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HYDROGEOLOGICAL RECONNAISSANCE OF THE YELIMANE-TAMBACARA AREA WITH REFERENCE TO THE VILLAGE WELLS PROJECT

WASH FIELD REPORT NO. 32

FEBRUARY 1982

Prepared for:
USAID Mission to the Republic of Mali
Order of Technical Direction No. 64

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WASH

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February 10, 1982 T-64

Mr. David Wilson
Mission Director
USAID Mali
Bamako

Attn: Mr.Thomas Park

Dear Mr. Wilson:

On behalf of the WASH Project I am pleased to provide you with fifteen (15) copies of a report on Hydrogeological Reconnaissance of the Yelimane-Tambacara Area with Reference to the Village Wells Project.

This is the final report by George C. Taylor and is based on his trip to Mali from November 19 to December 3,1981.

This assistance is the result of a request by the Mission on June 16, 1981. The work was undertaken by the WASH Project on October 20, 1981 by means of Order of Technical Direction No. 64 authorized by the USAID Office of Health in Washington.

If you have any questions or comments regarding the findings or recommendations contained in this report we will be happy to discuss them.

Sincerely,

David Donaldson
Acting Director
WASH Project

DD:cdej

cc: Mr. Victor W.R. Wehman, JR.
S&T/HEA

WASH FIELD REPORT NO. 32

REPUBLIC OF MALI

HYDROGEOLOGICAL RECONNAISSANCE OF THE YELIMANE-TAMBACARA AREA WITH REFERENCE TO THE VILLAGE WELLS PROJECT

Prepared for USAID Mission to the Republic of Mali
under Order of Technical Direction No. 64

Prepared by

George C. Taylor, Jr.

February 1982

Water and Sanitation for Health Project
Contract No. AID/DSPE-C-0080, Project No. 931-1176
is sponsored by the Office of Health, Bureau for Science and Technology
U.S. Agency for International Development
Washington, DC 20523

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SUMMARY

This report presents the results of a hydrogeologic reconnaissance of the Yélimané-Tambacara area in the Kayes Region of northwestern Mali. The objectives of the reconnaissance were to evaluate the hydrogeologic feasibility of constructing new large-diameter open wells or of deepening existing wells at 24 villages in the area. These villages have agreed to provide about 50 percent of the cost of the work, with USAID providing the rest. All of these villages were visited by the writer, and appropriate observations were made in each with respect to the proposed construction. These observations and relevant recommendations for the siting of new wells are described in detail in Chapter 4 of this report. General hydrogeologic conditions in the area and criteria for groundwater development for village water supply are discussed in Chapters 2 and 3 respectively.

With the exception of two villages, it was possible to select convenient sites for large-diameter open wells which have reasonable expectation of dry season viability. It must be recognized, however, that the prevailing rock aquifers of the area will generally yield only about 2.2 to 12 m^3/d (cubic meters per day) to these wells in the wet season and in the early part of the dry season, but only about 50 percent of this amount toward the end of the dry season. Higher capacity boreholes yielding from one to as much as 12 m^3/h (cubic meters per hour) are obtained at a limited number of favored sites in the area. These boreholes must be very carefully sited on narrow fracture zones commonly associated with intrusive dolerite dikes. The siting process involves a judicious combination of photo-geological and electrical and magnetometrical geophysical studies combined with test drilling. Even with this array of sophisticated techniques the results are not always successful. In those villages located near the Kolinbiné and Terekolé River Valleys there are also promising prospects for siting large diameter wells in alluvial aquifers. These aquifers have a much higher degree of dry season viability than that of the rock aquifers. They can be expected to yield from about 5 to 20 m^3/d to large diameter wells in the wet season and early dry season, and somewhat less than this amount at the end of the dry season.

A large zone in the southeastern and east central part of the area is underlain by aquifers which yield only brackish or saline groundwater. Two villages are located in this zone. The alternatives for fresh water supply are: nearby surface-water catchments (which are not practicable or desirable), the importation of fresh water by donkey cart, or by pipe-line from more distant groundwater sources. These options are discussed in more detail in the report.

