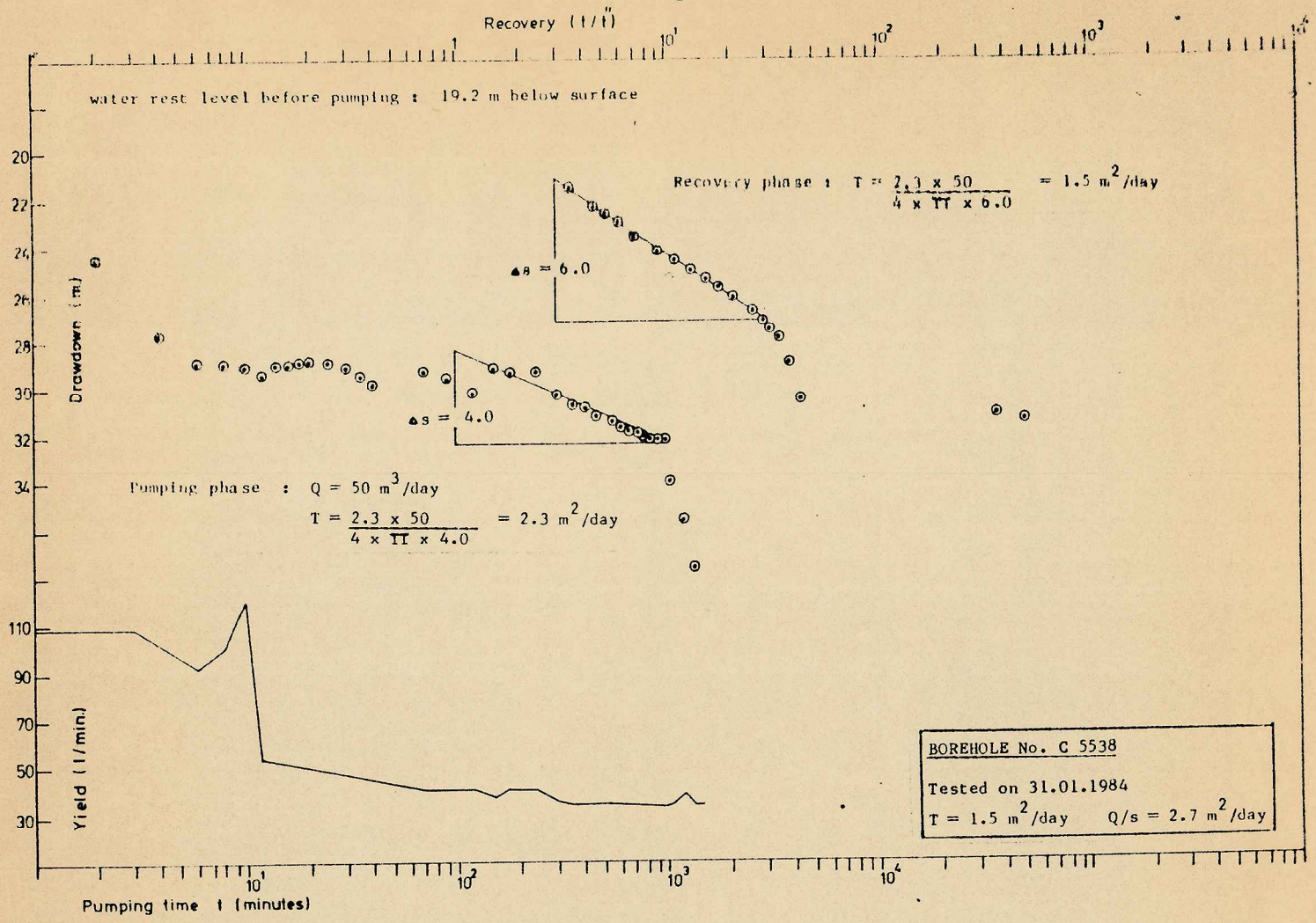

Recovery (t/t')
1
10¹
10²
10³
water rest level before pumping : 17.3 m below surface
Recovery phase: T = 2.3 x 144 / 4 x Π x 11.0 = 2.4 m²/day
Drawdown (m.)
19
21
23
25
27
29
31
33
35
Δs = 11.0
Δs = 14.0
Pumping phase : Q = 144 m³/day
T = 2.3 x 144 / 4 x Π x 14.0 = 1.9 m²/day
100
Yield (l/min.)
BOREHOLE No. C 5414
Tested on 18.01.1984
T = 2.5 m²/ day Q/s = 7.6 m²/day
10¹
10²
10³
10⁴
Pumping time t (minutes)

