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HYDROGEOLOGY OF KITETO DISTRICT

ARUSHA REGION, TANZANIA

By

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HYDROGEOLOGY OF KITETO DISTRICT, ARUSHA REGION, TANZANIA

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Kiteto District, the southern half of what formerly was called "Masailand", covers an area of about 28,000 square kilometers. It is almost entirely semiarid with an average annual rainfall of about 16 inches or 400 millimeters. The rainfall is so negligible that the drainage network is poorly developed. This means much of the surface runoff collects in waterholes. These may contain water for months but most dry up before the start of the next rainy season. The one and only perennial river is the Ruvu or Pangani, which forms the eastern boundary of the district.

Ground water is neither abundant nor everywhere available. In the Makami Depression, the ground water is unpotable except for a thin lens of fresh water floating on saline water. The saline water has been concentrated by evaporation of fresh-water inflow. This process has continued for a long time for the water is now twice as salty as sea water. In spite of such problems, the meager ground-water supply is vital for development. In the district, it constitutes the only source of water for most of the area.

Purpose and Scope

The purpose of this report is to show by using the minimal amount of data available, that a trained hydrogeologist can make vitally significant interpretations regarding the amount, distribution, and availability of ground water in Kiteto District. From this, hopefully district and regional officials will realize that the water resource must be more thoroughly monitored and studied to achieve maximum development at minimum cost.

ie scope is to present the borehole data and the chemical ses which have been assembled, to draw a water-level contour to make estimates of transmissivity, and from interpretation

of all these to make some quantitative estimates. From these one can, prior to drilling a borehole, have a reasonable idea as to the depth to water, the water quantity, and the water quality. As each new borehole is drilled, if its data are systematically and accurately collected and added to what is already known, predictions will become more and more accurate and precise.

Previous Studies

A Swedish engineering geologist, F. M. Coster, worked in Tanganyika from 1927 till his retirement in 1958. He was concerned chiefly with ground water and the knowledge which he amassed was summarized in "Underground water of Tanganyika" (Coster, 1960). Because the book covers all of what is now mainland Tanzania, relatively little relates to Masailand or Kiteto District. No records of individual boreholes are included. A table for Northern Province (Coster, 1960, p. 89)merely summarizes borehole statistics divided as to horeholes in volcanic rock and those in basement.

The "Masailand comprehensive report", compiled and authored by H. Kametz (1962), contains a wealth of hydrologic data for the area which now includes Kiteto and Monduli Districts. Some qualitative and quantitative data are given on boreholes, wells, spring, streams and even some rain pools (waterholes). Accompanying maps show watering points and the area on which cattle that use the point can be expected to graze. This distinguishes areas that are watered from those that are not. The Kametz report, although never formally published, was given limited distribution through duplication. This report has been the single most useful report available on Kiteto District.

Both an hydrogeologist and a soil scientist from the United States each spent three months in the Arusha Region. Their report (Gordon and)'Rourke, 1973) titled "Proposed water-resources and land capability investigation, Arusha Region, Tanzania" gives a summary of geology, climate, and water resources, as well as a hydrologic map of the region. The project as proposed was never accepted or implemented. However, this report accords with their remmendation that existing data be gathered and interpreted.

An excellent paper, "Status of water resources activities and development in Tanzania" was authored by F. K. Lwegarulila (1973), the late Principal Secretary of the Ministry of Water, Energy, and Minerals. His paper, although published and distributed throughout the developed world is not available in Tanzania and reprints were not even furnished to him as an author. This points up the problem of the lack of library and reference facilities.

Sources of Data

Data for this report have come almost entirely from original sources. Borehole data were assembled from completion reports on file in the Maji (Water Department) offices in Arusha and Dodoma. These were supplemented when possible by field visits to get locations so the sites could be spotted on maps and elevations ascertained. These data unfortunately are not collected routinely and included with the other data on the borehole completion report forms. The chemical analyses were compiled from files at Maji in Arusha, from Madini (Mineral Resources) in Dodoma, and from Ubungo (Water Laboratory) at Dar Es Salaam.

Lithologic samples from recently drilled boreholes of the Masai project have been logged. Suites of the older borehole cuttings on file at Maji in Dodoma are still awaiting study. Logging of these would be helpful in relating yield of boreholes to the local geology and in determining the thickness of overburden.

Pumping-test data have been studied but their value often is questionable. Those responsible for collecting such data often have failed to make measurements that are needed and often they did not have the equipment needed to make the measurements. Furthermore, the drillers have little appreciation or understanding that after a pumping test, measurements of water-level recovery should be made over as long a period as that during which the well was pumped. If such measurements are made, the recovery part of the test can be as valuable as the pumping part. Also, if the results of both parts when plotted agree, the test results can be accepted with much greater confidence.

Methods and Definitions

To do any more than the most elementary calculations regarding ground water, one needs to work with transmissivity and storage. Transmissivity is the permeability times the thickness of the aquifer. Because neither permeability nor thickness are usually known, transmissivity can better be thought of in a more practical form. In this report, transmissivity will be considered to be the rate at which water would flow through a meter width of aquifer with a hydraulic gradient of one meter. This gives cubic meters per day per meter of drawdown, which reduces to meters squared per day (m^2/day). Storage is here considered the volume of water that an aquifer releases from storage per unit area per unit decline in head. The unit of storage comes out to be nondimensional. Another assumption which I emply in this report is that storage represents a continuum from that of a surface body of water to that of ahighly confined aquifer. This gives a range in extreme values from 1 to 10^{-6}. Throughout the rest of this report and even in the references cited,T will be used instead of transmissivity and S will be used for storage. In this way, T stands for both transmissivity and its formerly used synonym, transmissibility. Similarly, S covers a number of terms meaning essentially the same thing: storage, storativity, coefficient of storage, specific yield, etc. For the purist who wants to know precise usage of these terms, the best reference to consult is "Groundwater" by Freeze and Cherry (1979). For the reconnaissance type of work described in this report, use of T and S seems adequate.

During his work in Tanzania, the author developed a new method for calculating T using only the data available from a pumped well. The method has been presented orally to the National Water Well Association and has been submitted for publication in the transactions of that meeting (Vorhis, 1979). This method is central to some of the calculations presented herein.

The topographic maps covering Kiteto District make it possible to use both latitude and longitude and Universal Transverse Mercator grid to locate hydrologic sites. Because each system has its own advantages the locations of boreholes are given in each. Where locations are known only generally, the latitude and

longitude are reported to degrees and minutes. Where the location is either known or an attempt was made to get as precise a location as possible, each is given to degree, minute, and second.

The most fundamental measurement in ground-water work is the depth to water in a borehole. In Tanzania, good measured depths are rare because suitable tapes are not available and because few have received adequate training in making such measurements. For the latter reason the method of measuring depth to water is given here in full.

In making measurements by the wetted-tape method the tape is let down into the borehole from a fixed measuring point (usually the top of the casing) until a short length at the lower end of the tape is submerged in the water. A reading is then made at the measuring point, the tape is pulled up, and a reading is made at the water mark on the tape.

The lower few feet of the tape are chalked by pulling the tape across a piece of dry blue carpenter's chalk. The tape (which is weighted at the end) should be lowered into the borehole slowly to prevent splashing. In making the mesurement is is generally desirable to hold a foot or meter mark of the tape at the measuring point and to submerge only a part of the lowest foot foot or meter of the tape. The tape should be held between the thumb and the forefinger with the mark exactly at the level of the measuring point, and the eyes should be as near the level of the measuring point as practicable. If possible the hand should be steadied by resting the fingers on a substantial surface adjacent to the measuring point, and in no case should the mark be permitted to fall below the level of the measuring point. The reading of the mark should be entered in a note book or on a water-level measurement card. Generally, the tape should be held at the measuring point only momentarily, because if it is held too long moisture tends to move upward by capillarity along the film of chalk and to obscure the water mark.

It is generally desirable to lift the tape from the borehole by hand and afterward wind it on the reel. In this way the water mark on the tape is rapidly brought to the surface for reading. This is important, particularly on a hot, sunny day when the wetted portion of the tape tends to dry quickly. After being brought to the surface

a reading is made of the water mark and entered in a note book. The tape should then be wiped dry or be permitted to dry before it is reeled up. Care must be taken not to injure the tape by stepping on it or allowing it to become kinked.

When measuring in feet, measurements should be made to the nearest hundredth of a foot. To insure accuracy it is always desirable to make two measurements, so that one may check the other. If the measurements do not check within a hundredth of a foot additional measurements should be made until the cause of the error is discovered or until the results do check.

The depth to water is then determined by subtracting the length of the wetted portion from the length of tape below the measuring point.

Acknowledgments

The cooperation and support of the Regional Water Engineer, Ndugu S. G. Hassanali has been of vital help in the work accomplished. Ndugu Kweka helped in obtaining some of the data. Ndugu Julius Shilungushela assisted for two months early in the project by assisting in compiling borehole data and by accompanying the author on a very arduous safari through Kiteto District and to Dodoma.

The Kiteto District officials have been most helpful and encouraging. Both Ndugu Israel Karyungi and Ndugu Marandu have accompanied the author on safaris to assist in gathering data.

The support and encouragement received from the chief of party, Mr. E. Pershing Vance, is gratefully acknowledged.

Dr. Prasad, head of the Geology Department at the University of Dar Es Salaam, kindly volunteered to see that this paper will be shepherded through to publication. For this the author is deeply grateful.

Ground-Water Occurrence

Rainfall that infiltrates the earth is the source of all ground water in Kiteto District. However, much of the water that reaches the ground can never become ground water for it is only the rainfall which exceeds the potential evaporation which can infiltrate the ground. In Kiteto District, so little rainfall exceeds the potential evaporation that it is possible that much of the current ground water represents water of other than annual recharge. It may be water that infiltrated in years when rainfall was unusually heavy and prolonged. It also may be water that infiltrated thousands of years ago when the climate may have been much more humid. If the ground water originated in either of these two ways, we can attach no quantitative values nor can we assume that such supplies are being replenished.

To make a quantitative estimate of the ground-water supply, the rate of recharge annually must be estimated. The Germans in their master water plan for the Tanga Region came up with an annual recharge rate of 10 mm/year.

The author has calculated the recharge rate at Engasumet to be 10 millimeters per year. The method, based on an equation by Carlston (1963), is one which has never , to the author's knowledge been used before to calculate recharge rate. Consequently, he was greatly reassured to see how close his figure matched that reported by the Germans for an adjoining area. The method is described below in the section on "ground-water hydraulics.

In order to estimate the quantity of water that goes into the ground each year, let us assume that 10 mm infiltrate uniformly the entire area of Kiteto District, 31,000 km^2:

$0.001\ m/yr \times 31{,}000\ km^2 \times 10^6\ m^2/km^2 = 3.1 \times 10^7$ cubic meters per year. Assuming that at maximum development about one-tenth of this could be captured by boreholes, that would mean an annual pumpage of $3.1 \times 10^6\ m^3/yr$. To make this a bit more meaningful let us divide that by the number of days in the year and the number of hours in the day to get cubic meters per hour. This still amounts to 360 cubic meters per hour. Unfortunately, the existing boreholes in Kiteto have a total reported potential yield of 40,000 m^3/hr. Immediately this ceases to be an academic exercise!

If the facts and assumptions used above are correct even as to order of magnitude, then a substantial percentage of the ground-water resource is already being used and further development will be increasingly more difficult and more costly. This points up the need to continue hydrogeological investigations and especially to begin monitoring water levels in existing boreholes.

The boreholes drilled in Kiteto District are tabulated in table 1. The table gives data on location, depth, yield, drawdown as well as nearly everything that is known about each borehole.

