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HYDROGEOLOGIC WORK ON THE MASAI PROJECT:

End-Of-Tour Report

by

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for

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INTRODUCTION

The Masai Project has completed its course and is being phased out. A new village Development Project will be starting soon and it will have a water component. This report is written in the hopes that a hydrogeologist will be a member of that project for its duration, that he will be provided with the proper equipment to do his work, and that he will be encouraged to continue the collection of basic data, the preparation of hydrogeologic maps, the logging of boreholes, and the creation of an office for ground-water investigation.

Any criticisms are intended solely to be helpful and to prevent as far as possible those things which might prove harmful to the new project and to indicate avenues by which future hydrogeologic work can be most productive.

ASSIGNMENT

Dates of Contract (with 2½ months extension):
16 February 1977 to 30 April 1979

Job description for Ground-water Hydrogeologist:
(given in Contract No. AID/afr-C-1279)

The hydrogeologist will be responsible to the Chief-of Party for carrying out field investigations to determine ground-water potential within the Ranching Association areas. In close day-to-day coordination with the Water Development Specialist, Heavy Equipment Specialist, and the Well Driller, he will:

a. Work with his Tanzanian counterparts in conducting such geological surveys as are required to determine the ground-water potential within the Ranching Association areas.

b. Determine in cooperation with the Range Management, Well Driller, and Water Development Specialists the sites where drilling is required for the development of water in support of the range management plans developed for each management unit.

c. Liaise with the other Tanzanian Government agencies whose resources are necessary to support the project's hydrogeological program, including the Geological Survey Department.

d. Compile data on ground-water potential for the development of an overall master plan for water development in Arusha Region, first for the Ranching Association areas, next for the other parts of Maasailand, and finally, if feasible, for the other districts of the Arusha Region.

ACCOMPLISHMENTS

Work Related to Job Description

Item "a" of my job description never applied to me because I had no counterpart(s) and Ranching Associations were inactive. The day I arrived in Arusha my "counterpart" went on leave for a month. When he returned he was so busily engaged in preparing to leave for four years of hydrogeology training in the U.S. that we had no opportunity to work together. No other counterpart was provided so I had no opportunity to train anyone to carry on my work. Also, the concept of ranching associations had been replaced by that of Ujamaa Villages.

Under item "b" I made several safaris with Mr. Martin and Mr. Booth, Range Management and Water Development Specialists, to evaluate areas as to type of water development needed. Range management plans never developed sufficiently to require locations of boreholes as water points.

Under "c", I wanted to contact Maji personnel in Dar es Salaam, and Professors in the Geology and Geography Departments at the University of Dar es Salaam when I arrived in the country. To my surprise I was denied that opportunity and rushed out of town to Arusha in less than 24 hours. During visits to Dodoma I have had contact with the Office of Chief Geophysicist and gathered borehole data from their files. I found they are equipped and

and staffed to make electrical resistivity surveys so I turned over the project geophysical equipment to them and called on them when such field surveys were required.

Under "d", I heard from several sources that the Government of Tanzania had requested the United States to prepare a master water plan for Arusha Region but I was never able to get any USAID official to confirm this or provide me with USAID official view regarding such work. Ellis Gordon and O'Rourke had each spent 3 months in Arusha preparing a project proposal for a water and soil project. Mr. Gordon, before I left the U.S. furnished me a copy of a letter from the Maji Principal Secretary Mr. Lwegarulilla in which he requested the U.S. to delete the soil aspects of the proposal but I could never find if any reply to this request was ever sent.

Essentially all of my effort during my tour has been spent in gathering and analyzing data to be able to determine the ground-water potential both for specific sites where boreholes might be needed and for Kiteto District. I realized that the span of two years would permit only the preparation of one detailed report along with compilation of data for the region. This restriction to Kiteto District was done on my initiative so that I would be able to leave something in print to establish the value of hydrogeological work.

Methods for determining location

Even though Tanzania is blessed by having an excellent set of 1:50,000 topographic maps, it is mighty hard during most safaris to know where one is. One method is to use the car odometer and measure the distance covered along the road taken as shown on the map. With the new drought roads being major routes for project travel, that method becomes difficult because the roads are too new to appear on the maps, and the odometer on my jeep underregistered by 14 percent.