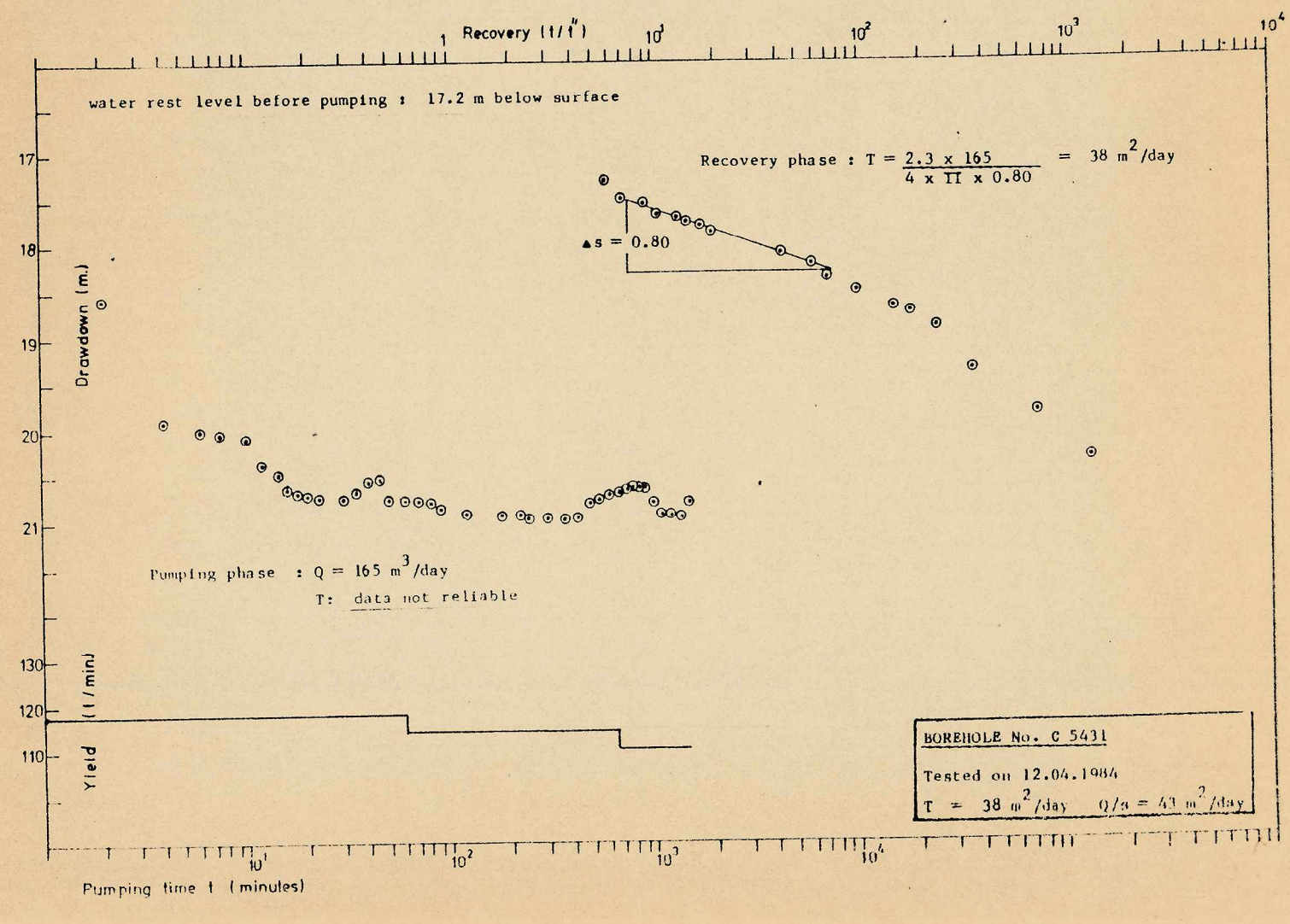

Recovery (t/t")
water rest level before pumping : 14.9 m below surface
Drawdown (m)
Recovery phase: T = 2.3 x 140 / 4 x 11 x 21.5 = 1.2
Δs = 21.5
Δs = 7.5
Pumping phase: Q = 140 m³/day
T = 2.3 x 140 / 4 x 11 x 7.5 = 3.5 m²/day
Yield (l/min)
BOREHOLE No. C 5415
Tested on 23.01.84
T = 1.2 m²/day Q/s = 5.0 m²/day
Pumping time t (minutes)