A summary of borehole yields is presented in table 2 along with a comparison of yields in the other districts of the lArusha Region. The yields in Kiteto District range from 5 to 3000 gallons per hour with a mean of 1000 and a median of 840 gallons per hour. These figures suggest what yields are likely to be obtained from future boreholes drilled in the district.

Table 3 presents the specific capacities reported for Kiteto boreholes and contrasts them with those found in the other districts. Because specific capacity is given in the same units as those used for transmissivity, these figures can be used as a fairly reliable approximation of transmissivity.

A statistical analysis was made of the borehole yields in each district and the results are plotted on figure 1 along with the median specific capacity. From this one gets a better feel for the data given in tables 2 and 3.

District	Number of Boreholes Drilled	Number Yielding Usable Water	Percent Success	Yield of Successful Boreholes (UK Gallons/hour)				
				Minimum	Maximum	Median	Mean	Standard Deviation
Arumeru	39	33	85	68	26,400	2,700	4,460	6,000
Arusha	10	10	100	1,250	15,500	3,600	5,850	4,800
Hanang	9	7	78	120	2,600	500	1,090	1,090
Kiteto	47	32	68	5	3,000	840	1,000	800
Mbulu	17	14	82	60	10,000	574	1,630	2,600
Monduli	66	32	48	2	3,300	490	880	915

Table . .--Borehole yields in Arusha Region.

District	Number of Boreholes	Specific Capacity, in cubic meters per day per meter of drawdown				
		Minimum	Maximum	Median	Mean	Standard Deviation
Arumeru	23	0.8	1,180	77	216	306
Arusha	9	4.0	176	31	51	56
Hanang	2	4.6	64	34	34	42
Kiteto	18	.6	405	12	74	132
Mbulu	7	.08	400	1.5	70	149
Monduli	9	.1	46	6.0	14	19

Table .--Borehole specific capacities in Arusha Region.

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Figure —:— Statistical analysis of borehole yields and median of specific capacity.

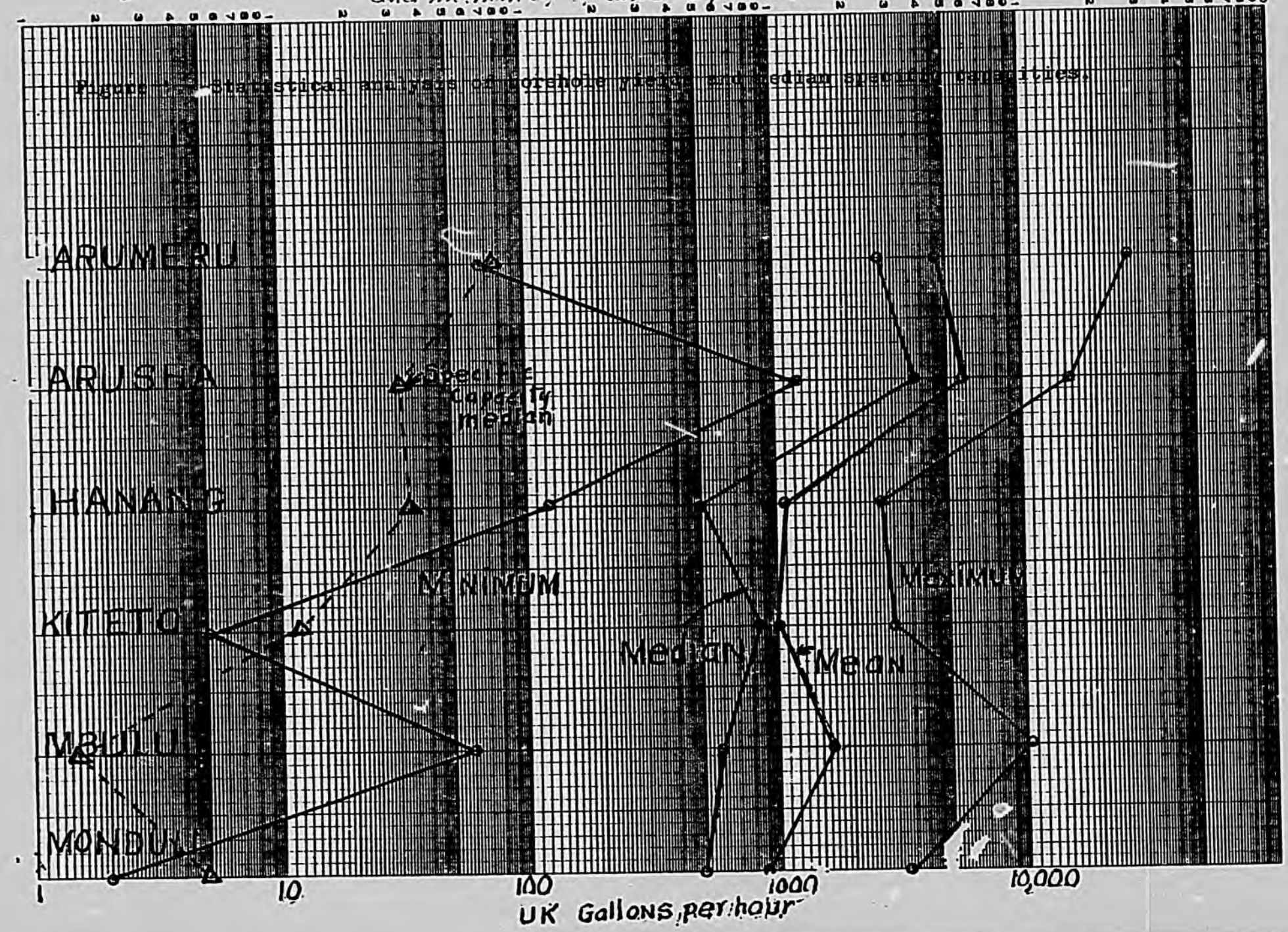

Figure —:— Statistical analysis of borehole yields and median specific capacities.

Drainage Basins

Tanzania has been divided into drainage basins in order to study the surface-water hydrology (Tanzania Ministry of Water Development and Power, 1976). The map accompanying the report cited shows that Kiteto District lies in three of the drainage basins. The northern and eastern part covering about 57 percent of the district discharges ground-water toward and into the Pangani River. The extreme southern part discharges into the Wami River. The remainder discharges into internal drainage basins such as Makami Depression and Lake Manyara.

In general the ground-water basins conincide with surface-water basins. Because much of Kiteto District drains to internal basins, these have yet to be delineated accurately.

Geology

The geology exercises several controls over ground-water occurrence. Most of Kiteto District is underlain by dense rock in which water occurs only in fractures. The borehole at Kibaya penetrated only granite gneiss. Such rock can never be expected to ~~yield~~ yield large quantities of water. On the eastern edge of Kibaya ultramafic rock crops out along the stream valley with salt crystals covering the exposures. This is mentioned not only as an explanation for the salty ground water but to illustrate how complex the bedrock geology probably is. Much intensive geologic mapping must be done before the geologic control of ground-water occurrence can be more than superficially understood.

The Makami Depression is a downfaulted block which formed an interior basin. Into this lake deposits have formed saturated with salty water.

Many low areas have a veneer of black cotton soil. This material is so tight that little water can descend through it and that which is trapped above it is evaporated.

Much of the higher land is covered by relatively impermeable laterite which also tends to prevent rainfall from becoming ground water.

Even though much of the area has been exposed to weathering for hundreds of millions of years, there is a surprising lack of h ghly porous weathered material and an equally surprising lack of thick sedimentary deposits, sand and graval, which if present could be a source of large quantities of water.

No modern detailed geologic map is availabl for any part of Kiteto District. This makes it difficult to apply other than the simplest geologic methods in the search for ground water.

Water-Level Map

The water-level contour map (figure 2) prepared for this report is the first one attempted for the district. Allhough it is based on a minimal number of data (the borehole data of table 1, stream elevations along the Pangani River, and mapped drainage courses) it provides a basis for understanding both ground-water occurrence and ground-water flow. From the use of this map along with a topographic map of the area one can determine the probable depth to water before drilling. The direction of flow is always down gradient and normal or at right angle to the contour line. The map in its present form has already been used to predict depth to water and subsequent drilling has shown that the prediction was close to that found. If data from new boreholes are added to the map the reliability of the predictions will be augmented.

In contouring the map some rather broad assumptions have to be made. Let me list those assumptions of which I was conciously aware: 1) No impermeable dikes or sealed faults are present in the subsurface such as would cause contours to terminate.

2) Ground water is recharged solely from rainfall and is discharged into streams and basins.

3)Ground water is deep enough that little or none is discharged by evaporation and transpiration.

4) Boreholes are so few and their pumpage so small that they nowhere have caused a regional cone of depression.

5) Just as work expands to fill the time available, so contours should spread to fill evenly the space available. Unless there is some logical and/or geological explanation, contours should not be tightly bunched in one are and absent in another. If this does occur the data themselves should support such an interpretation.

6) Contours should either close on the map or extend unclosed to the edge of the map.

7) The data points are interpreted as if they are exact. One must be aware that there are errors in picking elevations from contour maps, variation with time of the water level in a borehole, possible lack of precision in measuring the water level, etc. However, with the ~~xxxxxxxxxxx~~ topographic map having a contour interval of 50 meters, these errors are minor and should therefore have relatively little effect.

8) The water table tends to be a subdued replica of the topography so in drawing the contours, the topographic map may provide clues for the most reasonable direction and spacing of the contours.

9) On most contour maps, the contours are drawn solid where the data are certain and dashed where they are generalized. If this convention had been followed all of the contours would need to be dashed.

The base for the map was taken from the 1978 map of Arusha Region published by Tanzania Ministry of Lands and Surveys.

Several important ideas about ground water come to mind from study of the water-level map. The concentric contours at Kibaya, Kijungu, Engasumet, and Naberera suggest that recharge may be a bit more abundant at those places. There may be some recharge from Lolkisale. Contours tend to be less reliable at the edge of a map so it is uncertain whether the three contours near Lolkisale really indicate significant recharge.

Sunya, to the south southwest of Kijungu, lies in a drainage basin that has a surprisingly well developed network of valleys. This network drains eventually into the Wami River. Even though Sunya is probably the best potential site in the entire district for obtaining a productive borehole, The contouring for that area is the least reliable of any area on the map.

The entire eastern side of the district drains eastward into the Pangani River. This is true as far south as about 20 km ~~from~~ northwest of Kijungu.

The Makami Depression is an area of aridity. The widely spaced contours around the depression suggest that relatively little ground water percolates into the depression. The contours to the west of Makami suggest there may be another depression almost as large as Makami. The old trail north from Kibaya to Arusha seemingly followed the watershed divide between these two depressions.

The map at its northern end would benefit greatly ~~from~~ if one could tie the contour ends in with the contours for a map of Arumeru District. In its present form the map should be considered as a working hypothesis. Each borehole drilled willprovide a new check. If the new data and the map do not agree, then contours will probably have to be respaced but the general form of the map will probably stay.

Figure 2.--Water-level map of Kiteto District.

The original of this map is on file at the Regional office of Maji, in Arusha. The location in the files is known to Ndugu Lawrence Mbaga who can get prints made as needed.

Ground-Water Hydraulics

The Theis nonequilibrium equation is the basic equation used in solving problems of ground-water flow. When the equation was introduced, Theis (1935) noted that when a well penetrsting an extensive confined aquifer is pumped at a constant rate, the influence of the discharge extends outward with time and creates a cone of depression in the potentiometric surface. The rate of decline of head multiplied by the storage and summed over the area of influence equals the discharge. During pumping, because water must come from a reduction of storage within the aquifer, the head will continue to decline as long as the water-bearing formation is effectively infinite. Theoretically neither steady state nor equilibrium flow can exist, which explains the name nonequilibrium. The rate of decline, however, decreases continuously as the area of influence expands and will eventually become so small that it becomes negligible. For practical purposes that can be considered steady state or equilibrium.