ACKNOWLEDGEMENTS

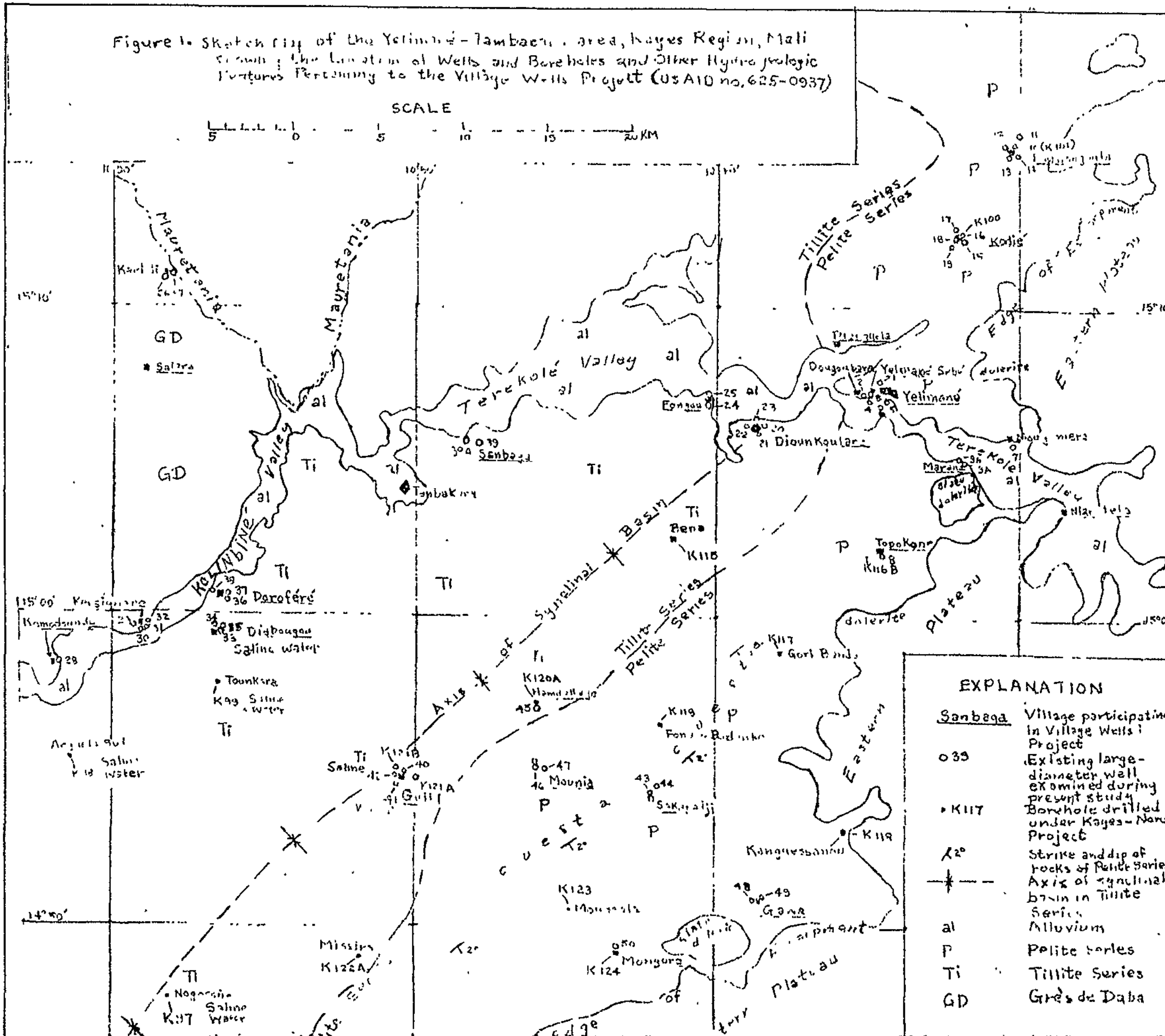
In carrying out this mission the writer received assistance from a number of individuals whose names are too numerous to mention here. The writer, however, does wish to acknowledge the assistance of Loel Callahan, Chief of Party of the Mali Rural Health Project; Thomas Park, Health Officer; and Lewis Lucke, USAID/Bamako, for their interest in the mission and provision of important logistic support. The writer benefitted greatly from technical discussions with Dominique Fougeirol of BURGEAP, Chief of the Kayes-Nord Project, and from the hydrogeologic data resulting from geophysical surveys and test drilling which he placed at the writer's disposal. Lastly and perhaps most importantly, the writer wishes to express his gratitude for all the help and support provided in the field by Roy Speed, Peace Corps volunteer working with the Mali Rural Health Project. Without his help the writer's field work could have been most difficult, but instead it proved to be most interesting and enjoyable.