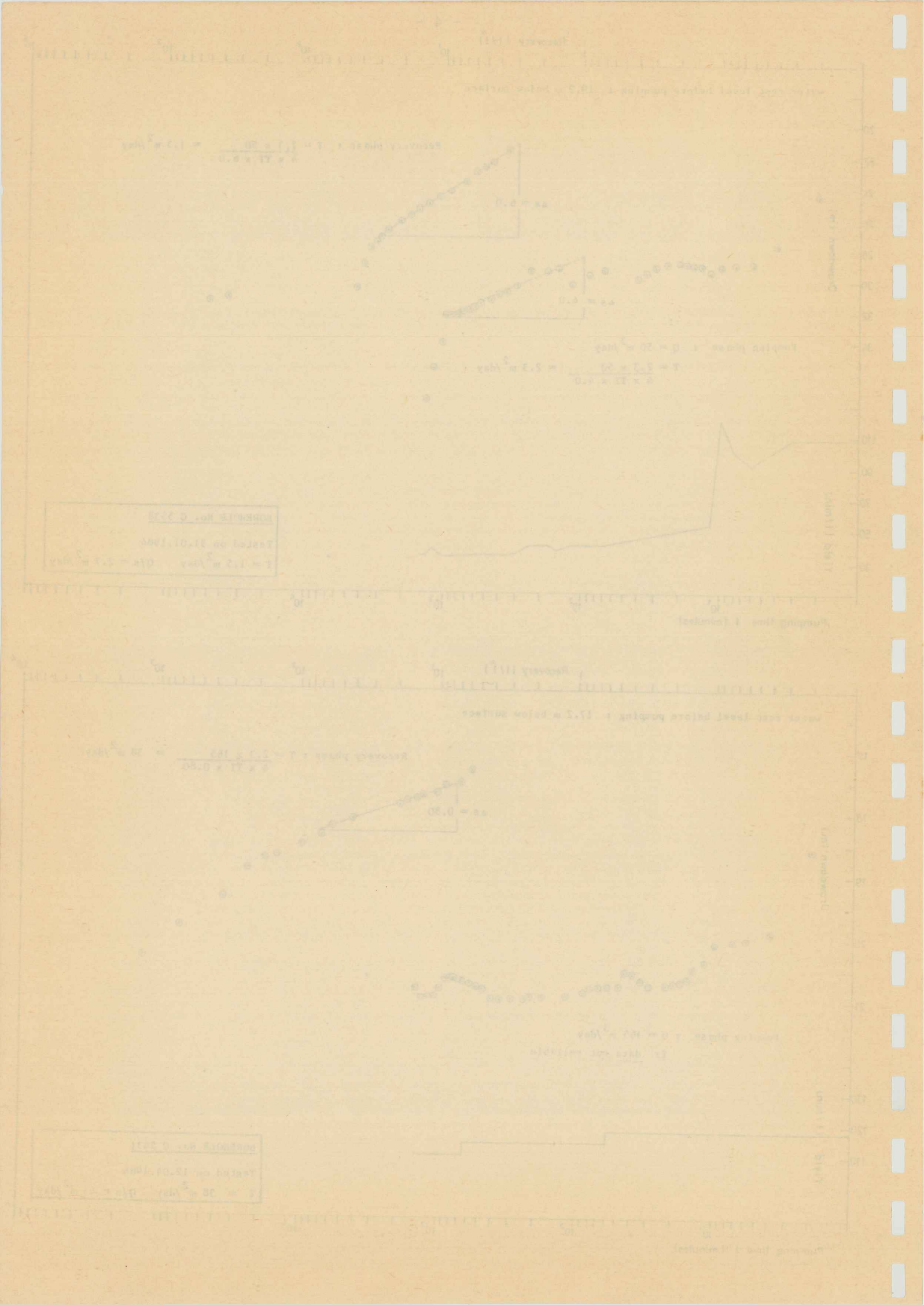

Recovery (t/t")
water rest level before pumping : 20.1 m below surface
Drawdown (m)
Recovery phase : T = 2.3 x 25 / 4 x 11 x 4.0 = 1.1 m²/day
Δs = 4.0
Δs = 4.5
Pumping phase : Q = 25 m³/day
T = 2.3 x 25 / 4 x 11 x 45 = 1.0 m²/day
Yield (l/min)
BOREHOLE No. C 5416
Tested on 17.02.1984
T = 1.0 m²/day Q/s = 0.7 m²/day
Pumping time t (minutes)


Recovery (t/t')
water rest level before pumping : 11.4 m below surface
Recovery phase : T = 2.3 x 43 / 4 x Π x 11.0 = 5.6 m²/day
Δs = 1.4
Drawdown (m)
Pumping phase : Q = 43 m³/day
T: data not reliable
Yield (l/min)
Pumping time t (minutes)
BOREHOLE No. C 5428
Tested on 10.02.1984
T = 5.5 m²/day Q/s = 2.3 m²/day


Recovery (t/t')
water rest level before pumping : 9.4 m below surface
Recovery phase : T = 2.3 x 185 / 4 x Π x 0.12 = 280 m²/day
Δs = 0.12
Δs = 0.12
Drawdown (m)
Pumping phase : Q = 185 m³/day
T = 2.3 x 185 / 4 x Π x 0.12 = 280 m²/day
Yield (l/min)
Pumping time t (minutes)
BOREHOLE No. C 5430
Tested on 30.03.1984