The Theis equation, which was derived from analogy between the flow of ground water and the conduction of heat, may be written as

$$s = \frac{Q}{4\pi T} \int_{u}^{\infty} \frac{e^{-u}}{u} \, du \qquad (1)$$

Where $u = r^2S/4Tt$

s is drawdown measured in meters (m)

Q is discharge in cubic meters per day (m^3/day)

S is storage (dimensionless)

T is transmissivity in meters squared per day (m^2/day)

t is time in days since pumping started, and

r is radius in meters (m)

In using the Theis equation, the following assumptions apply:

1) The water-bearing formation is infinite in areal extent;
2) The water-bearing formation is homogeneous, isotropic and of uniform thickness over the area influenced by the pumping test;

3) Prior to pumping, the potentiometric surface is practically horizontal;
4) The pumped borehole completely penetrates the water-bearing formation and thus receives water by horizontal flow from the entire thickness of the formation;
5) The borehole is pumped at a constant discharge rate;
6) The water-bearing formation is confined;
7) The flow to the borehole is in unsteady state; that is the drawdown differences with time are not negligible nor is the hydraulic gradient constant with time;
8) The water removed from storage is discharged instantaneously with decline of head; and
9) The diameter of the pumped borehole is small enough that the storage in the well can be neglected.

Even though these assumptions seem to depart widely from reality, the Theis equation has repeatedly given results that have been of great value in practical applications.

When equation 1 integrated , it becomes:

$$s = \frac{Q}{4\pi T} W(u) \qquad (2)$$

where

$$W(u) = -.577216 - \ln u + u - u^2/2 \cdot 2! + u^3/3 \cdot 3! \ldots\ldots u^n/n \cdot n!$$

The drawdown, s, is known so it makes sense to solve for T giving us the equation:

$$T = Q\, W(u)/4\pi s \qquad (3)$$

For a given drawdown, Q/4 s is a constant leaving only the well function of u, W(u), as a variable. However, $u = r^2S/4Tt$ of which $r^2/4T$ is a constant and S and T are variables. If S is arbitrarily assumed to be 0.1, then the only variable remaining is T. That gives an unknown T on the left side of the equation and an unknown variable T on the right side. A solution to this has been supplied by Vorhis (1979).

Specific capacity, Q/s, gives a good first approximation of T and can be substituted in equation 3 to calculate an initial value of u. Using it in the expansion of W(u) gives a value for W(u) that can be used to calculate a new value of T. The new T can then be used to replace the first approximation (specific capacity), thereby permitting a new u, W(u), and T to be obtained. This loop then continues until T as found on each side of the ewuation stabilizes at the same value. Because this T was calculated with an assumed S of 0.1, this value of transmissivity is denoted by the symbol T(0.1). This can be read as the T function of S of 0.1. Next, S of 0.0001 is used and the whole process is repeated until T stabilizes giving a second value denoted by T(0.0001).

After T(0.1) and T(0.0001) are known, the change in T per log cycle of S, which is the slope m, can be found using equation 4.

$$m = (T(0.1) - T(0.0001))/3 \tag{4}$$

Given T(0.1) and m, a T for any value of S can be found by using equation 5.

$$T(S) = T(0.1) - m(\log S + 1) \tag{5}$$

The procedure for calculating T(0.1), T(0.0001), and m utilizes a programmable calculator. The program which was used in interpreting the Kiteto data has been published (Vorhis, 1979) in a form suitable for use with the Hewlett-Packard HP-97 and HP-67 calculators.

Applications of Ground-Water Hydraulics

To calculate transmissivity four items of data are needed: 1)diameter of the borehole, 2) yield of the borehole, 3) drawdown in the water-level of the borehole during pumping, and 4) length of time from start of pumping until the drawdown was measured. For each borehole in Kiteto District which has a set of data as listed above, specific capacities and transmissivities have been calculated. The results are given in table 4. The best yielding borehole has a T 4300 times greater than the worst yielding one. By comparison the yields have a spread of only 24 times.

A 48-hour pumping test was made at Kibaya in borehole 25/78 from 0600 on 28 Dec. 1978 to 0600 on 30 Dec. after which recovery was measured periodically till 0800 on 1 Jan. 1979. The drawdowns and the times at which they were measured are given in table 5. Using the data from table 5, specific capacity, transmissivity (both for T=(0.1) and T=0.0001)) and slope have been calculated and plotted on figure5. Study of the figure shows that from about 300 minutes (=5 hours) onwards any spot measurement would give as good a result as the entire series of calculations. Having the set of drawdowns does lend an additional aura of credibility to the results. However, for those cases where only one drawdown is available after 6 or 8 hours of pumping, the transmissivity calculated from it can be given more credence knowing that in a complete set of data little departure from the norm can be expected.

One of the standard methods for analyzing drawdown data for T is to plot the drawdowns aga nst the logarithm of time. Theoretically the data should plot on straight lines. The change in drawdown over one log cycle of time is given the symbol delta s and plugged into the following equation:

$$T = (\ln 10)\, Q / 4\pi (\text{delta } s) \qquad (6)$$

The data of table 5 when so plotted fall so irregularly that it is difficult to draw a straight line or to choose which points represent the line that is needed. By using the calculator method such a decision can be avoided entirely.

Location	Borehole Number	Dia. in	Yield gph	Drawdown ft	Time hr	Specific Capacity	T(0.1)	T(0.0001)	Slope m
Amei	252/77	6.5	600	43.34	24	5.0	3.7	6.7	-1.0
Angata Sere	32/69	8	675	340.58	24	.7	.4	.8	-.14
Dosidosi	1/71	10	684	403	21	.6	.3	.7	-.12
Dosidosi	95/73	6	1895	187	108	3.6	3.1	5.3	-.71
Engasumet	25/75	6	2300	37	12	22	19	32	-4.4
Kibaya	247/75	6.5	905	34	12	9.5	7.1	13	-1.9
Kibaya	25/78	8	2100	50.33	48	15	13	22	-2.9
Kijungu	44/69	8	630	196	24	1.1	.7	1.4	-.23
Kitwei A	7/52	8	1370	2.08	24	240	250	380	-46
Lekiteju	3/52	8	2300	14.1	24	58	54	89	-11
Makami	61/73	10	1900	1.67	12	410	410	650	-80
Mtakuja B	49/70	14	3600	3.16	48	410	430	670	-79
Ndedo	72/78	12	5280	20	24	94	85	140	-19
Ndedo	35/79	7.5	1750	5.08	24	120	120	200	-24
Olboloti	45/54	8	1071	26.67	24	14	12	20	-2.8
Olboloti	146/75	6	220	520	24	.2	.1	.2	-.03
Songambele	183/73	10	950	230	48	1.5	.9	1.8	-.3

Table 4.--Specific capacity and transmissivity for Kiteto District boreholes.

Date and Time	Drawdown (m)	Time (min)
28/12/78		
0600	0	0
01	1.22	1
02	1.80	2
03	2.03	3
04	2.23	4
05	2.59	5
06	2.87	6
07	3.20	7
08	3.25	8
09	3.33	9
10	4.09	10
15	4.37	15
20	4.90	20
25	5.69	25
30	6.07	30
35	6.32	35
40	6.50	40
45	6.75	45
50	6.91	50
55	7.21	55
0700	7.67	60
15	8.46	75
30	8.86	90
45	9.24	105
0800	9.55	120
15	10.25	135
30	10.44	150
45	11.07	165
0900	11.35	180
1000	11.73	240
1100	12.22	300
1200	12.57	360
1300	12.60	420
1400	12.65	480
1500	12.75	540
1600	12.88	600
1700	13.01	660
1800	13.08	720
1900	13.39	780
2000	13.59	840
2100	13.67	900
2200	13.72	960
2300	13.92	1020
2400	13.92	1080

Date and Time	Drawdown (m)	Time (min)
29/12/78		
0100	14.28	1140
0200	14.37	1200
0300	14.45	1260
0400	14.55	1320
0500	14.55	1380
0600	14.58	1440
0700	14.68	1500
0800	14.76	1560
0900	14.96	1620
1000	15.04	1680
1100	15.14	1740
1200	15.19	1800
1300	15.19	1860
1400	15.19	1920
1500	15.19	1980
1600	15.22	2040
1700	15.22	2100
1800	15.24	2160
1900	15.26	2220
2000	15.26	2280
2100	15.29	2340
30/12/78		
0100	15.34	2560
0600	15.34	2880
RECOVERY		t/t'
0601	14.53	2881
02	14.20	1441
03	14.00	961
04	13.92	721
05	13.76	577
06	13.64	481
07	13.31	412
08	13.11	361
09	12.95	321
10	12.70	289
15	12.50	193
20	12.19	145
25	11.33	116
30	11.20	97
35	10.80	83
40	10.67	73
45	10.54	65
50	10.41	59
55	10.03	53

Table 5.--Pumping-test data for Kibaya borehole 25/78. (Diameter, 6½ inches; yield, 2250 UK gallons per hour for first 240 minutes and 2100 for remainder of test).

Table 5 .--Continued

Date and Time	Drawdown (m)	Time t/t
30/12/78 continued		
0700	9.85	49
15	9.60	39
30	9.47	33
45	8.84	28
0800	8.43	25
15	7.95	22
30	7.54	20
45	7.14	18
0900	6.81	17
1000	6.50	13
1100	5.79	10.6
1200	5.16	9.0
1300	4.57	7.9
1400	4.11	7.0
1600	3.48	5.8
1700	3.25	5.4
1800	3.12	5.0
1900	2.97	4.7
2000	2.87	4.4
2100	2.77	4.2
2200	2.64	4.0
2300	2.57	3.8
2400	2.46	3.7
31/12/78		
0200	2.21	3.4
0400	1.98	3.2
0600	1.70	3.0
0800	1.42	2.8
1000	1.19	2.7
1200	1.12	2.6
1500	.99	2.4
1800	.84	2.3
2100	.71	2.2
2400	.56	2.1
1/1/79		
0400	.43	2.0
0800	.28	1.9