Resection on laying the maps on a flat surface and orienting so that lines from each feature intersect at the point on the map where you are is next to impossible. There is no flat place or plane table on which to lay the map(s) and if there were, the wind is strong enough that the maps would not stay where you want them. To bypass this problem I developed a calculator program to determine mathematically grid coordirates by resection. Three or more compass azimuths are used with the grid coordinates of the points sighted. These are substituted into the point-slope equation of a line. The determinant of the equations for two lines is then solved to give the location of the point from which the azimuths were observed.

Another calculator program was developed to permit rapid calculation of latitude and longitude for any point on a 1:50,000 Arusha Region topographic map. Only three items are needed: map number, the distance on the map from

the top to the point and the distance from the west edge to the point. This program was used to calculate geographic coordinates for boreholes and for water points sampled for chemical analyses. The need for such a program resulted from extremely poor location data and from maps so generalized that boreholes were shown in the wrong quadrangle.

An attempt was made to write a program to convert latitude and longitude to Universal Transverse Mercator grid coordinates and vice versa. This would give a rapid check to make sure that both determinations agreed. Unfortunately I never was able to get this operational, but it is still worth doing.

Office files

The map files are in far better shape than when I took over. Where needed, maps have been ordered to complete coverage for Arusha Region. A master file contains one copy of each topographic map for office use in recording borehole, spring, dam, etc. locations. Other drawers contain maps for field use or as needed. All maps have been trimmed to fit in the drawers, are filed in numerical order and have been inventoried.

The air photos are filed in order by flight number. The flight number and photo numbers have been put on an index map showing which photos fall in each map quadrangle.

An alphabetical list of boreholes which was prepared and distributed has proven very useful. A table of borehole data was also compiled and made available to the Regional Water Engineer and several consultants. It has been gratifying to see these items used frequently during my meeting with him and by those seeking basic data.

Chemical analyses have been assembled and retabulated by district. These have been of great help in answering requests and have been used by several consultants.

Standardization

The chemical analysis data proved to be difficult to use because analyses were reported to varying numbers of significant figures. While compiling, I tabulated each constituent to only those values that could be significant. This makes the resulting table far easier to use and make the differences and similarities much easier to spot.

Because Tanzania has officially adopted the metric system, I have reported all my results in metric units. Previously specific capacity, a more meaningful measurement than yield, has not been calculated for Tanzania boreholes. To make specific capacity directly comparable with transmissivity, I have reported both in the same set of units, cubic meters per-day per meter of drawdown, which reduces to meters squared per day(m^2 day^{-1}). For borehole data, I have given both the english unit in which the data were collected, and the metric conversion.

This permits the data to be used in either system and makes it easier to check if data have been correctly transcribed.

Because one is faced with so many conversions going from english to metric and vice versa, I have compiled a table of conversion factors useful in hydrogeologic work. The format is new but hopefully is easily understood and used.

Aquifer hydraulics

A major accomplishment in Tanzania has been the development of a program to calculate transmissivity from drawdown measured in a pumped borehole. In the United States, transmissivity is almost always calculated from a pumping test using observation wells. When I found how difficult and expensive it is to drill just one borehole in Tanzania, I realized that observation wells are probably an unaffordable luxury both here and in other developing countries. My method requires the use of a rather sophisticated calculator (either a Hewlett-Packard HP-67 or HP-97) but I am so proud of my program I will be glad to calculate transmissivity for anyone in Tanzania who sends me the data needed to make the calculation (borehole diameter, yield, drawdown and length of pumping at time drawdown was measured).

Once transmissivity is known a wide range of hydrologic problems can be solved. For example:

Quantity of ground-water (Q) is measured by multiplying Transmissivity (T) by gradint (I) by length (L)

$$Q = TIL$$

I using transmissivities that I have calculated, I have estimated the annual rate of ground-water recharge in Kiteto District, ground-water flow that discharges into Pangani River, groundwater available for development in Kiteto District, and groundwater flow into Makami Depression. Transmissivity can also be used to predict water-table decline that would be caused by various rates of pumping, minimum spacing of boreholes to prevent mutual interference, and best setting for a pump.