T = 280 m²/day Q/s = 240 m²/day


Recovery (t/t')
water rest level before pumping : 19.2 m below surface
Recovery phase : T = 2.3 x 50 / 4 x π x 6.0 = 1.5 m²/day
Δs = 6.0
Drawdown (m)
Δs = 4.0
Pumping phase : Q = 50 m³/day
T = 2.3 x 50 / 4 x π x 4.0 = 2.3 m²/day
Yield (l/min)
BOREHOLE No. C 5538
Tested on 31.01.1984
T = 1.5 m²/day Q/s = 2.7 m²/day
Pumping time t (minutes)


Recovery (t/t')
water rest level before pumping : 17.2 m below surface
Recovery phase : T = 2.3 x 165 / 4 x π x 0.80 = 38 m²/day
Δs = 0.80
Drawdown (m.)
Pumping phase : Q = 165 m³/day
T: data not reliable
Yield (l/min)
BOREHOLE No. C 5431
Tested on 12.04.1984
T = 38 m²/day Q/s = 43 m²/day
Pumping time t (minutes)



Annex 5.3 Monitoring of groundwater levels (m below surface)

Borehole No.	Location	1982		1983				
		9-11	7-12	9-1	15-2	25-3	28-4	11-5
CD 146	Kunyao	9.15	8.84	11.20	11.47	11.62	12.02	12.00
CD 825	Karameni	17.40	16.35	-	-	24.87	-	-
CD 1503	Kunyao	11.20	9.60	12.05	12.23	-	10.01	10.12
CD 2306	Kacheliba	46.05	45.40	46.10	46.17	46.30	46.32	46.35