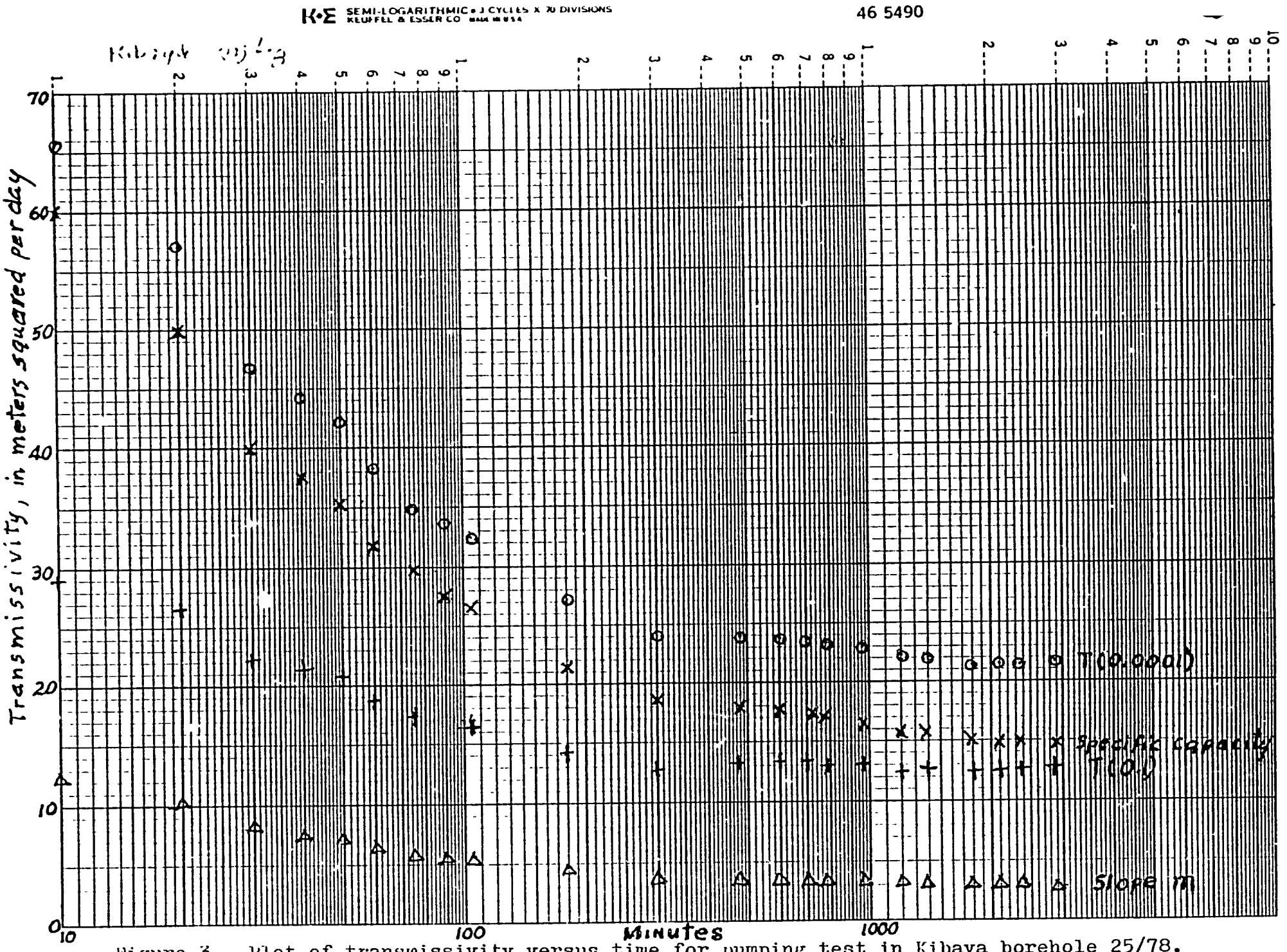

Figure 3. Plot of transmissivity versus time for pumping test in Kibaya borehole 25/78.

Much attention so far in this report has been given to the calculation of transmissivity but relatively little on how to use it once you have it. In the following example transmissivity will be used in computing the annual ground-water discharge into the Pangani River .

The water-level map (figure 2) shows that throughout much of the eastern part of Kiteto District ground-water flow is generally eastward to the Pangani River. Assuming that the transmissivity calculated for the borehole at Engasumet is typical of the entire area of this easterly discharge, then the annual discharge into the Pangani is given by the equation:

$$Q_{annual} = 365TIL \qquad (7)$$

Where Q_{annual} = cubic meters per year (m^3/yr)

T = meters squared per day (m^2/day)

I = gradient (m/m) with the vertical distance taken from the contours of figure 2 and the horizontal distance measured on the map;

L = length in meters (m) along a contour line parallel to the river

Substituting the measured values into equation 7:

$$Q_{annual} = 365 \times 20 \times 0.01714 \times 150{,}000$$
$$= 18{,}800{,}000\ m^3/yr \quad \text{or } 18.8 \times 10^6\ m^3/yr$$

If surface-water gaging stations were established along the Pangani River at proper points, the data collected would be able to show whether the above estimate is reasonable accurate or not. Unfortunately as yet no attempt has been made in locating gaging stations to choose places where they would provide checks on the ground-water component.

As mentioned above, the rate of recharge at Engasumet was calculated to be 10 mm/year. This was calculated after transposing and equation published by Carlston (1963). In developing his equation he assumed that two streams are flowing parallel with each other and separated by a ground-water divide half way between the streams. The distance from the ground-water divide to a stream is called a and the vertical distance from the level of the stream to the water table at the divide is called h_o. The equation as given by Carlston is

$$h_o = \frac{a^2 W}{2 T} \qquad (8)$$

Because W is the rate of recharge to the water table in meters per year and the transmissivity as used i n this report is in meters squared per day, the T must be multiplied by 365 to change it to annual units.. After inserting the 365 and transposing to solve for W, the equation assumes the form:

$$W = \frac{2 h_o T \times 365}{a^2} \qquad (9)$$

With T of 20, h_o of 700, and a of 32,000, we get

$$W = 2 \times 365 \times 700 \times 20 / (32{,}000)^2$$

$$W = 0.01 \text{ m} \quad \text{which is 10 millimeters.}$$

In applying this equation, the author assumed that only half the model described is needed. That is that only one stream is needed and that the distance from the Pangani River to Engasumet can be considered as a, and that the vertical distance between the stream level and the water level in the Engasumet borehole can be considered as h_o. The author felt in so doing that he might be stretching the original equation beyond its "elastic" limit. The fact that the recharge rate that was calculated agreed exactly with the rate given by the Germans in the Tanga Master Water Plan suggests that the method must be valid. The Germans gave no explanation as to how they arrived at their figure of 10 mm/year.

Ground-water hydraulics is complicated bythe use of mixed units. In Tanzania, depths to water are measured in feet and inches. Yield of boreholes is reported in UK gallons per hour. Some distances are given in miles while others are given in kilometers. To enable conversions to be made more easily, the author has prepared a table of factors that he has found useful in the work he has been doing. Table 6 lists these factors. In general, to go from nonmetric to metric, one reads from left to right; and from metric to nonmetric one reads from right to left. The factor and its reciprocal are listed in adjoining columns so one can choose whether he want to multiply or divide. Some factors are carried out to more places than are customarily used. The underscore show figures that can be dropped without any appreciable loss in accuracy. However, if one does desire to make a very precise calculation the factor given is there to be used.

Vorhis 29

Given	Multiply By	or	Divide By	To Get
LENGTH				
Inches (in)	0.0254		39.37008	Meters (m)
Feet (ft)	.3048		3.28084	m
Miles	1.60934		.62137	km
AREA				
Acres	4046.85642		2.471×10^{-4}	m^2
Acres	.40468		2.47105	hectares
Ft^2	.09290		10.76391	m^2
In^2	6.4516×10^{-4}		1550.0031	m^2
VOLUME				
UK gallons	.16054		6.22882	ft^3
UK gallons	4.54610		.21997	liters
UK gallons	.0045461		219.96876	m^3
UK gallons	1.20095		.83267	US gallons
US gallons	.13368		7.4805	ft^3
US gallons	3.78544		.26417	liters
US gallons	.00378		264.1723	m^3
Ft^3	.028317		35.31457	m^3
DISCHARGE				
UK gallons/hour	.10905		9.17010	m^3/day
UK gallons/hour	3.853		.2596	ft^3/day
US gallons/min	5.45108		.18345	m^3/day
US gallons/hour	.09085		11.007	m^3/day
US gallons/day	3.78547×10^{-3}		264.168	m^3/day
US gallons/min	192.4992		5.1948×10^{-3}	ft^3/day
US gallons/day	.13368		7.48052	ft^3/day
Ft^3/sec	2446.575		4.087×10^{-4}	m^3/day
TRANSMISSIVITY				
US gallons day^{-1} ft^{-1}	.012419		80.5195	m^2/day
US gallons day^{-1} ft^{-1}	.13368		7.48052	ft^2/day
Ft^2/day	.092903		10.76392	m^2/day
To Get	Divide by	or	Multiply by	Given

Table 6.--Selected factors useful in ground-water studies.

Quality of Ground Water

When water samples are collected and analyzed to determine the chemical and physical composition of a water body, one knows much about the suitability of the water for domestic, stock, agricultural and even industrial uses. Analyses also aid in understanding geochemical and hydrologic relations in nature and in evaluating man"s activities. When analyses are available, they can be interpreted as to nature source, and variability of matter present in the water.

The source and geographic location of a sample, and the conditions under which it was collected should be recorded along with the date at the time when it is collected. A water analysis is of maximumm value .f detailed information is available as to what the sample represents. To make certain that all pertinent details are recorded it is helpful to have a form on which a space is provided for each bit of datathat should be recorded.

As water seeps downward from land surface to the water table, particles held in suspension and microorganisms may be filtered out and removed. The extent of removal depends on the depth and charaater of the material. The bacterial quality of water also generally improves when water seeps through the ground because conditions there are usually unfavorable for bacterial multiplication and survival. By contract, water in streams, reservoirs, and even springs can often be contxaminated by actions of man and by cattle. other animals and birds.

Water analyses available for boreholes and springs of Kiteto District and tabulated in table 7. Because the analyses come from several laboratories and were made throughout a period of many years, the values have been modified in some cases so that each constituent is reported to the same number of significant figures. For example, three determinations of fluoride as 1.4, 1.36 and 1.375 would all be given in the tsable as 1.4. The method used for converting to a standard set of significant figures is given in table 8. The significant figure represents the probably accuracy in making the analysis.

Table 7. Cont.

Location	Date	Fe	Ca	Mg	Na	K	HCO_3	[illegible]	Cl
Msitu wa Tembo, Njoro Nyeupe sp.	29/3/72	1.4	21	23	380	23	810	[illegible]	50
Do	11/9/76	.5	23	27	340	17	846	–	51
Naberera, spring	8/9/70	.12	170	140	44	5	776	–	150
Namalulu, well	13/9/71	–	95	99	80	3.5	416	–	86
Namelok dam	–/10/77	1.0	38	13	11	[illegible]	[illegible]	–	16
Ndedo BH 72/78	–/6/78		45	310	–				–
Ndedo, well	–/7/69	–	35	22	130	15	496	–	24
Pagwi, spring	13/4/73	.04	26	19	55	–	203		72
Samatwa, upper spring	13/4/73	–	26	22	80	–	205	[illegible]	[illegible]
Shambarai BH 67/35 @ 100 ft.	28/10/68	–	22	10	90	31	527	15	12
Sangambele BH 133/73	5/12/73	–	33	19	54	–	280	24	28
Sunya, Olbiro sp.	28/9/71	1.4	43	25	140	3.1	224	–	210
Sunya, Korongo	14/4/73	.8	62	23	140	–	229	–	240
Terrat, Ngereyani sp.	24/6/77	1.6	130	32	110	37	[illegible]	–	120
Terrat, unnamed sp.	24/6/77	.7	130	40	160	45	539	–	260
Outside but near Kiteto District In Kilimanjaro Region across Kikuletwa from Nayase									
Mtakuja BH 49/70 @ 100 ft	25/5/70	.43	68	22	620	47	1190	–	110
Do @ 300 ft	13/6/70	.56	9.2	7.6	150	39	325	–	370
Zoissa, BH 36/52	30/9/71	.36	310	48	180	14	[illegible]	–	1100
Zoissa, Kinangali BH 27/54	14/10/71	.04	280	[illegible]	160	32	317		1100

Cl	F	NO_3		Dissolved solids	Hardness Total	Hardness Noncarb.	Spec. cond.	pH	Color	Turbidity			
50	6.8	1.0		810	150	0	1840	7.7	30	1			
51	7.8	.7		1040	170	0	1780	7.9	0	0			
150	.8	—		690	960	330	1150	7.1	60	10			
86	8.8	24		1000	440	300	1200	7.0	20	0			
16	.5	1.2		210	150	—	365	8.2	10	90			
—	1.7	—		—	1800	—	—	—	—	—			
24	.6	—		691	180	—	997	8.0	—	—			
72	.4	—		400	140	—	520	7.4	0	0			
200	.6	—		720	160	—	960	7.4	5	0			
12	1.4	2.2		717	98	—	1310	8.4	—	—			
28	.1	1.8		500	210	0	790	7.0	0	0			
210	.4	.3		710	210	25	1000	7.3	70	15			
240	.1	—		900	250	61	1000	7.3	0	0			
20	1.9	.9		760	450	—	1300	8.4	0	0			
260	1.5	7.1		930	500	160	1600	8.5	20	20			
110	7.4	.4		—	310	—	2900	8.1					
375	2.2	.6		—	55	—	1060	8.1					
1100	.4	7.4		2700	960	690	2900	7.2	30	10			
1100	.0	20		2400	940	670	3700	7.1	10	10			