GLOSSARY

The following terms are used throughout the text of this report. The French terms listed here and their English translations are specifically geologic in nature and/or are used because they are part of the local vocabulary and may be unique to the area:

ardoise	-	slate
argilite	-	argillite
buses	-	concrete rings used in well construction
dolomie	-	dolomite
en panne	-	"down," inoperational (with regard to pumps, motors or other equipment)
feuilletée	-	fissile
filon	-	dike
forage	-	borehole, tubewell or drilled well
galets	-	subangular pebbles
grès	-	sandstone
jaspe	-	jaspilite
margelle	-	headwalls of an open well
mare	-	small ephemeral lake along or near the channels of larger streams
marigot	-	stream channel which is seasonsally flooded
pelite	-	mudstone or pelite
puisard	-	temporary water hole in a stream channel
puits cimenté	-	open large-diameter well with concrete curbing
Série des pelites de Nara-Nioro	-	Pelite series of Nara-Nioro
Série des tillites	-	Tillite series
thalweg	-	buried valley

Figure 1. Sketch map of the Yelimané-Tambacara area, Kayes Region, Mali showing the location of Wells and Boreholes and Other Hydrogeologic Features Pertaining to the Village Wells Project (USAID no. 625-0937)



Chapter 1

INTRODUCTION

1.1 Scope and Purpose of Work

This report presents the results of a hydrogeologic reconnaissance of the Yélimané-Tambacara area during November 19 through December 3, 1981. In making this survey, on-site examinations of groundwater conditions were made in the vicinity of some 24 villages to assess the hydrogeologic feasibility of the proposed construction of some 21 new large-diameter open wells and of deepening eight existing wells. The field work combined hydrogeologic observations with water-level and depth measurements and water-taste tests of some 50 existing wells in or near the target villages. In addition, available data from the files of the National Directorate of Hydraulics and Energy on existing and abandoned boreholes* (forages) were examined in Bamako and checked in the field. Also, the results of recent (1980-81) geophysical surveys and exploratory drilling under the Kayes-Nord Project were discussed with the principals at Bamako, and field examinations were made of several of the drilling sites in the Yélimané-Tambacara area (BURGEAP, 1980 and CGG, 1980).

The present reconnaissance is a direct outgrowth of recommendations made in the Project Identification Document (PID) for the Yélimané-Tambacara Village Wells Project (USAID Project No. 625-0937), which is an adjunct to the Mali Rural Health Project (AID, 1981).

This document pointed out the need for improving the present precarious state of village water supplies in the project area as an essential base for continuing efforts in health and community development and in improving conditions of village hygiene. The writer on contract to USAID's Water and Sanitation for Health (WASH) Project was assigned to assist in carrying out these recommendations under Order of Technical Direction No. 64 (see Appendix A).

1.2 Location

The Yélimané-Tambacara area is located between 14°45' and 15°20' north latitude and 10°20' and 11°03' west of the Greenwich meridian (Figure 1). This area lies in parts of the Tambacara and Central Arrondissements of the Yélimané Circle, Kayes Region in the remote northwestern corner of Mali. Map coverage of the area includes parts of the Kayes, Yélimané and Sandaré sheets, (scale 1:200,000) of the Carte de l'Afrique de l'Ouest published by the Institut Géographique National,

* Also known as "tubewells" or "drilled wells."

Paris. Through courtesy of the USAID/TAMS Project (Inventaire de Ressources Terrestres [PIRT]), false-color, remote-sensing imagery (scale 1:200,000) was also made available to the writer for use in field work.