I have compared results of my methods with those from elaborate published tests and find surprisingly close agreement. This makes me believe I have made a major advance in ground-water hydraulics and one that will be especially useful in developing countries.

Miscellaneous

Written borehole site evaluations were prepared for 14 locations. Drill cuttings were logged for the new boreholes. An electric log was run in the borehole at Ngwiso. Numerous visits were made to evaluate ground-water possibilities.

During a large part of my tour I was in charge of the drilling program and I am amazed that I was not only able

to discharge that responsibility but simultaneously maintain active hydrogeological investigations. Elsewhere under similar conditions, I have observed the drilling program consume so much time and effort that relatively nothing could be accomplished on ground-water studies.

ORGANIZATIONAL RELATIONS

Host Country

My main contact in the Government of Tanzania has been the Regional Water Engineer for Arusha Region, Mr. S.G. Hassanali. The support I have received from him has been excellent. He has coordinated the drilling requests and developed a sensible, logical program into which it has been both easy and enjoyable to fit my efforts. Political decisions from time to time changed priorities but these produced little if any disruption in my work.

Even though I was brought to Arusha to make hydrogeological surveys, no funds were provided specifically for this purpose. Neith r AID nor GOT had a fund that I could draw upon for work that involved anyone other than myself.

USAID

Perhaps my greatest frustrations resulted from actions and inactions within USAID. An AID employee accompanied me to get my air freight and much to my surprise told me how much I had to bribe each office/person in order to get my property.

AID did not allow me to make any professional contacts in Dar es Salaam upon my arrival in Tanzania. In fact I was told that the one man whom I asked to meet was a nobody and I would be wasting my time. It turned out that that evaluation could not have been more wrong.

Shortly after my arrival in Arusha an AID Official requested members of the Masai team to submit orders of equipment needed. I submitted my list and waited and waited. After a year and a half I received one item. I still do not know if the others were ever ordered. Some of my work activities never could be undertaken because the equipment I ordered and needed never was received. For example, because of no tapes, no depths to water could be measured.

Paper that was ordered for a USAID purchased copying machine never was received. The machine has sat unused in the office for two years because the paper order was never processed. Items ordered by people unfamiliar either with the equipment or with hydrogeology was unusable for project work when it did arrive.

My contract had no allowance for transport of professional equipment and reference books. Without the equipment and books I brought with me, I would have been unable to accomplish any work of a hydrogeologic nature. Things I brought which were not provided otherwise included a brunton compass, programmable calculators,

logarithmic and semilogarithmic graph paper, camera, binoculars, boxwood rulers proportional dividers, pencils, pens, triangles, microscope light, papercutter, stapler, paper punch, but most important of all, my reference books. These caused my shipment to be overweight but I had to pay $700 transportation even though these were essential for my work.

Through an unfortunate chain of events neither anyone from AID nor anyone from the project met me on my arrival either in Dar es Salaam or at Kilimanjaro International Airport.

Contractor

The Near East Foundation and Dr. Loewenstein have handled all matters expeditiously and with great attention to details. The relations have been extremely cordial and it has been a joy to be employed by such a fine organization and to work with such remarkable individuals.

Project Team

The men with whom I have been associated on the Masai Project are as fine a group as any with whom I have ever worked. It has been a privilage and a pleasure to have been associated with them.

After writing that I would like to point out one problem. The project documents define goals so nebulously that progress toward them is difficult to measure and

and even methods to aim the team towards the goals are unclear. I feel that if the team had been asked to do so, it could have hammered out goals that were realizable, practical, and toward which measurable progress could have been made. Furthermore, through team planning we could have forged interdisciplinary links to accomplish things as a team that would have transcended those that we have been able to accomplish as individuals.

Personal Evaluation

The results that I achieved during my two-year tour amaze me for they show that I have been singularly productive. Much of my time and effort went into developing methodology suited to the needs of Tanzania. Included in methodology was developing and writing of programs that enabled me to maximize my production and minimize the time needed for otherwise time-consuming calculations. One such program not mentioned elsewhere in this report converts water-analysis data from milligrams per liter (mg/l or ppm) to milliequivalents per liter (ME/L), totals the anions and cations, and calculates the content by percent for each of seven major constituents. This and similar programs made it possible to accomplish as much as I did.