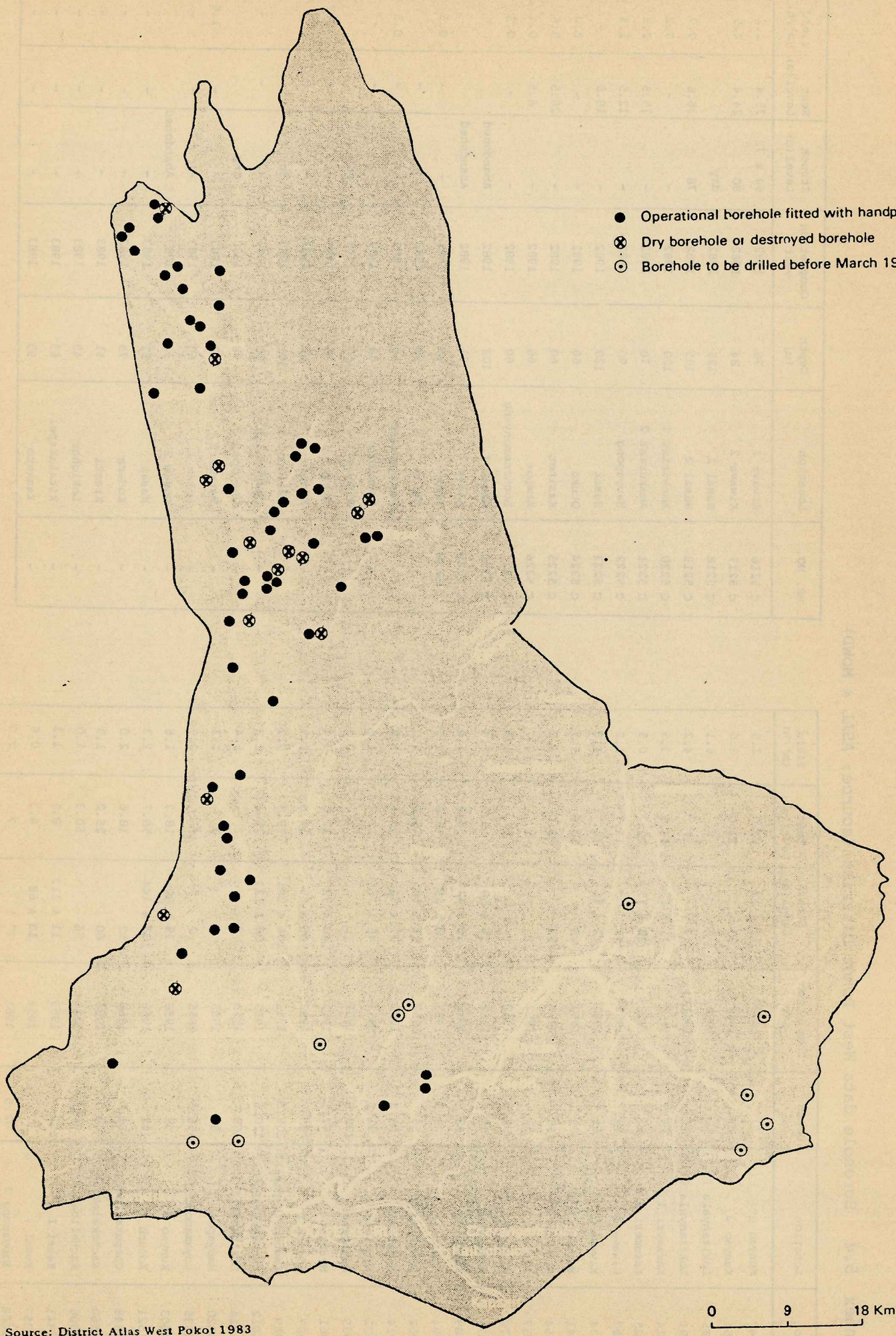
Annex 5.4 Borehole data West Pokot District (source: ASAL & MoWD)