1.3 Topography and Drainage

Most of the Yélimané-Tambacara area consists of low-erosional plains truncating the flat-lying to gently-dipping consolidated sedimentary rocks indigenous to the region. Local topographic relief is low -- generally no more than about 10 to 15 m, with elevations ranging from about 60 to 100 m above msl (mean sea level). A low, northeast trending ridge with elevations rising from 150 to 250 m above msl interrupts the continuity of the plains in the south-central part of the area. The eastern margin of the area is marked by the broken escarpment (falaise) of a high eastern plateau, whose summits rise from 380 to 475 m above msl and from 250 to 350 m above the low erosional plains to the west.

The entire Yélimané-Tambacara area is drained by the Kolinbiné River and its principal tributary, the Terekolé River. The Kolinbiné is in turn tributary to the Senegal River which it joins near Kayes. Both the Kolinbiné and the Terekolé flow through anastomosing systems of braided channels in shallow alluvial valleys which range from about 2 to 5 km wide and lie about 10 to 15 m below the adjacent surfaces of the erosional plains. Most of the lower lying parts of the Kolinbiné and Terekolé valleys are intermittently flooded during the rainy season as are the valleys of their larger tributaries.

1.4 Rainfall and Runoff

The climate of the Yélimané-Tambacara area is typical of the Sudano-Sahelian belt of West Africa. Virtually all the annual rainfall occurs during a brief rainy season lasting from July through September and occasionally extending into October. The remaining 8 to 9 months of the year constitute the long dry season during which there is very little or no rainfall. The average annual rainfall over the long-term has been about 600 mm; but because of recurring dry years during the past 10 years, the area has recently received only about 400 mm annually.

The rains generally come in brief intense storms during which the runoff from small upstream watersheds builds up rapidly and frequently overtops the "marigots" (flooded banks of stream channels) and floods the adjacent low-lying valley bottoms. When a conjunction of small storms or a large regional storm occurs, there is widespread flooding in the downstream alluvial valleys of the Kolinbiné and Terekolé rivers. The surface-flows from all the streams of the area generally cease

within a few weeks after the beginning of the dry season, but groundwater stored in the alluvial deposits of the larger valleys continues discharging into the sandy fill of the larger stream channels for several months more into the dry season. It is this inflow which sustains the "mares" (ponds and small lakes) along and near the channels of the larger streams.

Chapter 2

HYDROGEOLOGICAL CONDITIONS

2.1 General Statement

The following description of the general geologic setting of the Yélimané-Tambacara area is based on (1) the writer's review of the results of recent geophysical surveys and test drilling in the area under the Kayes-Nord Project (BURGEAP, 1980), together with technical discussions with project principals and (2) the writer's own field work.

2.2 Grès du Beredji Koukou (GB)

According to the hydrogeologic sketch map (scale 1:500,000) included in BURGEAP* (1980), the oldest rock formation in the area is the Grès du Beredji Koukou (GB) of Infracambrian age. These rocks consist largely of hard, fine-grained sandstone (grès) interbedded with thin layers of compact argillites (argilite). They do not crop out at the land surface but are present at depths of 65 to more than 125 m beneath rocks of the Tillite Series of the Nogossire-Guifi-Béna synclinal basin (BURGEAP, 1980). Test drilling thus far completed indicates that the GB rocks have little or no potential importance as aquifers for the village wells project.

2.3 Grès de Daba (GD)

Of somewhat younger Infracambrian age are the rocks of the Grès de Daba (GD) formation which crop out extensively to the west and northwest of the Kolinbiné River and directly underlie the environs of Komodounde, Kersignane, Salara, and Kardidi, which will participate in the village wells project. In surface outcrops and shallow open wells, the GD formation is predominantly hard, fine-grained sandstone of gray to buff and reddish-brown color. The sandstone is generally thin-bedded with some intercalations of shaly sandstone (grès argileux). No exploratory drilling has yet been done in these rocks near any of these villages. However, the shallow groundwater is generally of good chemical quality. Individual open wells (puits cimentés) in the rocks can be expected to yield from about 2.5 to 12 m^3/d at the end of the wet season and about 50 percent less towards the end of the dry season.