The report that I have prepared on Kiteto District not only describes the hydrogeology but includes description of the methods used so that it will be easier for someone to pick up where I had to leave off due to time constraints.

Prior to my arrival, the work of my predecessor had been remarkably restricted. He was expected to make specific borehole site selections based solely on a field visit plus an electrical resistivity survey and be used as a driller the rest of his time.

The work I have done has broadened that perspective to include:

(1) compilation and analysis of existing hydrogeologic data,
(2) logging of borehole cuttings,
(3) electric logging of boreholes,
(4) making accurate pumping tests and analyzing the data,
(5) preparation of water-level contour maps,
(6) compilation and interpretation of chemical analyses of water, and
(7) writing of reports on project investigations.

Even though I have had no counterparts, no funds to support field investigations, and lacked equipment, I feel that my two years have been remarkable productive, enjoyable, and a proof that further hydrogeologic work can be fruitful in furthering the aims of the host country. Basic hydrogeologic work such as I have started can show where maximum numbers of people and stock can be watered at minimum cost. For a country with limited resources such a program can pay for itself by showing where water can be developed economically and by warning where drilling will be costly and/or unproductive.

RECOMMENDATIONS

Training

During my tour here I have regretted having no one to work with, either as a counterpart or as an employee. I tried ineffectually to get my assigned counterpart's training in the United States postponed so that he would have some practical field experience prior to starting college work in hydrogeology. I failed in that but I did succeed in making certain that he was shifted from Agricultural Engineering, in which he was enrolled, to hydrogeology for which he had been sent.

While working for AID in Libya I had been singularly successful in establishing a ground-water office, training about 14 people, providing equipment and office space, and in placing the unit within the Government so that it has continued to operate effectively, even after expatriate personnel have long been gone. My aim in coming to Tanzania was to make similar progress in establishing nydrogeological studies.

Here in Tanzania there is a dearth of trained personnel. The situation is so bad that counterparts are not available. Looking back, I wonder if it would have been possible to set up a cooperative program with the University of Dar es Salaam whereby a student would spend 3 months, 6 months or a year with the project and then return to school while another dropped out to work with

the project. This would provide students with the much needed feel for applying theory to problems in the field and for how field problems can be solved with the help of theory. For encouraging and supporting undergraduate training this arrangement might be far more productive than sending participants to the United States for undergraduate degrees. Also those who participate in such a cooperative program could be provided the incentive to do their best by assuring them that if they do well both academically and on the job, they will be considered for graduate work abroad.

Stateside Contacts

The U.S. Congress has put a ceiling on the number of employees that can be on the rolls of the Federal Government. This has made Federal Agencies reluctant to loan personnel to other Agencies. Also AID seems to be reluctant to utilize the expertise or backstopping that could be provided by agencies. In my case, I feel it would have been highly advantageous to have had some form of backstopping from the U.S. Geological Survey provided officially by USAID. Many of the problems could be solved much more efficiently if one could call upon the services of such an organization. When a professional is sent abroad he needs to be able to do those things which are most important. If he has to work as an individual unable to contact organizations with expertise

in his field he is forced to waste his time reinventing the wheel, that is redoing things which have been done before elsewhere. I have received some help from the Office of International Activities in the U.S. Geological Survey on a personal basis. I was told that because they received no support for backstopping that there was a limit to which they could help me.

If AID were to engage in any formal activities related to a master water plan for Arusha Region, it is imperative that some provisions be made that those working on the project be backstopped by the U.S. Geological Survey.

Well drilling is fequently an activity of AID programs and it always seems to engender problems. Perhaps a consultant should be brought into advise on how to set up an effective organization for drilling, equip it properly, and train personnle. A person who would be sufficiently knowledgable is Dr. Jay H. Lehr, executive secretary, National Water Well Association, 500 W. Wilson Bridge Rd, Suite 130, Columbus Ohio 43085. He is co-author of Water Well Technology, the only book to review all current drilling methods. I feel that he could give some pertinent advice to steer the drilling program towards more fruitful production. A few days here on TDY might be well worth the cost.