#138) #0179 * MF07) ELSIE.MINISIS) #STDLIST * FRI, JUL 8, 1983, R
#138) #0179 * MF07) ELSIE.MINISIS) #STDLIST * FRI, JUL 8, 1983, R

Suspended Solids	Hardness Total	Hardness Noncarb.	Spec. Cond.	pH	Color	Turbidity			Lab # Analysis				
910	150	0	1340	7.7	30	1			U/449/72				
1040	170	0	1780	7.9	0	0			U/449/76				
630	960	330	1150	7.1	60	10			U/379/70				
1000	640	300	1200	7.0	20	0			U/965/71				
210	150	—	3[illegible]	8.2	10	90			U/861/77				
—	1800	—	—	—	—	—			U/497/73				
691	180	—	897	8.0	—	—			C/10/64				
400	140	—	520	7.4	0	0			U/185/73				
720	160	—	960	7.4	5	0			U/132/73				
717	98	—	1510	8.4	—	—			C/9/229				
500	210	0	790	7.0	0	0			U 1/74				
710	210	20	1000	7.3	70	15			U/1102/71				
900	250	61	1000	7.3	0	0			U/183/73				
760	450	—	1300	8.4	0	0			U/756/77				
930	500	160	1600	8.5	20	20			U/795/77				
—	310	—	2900	8.1					U/251/70				
—	55	—	1060	8.1					U/200/70				
2700	960	690	2900	7.2	30	10			U/1088/71				
2400	940	670	3700	7.1	10	10			U/1137/71				

17 Table 7. Cont.

Location	Date	Fe	Ca	Mg	Na	K	HCO_3	SO_4	Cl
Kibaya, Mbarte well	12/2/72	1.4	240	100	370	1.9	535	420	540
Do	13/10/77	.25	87	130	340	12	570	–	440
Kibaya, Silanga sp.	-/-/69	–	76	79	100	3.1	200	95	40
Kijungu BH 27/68	-/3/69	–	40	26	32	3.1	161	36	100
Do	-/3/69	–	–	26	28	3.6	181	–	85
Kijungu BH 44/69	20/9/69	–	180	58	58	9.2	108	51	160
Do @ 370 ft	-/6/69	–	73	41	60	–	299	22	150
Do	15/9/69	–	91	13	220	–	244	390	140
Kijungu, Lolangoawa sp.	-/-/69	–	32	27	30	3.4	58	–	32
Kitwei "A" BH 7/52	16/6/71	.9	56	56	300	14	310	–	630
Do	13/4/73	–	62	75	300	–	240	83	740
Kitwei "B" BH 32/52 @ 156 ft	5/6/71	.1	82	120	630	130	526	–	270
Lehitoju BH 3/52	-/1/59	–	67	33	35	27	330	–	90
Lengatei, Bohwa sp.	13/6/73	4.2	43	24	82	10	171	–	400
Lolera sp. (Jinja)	-/4/69	–	34	45	41	5.2	88	–	56
Makami BH 79/68 @ 62 ft	-/12/68	–	280	260	16000	–	488	4300	19000
Do @ 400 ft	-/2/69	–	84	100	36000	–	1290	11000	40000
Do @ 42 – 544 ft	-/3/69	–	130	96	36000	–	1270	13000	42000
Mburet BH 8/52	-/1/59	–	54	38	85	28	400	7	97

CO_3	SO_4	Cl	F	NO_3		Dissolved Solids	Hardness Total	Hardness Noncarb.	Spec. Cond.	pH	Color	Turbidity
535	420	540	0.8	1.0		2250	1080	560	2800	7.6	0	3
570	–	410	.8	1.0		1980	740	290	2810	5.3	20	45
[illegible]	95	40	1.8	–		1100	520	330	1440	7.8	–	–
161	36	100	–	.5		463	210	45	589	5.1	–	–
161	–	88	–	–		–	–	–	597	7.9		–
108	51	160	.6	–		1160	650	530	2170	8.4	–	–
299	22	150	1.0	–		512	–	–	–	8.4	–	–
244	390	140	6.0	–		1010	–	–	–	7.3	–	–
58	–	32	–	–		273	190	140	346	7.0	–	–
110	–	630	2.5	1.1		1500	370	120	2300	7.8	15	4
140	83	740	1.3	9.5		1600	460	260	2100	7.6	0	0
26	–	270	4.3	2.0		3300	690	260	3930	5.8	20	2
30	–	90	2.3	–		540	–	–	625	7.5		
71	–	400	.2	–		1230	210	66	1500	5.1	30	5
39	–	56	–	–		436	270	180	635	7.6	–	–
93	4300	19000	.0	–		38700	–	–	–	7.5	–	–
90	11000	40000	.8	–		94900	–	–	–	8.0	–	–
70	13000	42000	.0	–		92200	–	–	–	7.1	–	–
10	[illegible]	97	2.0	30		600	–	–	900	7.5	–	–

Hardness Total	Hardness Non-carb.	Spec. Cond.	pH	Color	Turbidity			Lab and Analysis No.	
1080	580	2800	7.5	0	3			U/84/72	
760	290	2800	8.3	20	45			U/359/77	
320	330	1440	7.8	—	—			C/10/80	
210	46	589	8.1	—	—			C/10/41	
—	—	597	7.9	—	—			C/10/175	
150	530	2170	8.4	—	—			C/11/94	Delete, Cardy out of Acclai
—	—	—	8.4	—	—			M/X10219/2	
—	—	—	7.3	—	—			M/X10219/4	
190	140	346	7.0	—	—			C/10/83	
370	120	2300	7.3	15	4			U/815/71	
460	260	2100	7.6	0	0			U/184/73	
590	260	3930	8.8	20	2			U/818/71	
—	—	625	7.5					M/X6494/2	SiO_2, 56.
210	66	1500	8.1	30	5			U/293/70	
170	180	635	7.6	—	—			C/10/82	
—	—	—	7.5	—	—			M/X10049/2	
—	—	—	8.0	—	—			M/X10049/4	
—	—	—	7.1	—	—			M/X10049/6	
—	—	900	7.5	—	—			M/X6494/2	

Table

Chemical constituents given

Chemical analys[illegible]

[illegible]illigrams per liter (Mg/[illegible]

Location	Sampling Date	Iron Fe	Calcium Ca	Magnesium Mg	Sodium Na	[illegible]	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl
Angata Sere BH 32/69 - @ 600 ft.	5/12/69	1.3	190	44	200	[illegible]	310	31	510
Do @ 523 ft	25/1/70	2.9	130	68	170	[illegible]	283	25	510
Do @ 521 ft	19/2/70	1.3	200	83	180	[illegible]	615	35	480
Do @ 295 ft	-/11/69	-	170	32	220	-	343	31	530
Dosidosi BH 6/54	1/2/71	.18	440	230	320	[illegible]	133	160	1800
Dosidosi BH 38/54 (Pingalome)	-/9/54	-	600	280	-	-	-	390	1800
Do @ 22m	-/11/69	-	820	260	280	-	386	220	2200
Do @ 40m	-/11/69	-	790	300	250		397	220	2200
Do @ 50m	-/11/69	-	820	310	240	-	403	230	2300
Dosidosi BH 1/71 @ 507 ft	20/4/71	.26	110	18	100	[illegible]	237	-	360
Dosidosi BH 70/72 @ 450 ft	23/9/72	14	600	300	550	[illegible]	134	180	2500
Do @ 446 ft	23/9/72	14	570	280	580	[illegible]	139	200	2400
Dosidosi BH 95/73	26/3/73	-	180	95	-	-	129	130	910
[illegible] BH [illegible] @ 142 ft		.01	200	210			415	[illegible]	750
[illegible]	[illegible]	.18	88	97	69	16	537	-	160
[illegible]	-/[illegible]	-	190	100	-	[illegible]	-	[illegible]	[illegible]
[illegible] BH [illegible] @ 85-[illegible] ft	[illegible]/5/72	.34	66	14	59	[illegible]	[illegible]	-	[illegible]
Kibaya BH 247/75	-/10/77	.08	100	12	80	[illegible]	275	-	75
Kibaya BH 25/78	25/6/78	.2	80	60	290	[illegible]	[illegible]	-	[illegible]
Kibaya, Engeitch Tik spring	-/[illegible]/69	-	[illegible]	6.9	150	[illegible]	294	25	9[illegible]
Do	13/[illegible]/77	.16	33	6.7	65	[illegible]	[illegible]	-	6[illegible]
Lengatei? Turiani [illegible] Turiani	25/4/72	[illegible]	130	81	270		[illegible]	300	52[illegible]

...mical analyses of water; Lifete District.

...ams per liter (Mg/l) Laboratory: C, Government Chemist ...

...bonate CO_3	Sulfate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3		Dissolved Solids	Hardness Total	Hardness Noncarbonate	Specific Conductance	pH	Color	Turbidity	
310	31	510	0.2	1.7		755	660	320	1910	8.4	5	25	
280	25	510	.4	1.7		1620	610	390	2150	7.7	5	5	
615	35	480	.4	1.2		1520	850	350	2100	7.4	5	5	
343	31	530	1.4	–		1200	–	–	–	7.9	–	–	
33	160	1800	.9	40		2250	2000	1800	3700	7.6	25	10	
–	390	1800	.6	–		–	–	–	–	8.0	–	–	
86	220	2200	1.8	–		4110	–	–	–	7.4	–	–	
97	220	2200	1.7	8.0		3960	–	–	–	7.3	–	–	
03	230	2300	2.3	9.0		4110	–	–	–	7.6	–	–	
37	–	360	.7	4.2		1290	360	120	1420	7.2	80	22	
24	180	2500	1.0	95		4300	2700		7000	7.6			
39	200	2400	.7	100		4600	2600		7500	7.7			
29	130	910	.3	12		1930	830	720	3030	7.4	0	0	
15	100	780	.6	6		[illegible]	1400	–	–	6.9	–	–	
37	–	160	.7	.3		740	620	0	1220	7.5	[illegible]	20	
–	350	[illegible]	–	–		2000	–	–	–	–	–	–	
72	–	51	.4	.1		510	230	32	780	8.6	20	2	
75	–	79	.3	.4		570	230	86	940	8.4	50	–	
[illegible]	–	880	.6	–		1300	490	0	2150	8.2	20	10	
94	25	92	.2	–		790	440	180	1010	7.6	–	–	
[illegible]	–	67	.3	.5		510	240	–	790	8.5	20	–	
[illegible]	300	520	.9	.1		2450	660	240	3770	7.2	50	10	

District.

Laboratory: C, Government Chemist; [illegible] at Dodoma; U, Ubungo at Dar Es Salaam.