BH.No.	Location	Depth (m)	Completion year	Struck Level(m)	Rest Level(m)	Yield (m^3/h)
CD 147	Kunyao I	30	1942	22 & 27	14.0	2.5
CD 268	Kunyao 2	30	1945	20	12.0	3.0
CD 685	Lokitanyala I	92	1950	?	?	6.1
CD 691	Lokitanyala 2	87	1951	?	?	4.2
CD 814	Karameri I	55.5	1951	21 & 53	14.5	3.5
CD 825	Karameri 2	62.5	1952	20 & 55	20.7	0.5
CD 827	Kiwawa I	55	1952	52	13.7	1.2
CD 834	Kiwawa 2	61	1952	12 & 55	10.7	4.5
CD 841	Burgich I	91	1952	85	50.3	1.7
CD 854	Burgich 2	58	1952	52	32.0	3.2
CD 857	Alale I	51	1952	?	?	0.7
CD 870	Alale 2	59.5	1952	?	?	1.6
CD 874	Amakuriat	67	1952	26 & 59	15.2	1.3
CD 889	Kamila I	49	1952	16 & 42	8.2	5.0
CD 894	Kamila 2	39.5	1952	10 & 35	9.8	6.5
CD 902	Kouriong I	56	1952	17 & 50	9.2	5.0
CD 914	Nakatimon	58.5	1952	27 & 56	26.5	3.5
CD 922	Kouriong 2	81.5	1952	46 & 76	13.7	1.8
CD 935	Nayagelel	128.5	1952	?	?	0.3
CD 961	Nyanga	62.5	1953	40 & 59	32.0	0.4
CD 987	Koduch I	93	1953	65 & 89	54.9	2.5
CD 989	Kachekelekenei I	208.5	1953	106 & 181	79.9	0.2
CD 1012	Kachekelekenei 2	120.5	1953	87 & 117	75.6	1.3
CD 1314	Lokitanyala 3	69	1953	?	?	5.4
CD 1320	Naoyapong I	85	1955	?	?	1.2
CD 1335	Loyamamosing	155.5	1955	?	?	0.9
CD 1503	Kunyao 3	98	1956	35 & 90	18.3	1.8
CD 1521	Koduch 2	152	1956	103 & 144	56.7	1.3
CD 1548	Chepukatina	61	1956	52	18.6	2.0
CD 1560	Kachekelekenei 3	69	1956	60	25.0	1.3
CD 2306	Kacheliba	70.5	1959	56	50.3	1.0
CD 2341	Kesei I	122	1959	11 & 113	8.5	1.3
CD 2357	Kesei 2	77	1959	13 & 68	4.3	0.6
CD 2668	Naoyapong 2	92.5	1961	?	?	2.0
CD 3547	Kamuketo	180	?	?	?	6.2
CD 3620	Nakany	122	?	?	?	0.9
C 2293	Kapenguria	45	1954	?	20.7	3.0
C 1557	Marich Pass	81	1979	42	37.4	6.5

BH. NO.	Location	Depth (m)	Completion year	Struck Level(m)	Rest Level(m)	Yield (m^3/h)
C 5216	Kiwawa I	76	1982	64 & 72	35.4	1.2
C 5217	Kiwawa 2	84	1982	80	24.4	2.5
C 5218	Nasal I	128	1982	dry		
C 5219	Nasal 2	105	1982	78	36.6	0.7
C 5220	Amakuriat I	120	1982	-	-	0.2
C 5221	Amakuriat 2	78	1982	-	19.5	2.5
C 5222	Nauyapong	90	1982	-	12.5	1.5
C 5223	Sasak	120	1982	-	18.5	-
C 5224	Otuko	66	1982	-	-	2.0
C 5225	Kasitet	60	1982	-	26.5	0.6
C 5226	Kempur	66	1982	-	6.5	0.4
C 5227	Locheremonyang	60	1982	-	-	0.5
C 5228	Kases I	102	1982	Abandoned		
C 5229	Kases 2	51	1982	Abandoned		
C 5230	Amam	69	1982	-	-	0.5
-	Kalas	51	1983	-	-	-
-	Parakapelemoi	60	1983	-	-	0.3
-	Kauriong	36	1983	-	-	-
-	Kiwawa 3	150	1983	dry		
-	Kiwawa 4	96	1983	-	-	2.7
-	Katuda	63	1983	-	-	-
-	Chelopoi I	101	1983	dry		
-	Chepkenagh	60	1983	-	-	-
-	Chelopoi 2	93	1983	dry		
-	Natemeri	102	1983	-	-	1.6
-	Losam I	60	1983	-	-	-
-	Losam 2	32	1983	Abandoned		
-	Kasei	51	1983	-	-	-
-	Kodera	75	1983	-	-	-
-	Kremti	51	1983	-	-	-
-	Lokichar	45	1983	-	-	-
-	Kitalakapel	63	1983	-	-	-
-	Kamketo	93	1983	-	-	-

- data not yet available

Boreholes in West Pokot District, 1983



Source: District Atlas West Pokot 1983

LIST OF PLATES

2.1 West Pokot geological map

4.1 Hydrological map

4.2 Isohyetal map for longterm annual rainfall

5.1 Hydrogeological map

6.1 Water availability map