Equipment

Upon taking the post of hydrogeologist, I found equipment much of which was unusable. A Leupold and Stevens water-level recorder had been purchased without parts essential for its operation. It came with just one chart when many would be needed for any use at all. There was no beaded cable, no float, and no counter weight. Having the instrument without these items is like buying a car without any wheels.

A Belmont water-level recorder is a make that I have never seen used by U.S. Agencies and I feel it is a mistake to saddle a professional oversees with off-brand products that use up precious time learning how to make them operate. This particular one has an electric drive which does not function and which cannot be repaired locally.

A small size portable seismograph had been purchased to operate in tandem with a truck drawn thumper. This combination is analagous to using a sledge hammer to drive a tack.

My experience has been that it is false economy to order things from surplus property lists. Spares are not available and much proves to be nonstandard, unusable, or unrepairable.

Economics

The rate of borehole completion has been very slow, but one of the consolations has been knowing that the country could not afford a rapid rate. Each borehole now costs around 123,000/-, headworks costs another 136,000/-, and the cost of an operator and fuel about 5,000/- per year. If boreholes had been completed at the rate of one a week, well within the capability of the equipment, the GOT would have had to budget about 6,000,000/-. With funds appropriated of only 250,000/- one appreciates what a financial strain "success" would have caused!

Driller Training

Local drillers have never been exposed to efficient drilling operations. While in Libya I sent three drillers to the United States for training arranged by the U.S. Geological Survey with American drillers. They returned to Libya and became far more effective that they had been previously.

Transport

For a project to be successful in a country where distances are great and roads are wretched, adequate transport is essential. Supplying transport only for American personnel is not enough. To solve this problem requires some new approaches.

Funds for operating

Some funds from U.S. sources need to be available so American Personnel can work effectively. All too often things do not get done because the host country does not have the resources to finance the work that expatriate personnel are capable of performing.

Equipment for aquifer tests

One of the major sources of hydrogeologic data is good pumping tests The Masai Project has not had available the pump and the measuring equipment to maximize the data that could be collected.

Language Training

Any expatriate whose work requires him to travel alone around the country definitely needs training in Kiswahili. I have made safaris to visit remote sites where a borehole site needs to be picked. The person from whom I was to get information spoke only Kiswahili. The results of such a visit were greatly diminished because I could not communicate effectively. I feel that both the husband and wife should be required to have 2 or 3 months of language training upon arrival so that both can have maximum effectiveness during their tour.

Property Management

Better property management is needed. Upon receipt, of supplies and equipment the person who ordered or who

needs the item should be informed immediately (not 6 months later as I was). Adequate and safe storage space should be provided. Pilferage should be prevented, items should be issued formally so that responsibility and accountability can b checked. There should also be planning regarding the proper disposal of project equipment.

Sample Library for borehole cuttings

At Dodoma, cuttings from boreholes drilled over 40 years are stored awaiting study. Simultaneously with logging these, they need to be cut, filed in well marked envelopes, and stored in boxes. In other words a sample library needs to be organized and established in conjunction with logging of the cuttings.

SIGNIFICANT RESULTS

The Makami Depression in Kiteto District is an area where water is needed badly. Boreholes drilled in the depression encountered water twice as salty as ocean water. Because dug wells yield some fresh water, a mobile auger was sent to drill a hole to only a few tens of feet and a static level of 47 feet. This indicates that a lens of fesh water overlies the salt water and that with reasonable development it can be a valuable water supply for humans and stock.

At Ngwiso in Monduli District near the Tanzania-Kenya border town of Namanga, a borehole site was picked where ground-water flow is funneled through a valley cut through a range of bedrock hills. Three unproductive boreholes had been drilled previously but at the new site a good yielding borehole has been drilled. A pumping test gives a yield of 4500 gph with a draw-down of 2 feet. This indicates a specific capacity of 750 m^2 day^{-1}, 16 times greater than for any borehole previously tested in Monduli District.

Three attempts to drill a borehole at Ng'abolo in Kiteto District were unsuccessful. However, the data obtained, when used in conjuction with a water-level map that I had just prepared enabled me to site the fourth borehole in which water was struck.

A map showing water-level contours in Kitetc District enables depth to water to be estimated prior to drilling. Using it one can pick sites where water may be obtained and eliminate those where water may be too deep for drilling.