Hardness Total	Hardness [illegible]	Specific Conductance	pH	Color	Turbidity	[illegible]	Lab and analysis number	
660	320	1910	8.4	5	25		U/[illegible]/69	
610	390	2150	7.7	5	5		U/141/70	mn, 0.2.
850	350	2100	7.4	5	5		U/174/70	
–	–	–	7.9	–	–		M/X 10359/2	
2000	1800	3700	7.6	25	10		U/597/71	SiO[illegible]
–	–	–	8.0	–	–		M/X 4052	
–	–	–	7.4	–	–		M/X 10315/2	SiO_2, 28.
–	–	–	7.3	–	–		M/10315/3	[illegible]
–	–	–	7.6	–	–		M/10315/4	SiO_2, 60.
360	120	1420	7.2	80	22		U/703/71	
2700		7000	7.6				U/497/72	
2600		7500	7.7				U/498/72	
830	720	3030	7.4	0	0		U/527/73	
1400	–	–	6.9	–	–		U/26/75	
620	0	1220	7.5	[illegible]	20		[illegible]	150 mg/l of SO_4 if [illegible]
–	–	–	–	–	–		[illegible]	
230	32[illegible]	780	8.6	20	2		U/[illegible]	
230	86	940	8.4	50	–		U/862/77	
490	0	2150	8.2	20	10		U/[illegible]/78	
440	130	1010	7.6	–	–		C/16/91	mg must have had dec pt
240	–	790	8.5	20	–		U/[illegible]/77	
660	240	3770	7.2	50	10		U/176/72	

Constituent	Reporting Unit	0 to	1.0 to 10	10 to 100	100 to 1000	1000
Iron	mg/l	0.XX	X.X	XX	-	-
Calcium	mg/l	0.X	X.X	XX	XX0	XX00
Magnesium	mg/l	0.X	X.X	XX	XX0	XX00
Sodium	mg/l	0.X	X.X	XX	XX0	XX00
Potassium	mg/l	0.X	X.X	XX	XX0	XX00
Bicarbonate	mg/l	-	X	XX	XXX	XXX0
Sulfate	mg/l	0.X	X.X	XX	XX0	XX00
Chloride	mg/l	0.X	X.X	XX	XX0	XX00
Fluoride	mg/l	0.X	X.X	XX	-	-
nitrate	mg/l	0.X	X.X	XX	XX0	-
Dissolved solids	mg/l	-	X	XX	XXX	XXX0
Hardness	mg/l	-	X	XX	XX0	XX00
Specific conductance	micromhos	-	X	XX	XXX	XXX0
pH	units	-	X.X	-	-	-

Table 8.--Number of significant figures used for reporting quality of water constituents.

The analyses given in table 7 have most of the constituents reported in milligrams per liter which in repect to units is weight (milligrams) per volume (liter). In order to be able to compare constituents more meaningfully, it is necessary to multiply the reported milligrams per liter by the reciprocal of the molecular weight. For example, to compare sodium and chloride to see if the amounts of each could have come from solution of table salt, the sodium is multiplied by 0.0435 and the chloride by 0.02821. If the resulting pair of numbers are equal, one can be certain that the solution came from salt dissolving in water. The factors used to calculate milliequivalents per liter are given in table 9. For those analyses in table 7 which are essentially "complete", milliequivalents have been calculated and are given in table 10. In that table following the milliequivalent figure is another figure in parentheses. This shows the percent of anions or cations that the milliequivalent represents. When the percentages of calcium, magnesium and sodium are added they come to 100 percent. Similarly the percentages of bicarbonate, sulfate, and chloride add to 100 percent.

In table 10,columns four and three from the right give the sum of the milliequivalents of the cations (calcium + magnesium + sodium) and the sum of the anions (bicarbonate + sulfate + chloride). The second column from the right gives the percent difference between the two columns of sums. Theoretically a perfect analysis would have no percent difference with the sum of the cations being exactly equal to the sum of the anions. For those analyses in which the sum of the anions is greater than the sum of the cations, the percentage has been placed in parentheses. The percent difference provides a check on the reliability of the analysis. A low percent difference suggests an accurate analysis. A large percent difference suggests either error in analysis or failure to test for some major constituent.

Constituent	Ion	Multiply Mg/l by
Aluminum	Al^{+3}	0.11119
Bromide	Br^{-1}	.01251
Calcium	Ca^{+2}	.04990
Chloride	Cl^{-1}	.02821
Carbonate	CO^{-3}	.03333
Fluoride	F^{-1}	.05264
Iron	Fe^{+2}	.03581
Iron	Fe^{+3}	.05372
Bicarbonate	HCO_3^{-1}	.01639
Iodide	I^{-1}	.00788
Potassium	K^{+1}	.02557
Lithium	Li^{+1}	.14411
Magnesium	Mg^{+2}	.8226
Manganese	Mn^{+2}	.03640
Manganese	Mn^{+4}	.07281
Sodium	Na^{+1}	.04350
Nitrate	NO_3^{-1}	.01613
Sulfide	S^{-2}	.06238
Sulfate	SO_4^{-2}	.02082
Strontium	Sr^{+2}	.02282
Zinc	Zn^{+2}	.03060

Table 9.--Factors for converting milligrams per liter to Milliequivalents per liter (based on 1961 atomic weights).

Table 10 (Continued)

	Calcium	Magnesium	Sodium plus Potassium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate	Σcations	Σanions	% difference	sodium Adsorption Ratio
[illegible] BH 3/52	3.34 (40.4)	2.71 (32.8)	2.21 (26.8)	5.41	—	2.54	.11	[illegible]	8.27	8.05	1.3	.9
Mburet BH 8/52	2.69 (26.3)	3.13 (30.5)	4.42 (43.1)	6.56 (64.5)	.15 (1.5)	2.74 (29.0)	.11	.32	10.23	9.87	1.8	2.2
Njoro Nyeupe spring at Msitu wa Tembo	1.05 (5.2)	1.89 (9.4)	17.12 (85.3)	13.28 (80.6)	1.79 (10.9)	1.41 (8.6)	.36	.02	20.06	16.85	8.7	14
Shombosi BH 67/68 (100ft)	1.10 (16.6)	.82 (12.4)	4.71 (71.0)	8.64 (93.0)	.31 (3.4)	.34 (3.6)	.07	.04	6.63	9.40	(17.3)	4.0

Table 10. Selected chemical analyses converted to milliequivalents [illegible] and percentages.

Table 10

	Calcium	Magnesium	Sodium plus Potassium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate	Σcations	Σanions	% Difference	Sodium adsorption ratio
Angata Sere BH 32/69 (285 ft)	8.48 (41.0)	2.63 (12.7)	9.57 (46.3)	5.70 (26.8)	0.65 (3.0)	14.95 (70.2)	—	—	20.69	21.43	(1.0)	—
Angata Sere BH 32/69 (521 ft)	9.98 (39.6)	6.83 (27.1)	8.42 (33.4)	10.08 (41.4)	.73 (3.0)	13.54 (55.6)	.02	.02	25.23	24.39	1.7	2.7
Angata Sere BH 32/69 (523 ft)	6.49 (32.7)	5.59 (28.2)	7.78 (39.2)	4.59 (23.5)	.52 (2.7)	14.39 (73.8)	.02	.03	19.86	19.55	.8	3.0
Angata Sere BH 32/69 (600 ft)	9.48 (42.3)	3.62 (16.1)	9.34 (41.6)	5.08 (25.3)	.65 (3.2)	14.39 (71.5)	.01	.03	22.44	20.15	5.4	3.4
Dosidosi BH 6/54	21.96 (39.9)	18.92 (34.4)	14.11 (25.7)	2.18 (3.9)	3.33 (5.9)	50.78 (90.2)	.05	.65	54.99	56.98	(1.8)	3.1
Dosidosi BH 38/54 (50 m)	40.92 (53.2)	25.50 (33.2)	10.44 (13.6)	6.61 (8.7)	4.79 (6.3)	64.88 (85.1)	.12	.15	76.86	76.54	.2	1.8
Dosidosi BH 1/71 (507 ft)	5.49 (47.3)	1.48 (12.8)	4.63 (39.9)	3.88 ([illegible])	—	10.16 ([illegible])	.04	.07	11.60	14.14	(9.9)	2.3
Dosidosi BH 70/72 (450 ft)	29.94 (37.3)	24.68 (30.7)	25.64 (31.9)	2.20 (2.9)	3.75 (4.9)	70.53 (92.2)	.05	1.53	80.26	78.05	1.4	4.8
Engasumet well	4.39 (27.8)	7.98 (50.6)	3.41 (21.6)	9.62 ([illegible])	—	4.51	.04	.00	15.78	14.18	5.4	1.2
Engasumet BH 25/75 (142 ft)	9.98	17.27	—	6.80 (22.0)	2.08 (6.7)	22.00 (71.2)	.03	.10	27.25	31.02	(6.5)	—
Kibaya BH 247/75	4.99 (50.8)	99 (10.1)	3.84 (39.1)	4.51	—	2.23	.02	.01	9.82	6.76	18.4	2.0
Kijungu BH 27/68	2.00 (35.5)	2.14 (38.1)	1.48 (26.4)	2.64 (42.5)	.75 (12.1)	2.82 (45.4)	—	.01	5.62	6.22	(5.1)	1.0
Kijungu BH 44/69	4.54 (29.9)	1.07 (7.0)	9.57 (63.0)	4.00 (24.9)	8.12 (50.5)	3.45 (24.6)	.32	—	15.18	16.38	(3.8)	5.7
Kitwei BH 7/52	3.09 (13.9)	6.17 (27.6)	13.05 (58.5)	3.93 (14.8)	1.73 (6.5)	20.88 (78.7)	.07	.15	22.31	26.76	(9.1)	6.[illegible]
Kitwei BH 32/52 (156 ft)	4.09 (9.2)	9.87 (22.1)	30.73 (68.8)	3.32	-	7.6[illegible]	[illegible]3	.03	44.69	16.[illegible]	[illegible]46.1	1.[illegible]

Stock and Wildlife Watering

Water quality suitable for stock and wildlife is a major concern in Kiteto District. To make available what little is known, the following has been abstracted from McKee and Wolf (1963, p.112).

Data with respect to the water-quality requirements of animals are abundant but incomplete. Quantitative data concerning water-quality tolerances of livestock and poultry are few. Studies of this nature have been made chiefly in Australia and South Africa, places where water for livestock is commonly highly mineralized.

Since the total quantities of substances ingested daily are the critical values for animal metabolism, the permissible concentrations of such substances in water depend largely on the daily water consumption of the animals. Estimates of the quantity of water required for livestock and poultry are as follows:

Animal	UK Gallons per day per head	Liters per day per head
Beef cattle	6 to 10	25 to 45
Dairy cattle	8 to 13	35 to 60
Horses	6 to 10	25 to 45
Swine	2.4 to 4	10 to 20
Sheep and goats	.8 to 3	3.5 to 15

It has been assumed that water safe for human consumption may be used safely for stock. On the other hand, it appears that animals can tolerate higher salinities than men, and it is concievable that the differ in their tolerance of specific substances.

The use of highly mineralized water can cause among animals, as well as among men, physiological disturbances of varying degrees of severity, such as gastrointestinal symptoms, wasting disease, and death. Among the functions of animals, lactation and reproduction are the first to be disturbed by continuous use of water with unfavorable mineral concentration.

Within limits, animals can adjust to the use of saline water that at first was impossible to consume. On the other hand, sudden changes from slightly mineralized to highly m ncralized water may cause acute salt poisoning and rapid death.

The Government of Western Australia has listed the threshold concentrations of salinity tolerated by animals that they observed. In general, water contaáning less than 5,000 milligrams per liter (mg/l) can be used by all livestock. Sheep are more tolerant than cattle, and cattle are more tolerant that horses and pigs. The standards in use in Western Australia as the safe upper limits for stock are reported as follows:

Animal	Dissolved Solids (mg/l)
Poultry	2,500
Pigs	4,300
Horses	6,400
Cattle, dairy	7,200
Cattle, beef	10,000
Sheep	13,000

When dissolved solids exceed the above listed concentrations, practical tests are needed to show whether or not the water may be marginally safe. When green feed is available, animals can tolerate more saline water than when bush or scrub is the only feed. When feed is low in salt content, water of higher salinity is also tolerable. Sheep have used water containing 18,000 mg/l temporarily but lambs and ewes should be watched carefully when water has over 10,000 mg/l. The milk production of cows is reduced by water containing about 7,000 mg/l.

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Table 1. Borehole Data For Kitete

Place	Borehole Number	Lat. ° ' "	Long. ° ' "	Land Surface Elevation (ft)	(m)	Map No.	Grid Coordinates East	No
Amei Ranch, northwest of Kijungu	129/74	5	37	—	—	127/3	—	—
Amei Ranch	189/74	5 18 53	37 [illegible] 33	4030	(1228)	do	290.5	94[illegible]
Amei Ranch	200/74	5 18 20	37 08 35	4100	(1250	do	294.2	[illegible]
Amei Ranch	252/77	5 17 09	37 07 24	3990	(12[illegible]6)	do	292.[illegible]	9[illegible]
Angata Sere.	32/69	5 24 30	37 18 37	3950	(120[illegible])	127/4	312.8	94[illegible]
Dosidosi	6/54	5 33 38	36 29 02	4740	(1445)	144/2	221.1	93[illegible]
Dosidosi (believed to be near BH 32/61)	38/54	5 37 23	36 24 44	4650	(1417)	do	213.5	93[illegible]
Dosidosi	32/61	5 37 23	36 24 44	4650	(1417)	do	213.5	93[illegible]
Dosidosi	1/71	5 33 42	36 28 55	4750	(1448)	do	221.0	93
Dosidosi	70/72	5 37 18	36 24 51	4650	(1417)	do	213.6	93
Dosidosi (4 ft. South of BH 70/72)	95/73	5 37 18	36 24 51	4650	(1417)	do	213.6	93[illegible]
Dosidosi (See also Zoissa)								

Borehole Data For Kiteto District, Arusha Region

Long. ° ' "	Land surface Elevation (ft)	(m)	Map No.	Grid Coordinates East	North	Type of Power	Type of Pump	Use of Water	Remarks
7	—	—	127/3	—	—	—	—	—	Abandoned, hole off centre
7 06 33	4030	(1228)	do	290.5	9412.3	—	—	—	Abandoned, no water
37 08 35	4100	(1250	do	294.2	9413.2	Lombardini Diesel	Mono	S, D	Water struck at 355 ft.
37 07 24	3990	(1216)	do	292.2	9415.5	None	None	None	Awaiting pump
37 18 37	3950	(120.)	127/4	312.8	9402.0	Lister Diesel	Climax	S, Dip	
36 29 02	4740	(1445)	144/2	221.1	9384.8			Abandoned	Chloride 1300 mg/l.
36 24 44	4650	(1417)	do	213.5	9377.9				Chloride 2300 mg/l.
36 24 44	4650	(1417)	do	213.5	9377.9				
6 28 55	4750	(1448)	do	221.0	9384.7				Chloride 360 mg/l.
6 24 51	4650	(1417)	do	213.6	9378.0				Water at 100, 150, 205, and 255 ft. Chloride 2500 mg/l.
6 24 51	4650	(1417)	do	213.6	9378.0				Water at 455 ft. Chloride 910 mg/l.

A-1b

Table 1.

Place	Borehole Number	Diameter (in)	Borehole Depth (ft)	Depth (m)	Depth to water (ft)	(m)	Yield (Gall/hr)	(m³/hr)	Drawdown (m)
Amei Ranch	129/74	6½	80	(24.4)	—	—	—	—	—
Amei Ranch	189/74	6½	540	(165)	—	—	—	—	—
Amei Ranch	200/74	6½	500	(152)	272.42	(83.0)	660	(3.0)	—
Amei Ranch	252/77	6½	425	(130)	243	(74)	600	(2.7)	4334(13.
Angata Sere	32/69	10,8,6	900	(274)	180	(55)	575	(3.1)	340.58(1
Dosidosi	6/54	—	480	(146)		—	960	(4.36)	550(1
							640	(2.91)	250(-
Dosidosi	38/54	—	300(91)		?		1300	(5.9)	—
Dosidosi	32/61	—	173(53)		16 (4.9)		1650	(7.5)	—
Dosidosi	84/68	delete							
Dosidosi	1/71	12,10	707(215)		104(31.7)		584(3.1		433(122
Dosidosi	70/72	6	450(137)		68 (20.7)		[illegible]		—
Dosidosi	95/73	6	700(213)		81 (24.7)		95	8.6	27 (5

Depth (m)	Depth to water (ft)	(m)	Yield (Gall/hr)	(m³/hr)	Drawdown (m)	Hrs Pumped	Date	Casing and finish	Transmissivity (ft) T(0.1)	(m)	Lithology
24.[illegible])	—	—	—	—	—	—		—	—		—
65)	—	—	—	—	—	—		—	—		—
152)	272.42	(83.0)	660	(3.0)	—	12	9/1/75	—			
130)	243	(74)	600	(2.7)	4334(13.2)	24	25/5/78	51' of 6"	[illegible]		Claystone, sand and silt (345), sand (40) syenite.
274)	180	(55)	575	(3.1)	340.58(103.81)	24	17/2/70	—	[illegible]		
46)		—	960	(4.36)	350(106.7)			—			
			640	(2.91)	250(76.2)						
	?		1300	(5.9)	—	—	—	—	—		Water at 170, 195, and 270
	16 (4.9)		1650	(7.5)	—	—	—	—	—		
	104 (31.7)		[illegible]	(3.1)	433(122.83)	21	7/4/71	62' of 8"	[illegible]		
	68 (20.7)		[illegible]		—	24	25/6/72	—	—		
	81 (24.7)		[illegible]	8.6	87 (57.0)	[illegible]	26/8/73	400' of 6"	[illegible]		21m of clastics over gneiss; Driller reported fresher H_2O at depth.

x-2a

Table 1.

Borehole Data

Place	BH no.	Lat.	Long.	L.S. Elev. (ft)	L.S. Elev. (m)	Map No
Engasumet	36/51	4 27 15	37 12 28	4430	(1350)	88/3
Engasumet	25/75	4 27 37	37 12 24	4400	(1341)	do
Engasumet	81/75	—	—	—	—	do
Engasumet (2.5 m north of village)	109/75	—	—	-	-	do
Engosero Eraswa (Olmeto)	11/53	4 01 54	36 37 38	4530 (1381)		87/1
Kibaya (on east side of town)	23/50	5 18 48	36 34 19	4963 (1519)		126/.
Kibaya (near national housing)	245/75	5 18 29	36 33 40	5056 (1539)		do
Kibaya (near pump station)	247/75	5 18 55	36 33 34	4950 (1509)		do
Kibaya (on river bank near old dip)	25/78	5 19 21	36 34 04	4900 (1494)		do
Kijungu (0.7 m west of town)	27/68	5 23 45	37 13 27	4480 (1366)		127/:
Kijungu	44/69	523 53	37 10 54	4490 (1369)		do
Kimana	26/50	5 17	36 44	4000 (1219)		126/:

rehole Data

L.S. Elev. (ft)	(m)	Map No	Grid Coord E	N	Power	Pump	Use	Remarks
4430	(1350)	88/3	301.1	9507.5	—	—	—	
4400	(1341)	do	301.0	9506.8	Lister	Mono	D, S	Water struck at 25, 301 feet. Chloride 780 mg/l.
—	—	do	—	—	—	—	—	Abandoned, drilling problems
—	—	do	—	—	—	—	—	Water struck at 165 ft. Abandoned, because of [illegible] development.
4530 ([illegible])		87/1	236.5	9354.0	—	—	Abandoned	~~Abandoned~~ in 1956 ~~system~~ supply failed
4963 (1513)		126/3	230.9	9412.3	Lister	Climax	PS	Chloride of 580 mg/l.
5056 (1539)		do	229.7	9412.8	Lister	Climax	PS	Chloride 51 mg/l.
4950 (1509)		do	229.5	9412.0	Lombardini	Mono	PS	Chloride 79 mg/l.
4700 (1494)		do	230.4	9411.2	None	None	unused	Awaiting pump.
4480 (1366)		127/3	297.7 ~~298.5~~	9403.3	None	None	unused	Chloride 100 mg/l. ~~Unused~~
4490 (1369)		do	296.5	9403.0	Lister	Climax	S, dip, D	Chloride 150 mg/l
4000 (1219)		126/3	250	9415	—	—	—	

A-2b

Table 1.

Place	BH No.	Dia (inches)	Depth (ft)	Depth (m)	DTW (ft)	DTW (m)	Yield (Gal/hr)	Yield (m^3/hr)	D/e (m)
Engasumet	36/51	8,6	70	21	50	(15)	250	(1.1)	–
Engasumet	25/75	6	420	128	58.42	(17.8	2300	(10.5)	37 (11
Engasumet	81/75		45	(14)					–
Engasumet	109/75		405	(123)			[illegible]	est. (1.[illegible])	–
Engosero Erasula	11/53		410	(125)	248	(75.6	840	(3.8)	–
Kibaya	23/50	8,6½	150	(46) ~~(45.7)~~	17 (5.2)		500	(2.3)	–
Kibaya	245/75	6	185	(56) ~~(56.4)~~	85 (26)		440	(2.0)	–
Kibaya	247/75	6½	353	(108)	22 (6.7)		905	(4.1)	34 (10.4
Kibaya	25/78	8,6½	350	(107)	13 (4.0)		2640	(12)	–
					10 (3.0)		2100	(9.5)	50.33 (15
Kijungu	27/68	8,6	300	(91) ~~(91.4)~~	114 (34.7)		320	(1.4)	–
Kijungu	44/69	10,8,6	401	(122)	173.67 (52.9)		630	(2.9)	196 (59.8)
Kimana	26/50		465	(142) ~~(141.7)~~	350 (107)		475	(2.2)	–

(m)	DTW (ft)	(m)	Yield (Gall/hr)	(m³/hr)	D/d (m)	Hrs. pumped	Date	Casing	[illegible]	Lithology
21	50	(15)	250	(1.1)	–	9	15/1/52	–	–	Limestone over gneiss.
128	58.42	(17.8	2300	(10.5)	37 (11.3)	12	8/4/75	164' of 8" Screen: 39.6-48.8m	18	-5)
14)					–	–	–	170'		
123)			[illegible]	(1.4)	–	–	–	–	–	
125)	248	(75.6	840	(3.8)	–	–	–			
5)	17 (5.2)		500	(2.3)	–	8	[illegible]			Gneiss and schist.
)	85 (26)		440	(2.0)	–	12	2/10/75			Gneiss.
3)	22 (6.7)		905	(4.1)	34 (10.4)	12			[illegible]	Gneiss.
)	13 (4.0)		2640	(12)	–	24		10' of 8"	[illegible]	Gneiss.
	10 (3.0)		2100	(9.5)	50.33 (15.34)	48	31/12/78		[illegible]	
)	114 (34.7)		320	(1.4)	–	–				
2)	173.67 (52.9)		630	(2.9)	196 (59.8)	24	14/9/69		0.7 [illegible] .3	
2)	350 (107)		475	(2.2)	–	–	–			

3a

Table 1.

Kamatz Loc.

	Bit No	Lat	Long	Land Surface Elevation ft (m)	Map no.	Grid	
Kitwei	6/52	4 50 58	37 11 04	3200 (975)	107/3	298.7	9
Kitwei "A"	7/52	4 48 31	37 09 10	3270 (997)	do	295.1	9
Kitwei "B"	32/52	4 54 42	37 18 23	2950 (899)	107/4	312.2	9
Lekiteju	3/52	3 55 55	36 25 10	5050 (1539)	70/4	213.5	9
Lendanai	28/50	4 04	37 17	3225 est (93)	53/2	307	7
Lolbene (Oldonyo Loscido)	5/50	(3°42'45"	37 06 30)	-	72/3	-	
Lolbene	20/50				do		
Olbene (Ambussel)	25/50	3 55 30	37 15 15	3100 (945)	72/4	306	95
Makami	79/68	-	-	3360 (1024)	106/1	--	
Makami	61/73			3350 (1021)	do	247	9
Muret	8/52	3 58 25	36 26 17	4950 (1509)	70/4	216.5	9
Muja B (in Hai District)	49/70	3 28 49	37 04 29	2855 (870)	70/3	[illegible]	[illegible]

Water Loc.

Long	Land Surface Elevation ft (m)	Map no.	Grid		Power	Pump	Use of Water	
37 11 04	3200 (975)	107/3	298.7	9463.7	None	None	None	Well filled with rocks.
37 09 10	3270 (997)	do	295.1	9468.2	Lister	Climax	S, D.	
37 18 23	2950 (899)	107/4	312.2	9456.9	Lister	Climax	S, D	
36 25 10	5050 (1539)	70/4	213.5	9565.0	—	—	S	
37 17	3225 est (983)	53/2	307	7549	—	—	Abandoned	No water.
[illegible]	-	72/3	—	—	—	—	Abandoned	No water,
		do					Abandoned	
37 15 15	3100 (945)	72/4	306	9566	—	—	Abandoned	
-	3360 (1024)	106/1	—	—	None	none	none	Saltier than sea wate Chloride 40,000 mg/l
	3350 (1021)	do	247	9464	None	None	None	Saltier than sea wate
36 26 17	2950 (1509)	70/4	216.5	9560.3	Lister	Climax	S, D	chloride 97 mg/l.
37 04 29	2955 (900)	70/3	[illegible]	9615.1			D	Water struck [illegible] ft.

4-3b

Table 1.

	Borehole Number	Dia.	Depth	Depth to water	Yield	Drawdown	Hours Pumped	Date
Kitwei	6/52	8	122 (37.2)	45 (13.7)	300 (1.4)	–	5	15/2/52
Kitwei "A"	7/52	8	104 (31.7)	71 (21.6)	1600 (7.3)	–	2	/52
					1370 (6.2)	2.08 (0.6)	24	7/6/71
Kitwei "B"	32/52	8	153 (46.6)	103 (31.4)	840 (3.8)	–	4	/52
Lekiteju	3/52	8,6	284 (86.6)	170 (51.8)	900 (4.1)	–	4	/52
				171 (52.1)	2300 (10.5)	14.1 (4.3)	24	4/1/78
Lendanai	28/50	8, 6½	364 (110.9)	–	–	–		
Lolbene	5/50	8,6	440 (134)	–	–			
Lolbene	20/50	8,6	364 (111)	228 (69.5)	1050 (4.8)	–	24	–
Lolbene	25/50	8,6½	288 (87.8)	144 (43.9)	680 (3.1)	–	20	–
Nakami	79/68	8,6	544 (166)	55 (16.8)	1800 (8.2)	–	24	–
Nakami	61/73	–	259 (78.9)	55.75 (17.0)	1900 (8.6)	1.67 (0.51)	12	25/4/73
Nouret	8/52	8, 6½	256 (78.0)	200 (61.0)	55 (0.25)	–	–	12/12/52
			575 (175)	161 (49.1)	840 (3.8)	–	[illegible]	
[illegible]	[illegible]	14, 12	300 [illegible]	70.25 (21.7)	3600 (16)	[illegible]	[illegible]	[illegible]

Depth to water	Yield	Drawdown	Hours Pumped	Date	Casing	T(0.1) 'm	Lithology
5(13.7)	300 (1.4)	—	5	15/2/52			
71(21.6)	1610(7.3)	—	2	/52			
	1370(6.2)	2.08(0.6)	24	7/6/71		258 ~~50~~	(after cleaning).
3(31.4)	840 (3.8)	—	4	/52			
0(51.8)	900(4.1)	—	4	/52			Clay and gneiss.
71(52.1)	2300(10.5)	14.1(4.3)	24	4/1/78		57 ~~31~~	(after cleaning).
—	—	—	-	-	—	—	Black cottonsoil and gneiss.
—	--		-		—	—	Limestone, clay, and gneiss.
3(39.5)	1053 (4.8)	—	24	—	--	--	Alluvium and gneiss.
4(43.9)	680(3.1)	—	20	—	—	—	Limestone and gneiss.
5(16.8)	1800(8.2)	—	24	—	—	—	Limestone, sand, gneiss.
5(17.0)	1900(8.6)	1.67(0.51	12	25/4/73	--	~~440~~ 70	Limestone, sand, gneiss.
0(61.0)	55 (0.25)	—	—	12/12/52			
1 (49.1)	840(3.8)	--	3				(after deepening in 1953)
25(5.17)	3600(16)	3.13 [illegible]	[illegible]	[illegible]		432 ~~79~~	

Table 1.

C-4a

	Borehole No	Lat	Long	Elevation	Map No	Grid	Co
Nagotila Catholic Mission	-/63	4 01 54	36 38 59	4470 (1362)	87/1	239	955
Name lok	11/54	5 26	36 33	4900 (149[illegible])	126/3	229	939
Ndedo	72/78	4 52 30	36 47 27	3360 (1024)	106/4	255	94[illegible]
Ndedo	35/79	4 52 23	36 47 43	3360 (1024)	106/4	255.5	94[illegible]
Ng'abolo	111/78	5 07 54	36 34 06	4180 (1274)	126/1	230.4	94[illegible]
Ng'abolo	121/78 & 171/78	5 07 12	36 33 08	4200 (1280)	do	228.6	9[illegible]
Ng'abolo (near site of former school)	172/78	5 06 37	36 37 15	3880 (1183)	do	236.3	943
Olboloti (Mrijo)	13/50	5 10	36 15		125/2	19	942
Olboloti (Mrijo)	45/54	5 10	36 15		do	19	942
Olboloti	9/68	5	36		do	19	942
Olboloti	93/75	5	36		do	19	942
Olboloti	146/75	5	36		do	19	942
Elkenai (Magazeni) (=Olgine) (=Lugine)	38/53	5 41 31	36 31 21	4350 (1326)	145/1	225.6	937

Long	Elevation	Map No	Grid	Coord	Power	Pump	use	
6 38 59	4470 (1362)	87/1	239	9554	None	None	unused	
6 33	4905 (1494)	126/3	229	9399	—	—	Abandoned	No water.
6 47 27	3360 (1024)	106/4	255	9461	None	None	unused	Salty water
6 47 43	3360 (1024)	106/4	255.5	9461				
6 34 06	4180 (1274)	126/1	230.4	9432.3	None	None	Unused	Too little water.
6 33 08	4200 (1280)	do	228.6	9433.6	Hole abandoned because of drilling prob'ms.			
6 37 15	3880 (1183)	do	236.3	9434.7	None	None	Unused	Awaiting pump.
15		125/2	19	942				
15		do	19	942				
6		do	19	942				No data.
6		do	19	942			Abandoned	Dry hole.
6		do	19.	942				
6 31 21	4350 (1326)	145/1	225.6	9370.3				

Table 1.

4-Ab

	BH No.	Dia	Depth	PTW	Q	s	t	date	
Ngotila	-/63	8,6	284 (86.6)	219 (66.8)	1100 (5.0)	–	12	–	182' of
Namelok	11/54	–	430 (131)	–	–	–	–	–	
Ndedo	72/78	12,8	255 (77.7)	50.67 (15.4)	5280 (24)	20 (6.1)	24	30/5/78	42' of
Ndedo	35/79	7.5	92 (28.0)	47 (14.3)	1750 (8.0)	5.08 (1.6)	24	14/2/79	
Ng'abolo	111/78		300 (91)	236 (71.9)	5 (.02)	–	1/4	[illegible]	10' of
Ng'abolo	121/78 & 171/78		200 (61)	–	None	–	–		No
Ng'abolo	172/78		420 (128)	83.40 (25.42)	300 (1.4)	–	[illegible]	[illegible]	[illegible]
[illegible]	13/50		515 (157)	370 (112.8)	28[illegible] (12.7)				
[illegible]	75/54	8,6	600 (183)	358 (109.1)	[illegible] 12.7	–	24		
			600 (183)	365 (111.3)	1571 (4.9)	26.67 ([illegible]	24	[illegible]	
[illegible]	2/63		–	–	–	–	No data)		
[illegible] (in road)	93/75	10	525 (160)	–	–	–		–	11' of
[illegible] in [illegible]	146/75	6	643 (196)	450 (122)	220 (1.0)	520 (240) ([illegible])	24	[illegible]	54' of
[illegible]	[illegible]		267 (81)	151 (46)	750 ([illegible])	–		–	

w	Q	s	t	date	casing	T(0.1) m	Lithology
(66.8)	1100 (5.0)	–	12	–	182' of 6"	–	
–	–	–	–	–	–	–	
57(15.4)	5280 (24)	20 (6.1)	24	30/5/78	42' of 10"	~~85~~ 22	Limestone (190'), sand (60'), gneiss (salty water)
(14.3)	1750 (8.0)	5.08 (1.6)	24	14/2/79		~~124~~ 24	Limestone
(71.9)	5 (.02)	–	1/4	8/78	10' of 8"		Gneiss,
–	None	–	–		No casing		Sediments (Mbuga ?).
40(25.42)	300 (1.4)	–	3	11/78	10' of 8"		Gneiss.
(12.5)	2800 (12.7)						
(109.1)	[illegible] 12.7	–	24		–		
(111.3)	1171 (4.9)	26.67 (6.[illegible])	24	14/5/71	–	~~12~~ 3.33	
–		–	No data)		–		
–	–	–		–	11' of 10"	–	Dry hole
(122)	220 (1.5)	520 (340) [illegible]	24	[illegible]/75	54' of 6"	~~0.2~~ 0.3	No drawdown measured
(46)	750 ([illegible])	–		–	–		

5a

Table 1.

	BH No	Lat	Long	Elev.	Map No	Grid		Power	Pump.	use
Shambarai	67/68	3 36 50	36 50 11	3100 (945)	71/2	259.6	9660.3			
Songambele (Olgine)	183/73	5 38 43	36 27 28	4900 (1494)	144.2	218.3	9375.4	Lister Lombardini	Climax Mono	}
Sunya	190/77	5 44 02	37 05 53	3510 (1070)	146/1	289.3	9365.8	None	None	Abundant water but it was cased out! Pump test was meaningless.
Outside Kiteto District but near Dosidosi										
Loissa	36/52	5 41 14	36 24 48	4655 (1419)	144/2	213.55	9370.7			
Loissa, Kinangali	27/54	5 42 16	36 23 54	4475 (1364)	do	211.95	9369.35			

Table 1.

		Dia	Depth	DTW	Q	s	t
Shambarai	67/68	10	300(91)	47(14.3)	2100(9.6)	11(3.35)	48
Songambele	183/73	10, 6	512(156)	251(76.5)	950(4.3)	23.0(70.1)	48
Sunya	190/77	6	105(32)	6.00(1.83)	—	—	—
Outside Kiteto District but near Dosidosi							
Loissa	36/52	8	235(72)	138(42.1)	600(2.7)	—	6
Loissa, Mnangali	27/54	8	162(49)	94(28.6)	640(2.9)	—	3

d	t	date	casing	T (m)	
(3.35)	48	28/10/68	—		
33 (70.1)	48	5/12/73	326' of 6"	~~66~~	Water at 490 ft.
—	—	-			Alluvium.
—	6	—	154' of 3"		Water at 154 and 214 ft
—	3	—	54' of 3"		Water at 115 ft.