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* Bureau de la Geologic Appliqué

2.4 Tillite Series (Ti)

The erosional plains in the central and west-central parts of the Yélimané-Tambacara area are directly underlain by a group of rocks known as the Tillite Series (Série des tillites) of Cambrian age which, in turn, rest on rocks presumed to be the Infracambrian GB formation, described above. The Tillite Series lies in a northeast trending belt some 20 km wide directly underlying the villges of Doroféré, Diabougou, Guifi, and Hamdallaye. The Tillite Series is further subdivided into an upper tillite member and a lower argillite (argilite) member. Extensive test drilling in the Kayes-Nord Project has produced evidence that the rocks of Tillite Series lie in an elongated synclinal basin trending northeast and having an axis extending from Nogossire to Guifi to Béna and as far northeast as Dionkoulane. The upper tillite member, considered to be an ancient glacial deposit, is composed of a heterogeneous mixture of angular to subangular pebbles (galets) of different kinds of rock ranging from a few centimeters to several decimeters in diameter. These pebbles are randomly scattered through a more or less compact clay-to-sandy matrix.

The lower argillite member includes indurated, gray-to-black fissile (feuilletées) argillites with some intercalated sandstone beds ranging up to several meters thick.

Thirteen (13) boreholes have been drilled into the tillite member in or near the area. Of these only four produced yields of 1 m^3/h or more. Water-bearing zones were encountered at depths ranging from 14 to 97 m in six of the boreholes with yields ranging from 0.2 to 4 m^3/h, and exceptionally, 21.6 m^3/h in one borehole. The high yield from this borehole was obtained in a fracture, pointing up the need for and importance of geophysics in proper siting of larger yield boreholes. All the open wells in the vicinity of Doroféré draw water from the tillite member, which is of good-to-mediocre chemical quality. The individual yields of the wells are low -- probably in the range of 2.2 to 7.0 m^3/d at the end of the wet season and declining to about 50 percent of this range at the end of the dry season.

Nine (9) boreholes have been drilled into the argillite member, of which three produced yields of 1 m^3/h or greater. Water-bearing zones were encountered at depths ranging from 20 to 124 m in eight boreholes. Among these boreholes five had yields of less than 0.4 m^3/h (equivalent to 9.6 m^3/d), and three produced yields ranging from 1 to 5 m^3/h. Among the three productive boreholes, two had water-bearing zones in the argillite member itself; and the third was found to be in contact with the underlying sandstone substratum (presumably the GB formation). The open wells of Diabougou, Guifi, and Hamdallaye, which tap shallow groundwater in the argillite member, all have yield characteristics similar to those of the tillite member. At Diabougou the rocks of the argillite member en-

countered in shallow wells contain gypsum and perhaps also other soluble evaporites. Similar conditions are suspected at Guifi (boreholes K 121 A and B), Tounkara (K 99), Arguela Sud (K 98), and Nogossire (K 97) where both the shallow and deep groundwater is of poor, virtually unusable chemical quality. All these localities lie in the synclinal basin of the Tillite Series. On the other hand, at Doroféré on the western margin of this basin and at Hamdallaye on the eastern margin of the basin, the shallow groundwater in the argillite member is of good to mediocre (but usable) chemical quality.

2.5 Pelite Series of Nara-Nioro (P)

The plains in the eastern part of the Yélimané-Tambacara area and the re-entrants in the eastern escarpment (falaise) are directly underlain by a group of rocks known as the Pelite Series of Nara-Nioro (Série des pelites de Nara-Nioro) of Cambrian age. Rocks of the Pelite Series, in turn, rest on the Tillite Series which have been previously described. In surface exposures, slates (ardoises) appear to be the predominant rock type, but mudstones (pelites) and argillites are also abundant in borehole sections. Dolomites (dolomies), sandstones, and quartzites are also present in borehole sections but do not crop out commonly at the land surface. A prominent layer of hard brittle jaspilite 5 to 15 m thick occurs in the lower part of the Pelite Series. This layer forms a conspicuous, low cuesta ridge in the south central part of the area. It strikes approximately northeast and dips about 1° to 2° to the southeast. Rocks of the Pelite Series directly underlie the villages of Bandiougoula, Kodié, Marana, Niartela, Diabguela, Yélimané, Yélimané Sébé, Dougoubara, Topokone, Sakaradji, Mounia, Gawa and Mongoro.

Fifteen (15) boreholes have been drilled by the Kayes-Nord Project in rocks of the Pelite Series of the Yélimané-Tambacara area. Of these, eight were test boreholes less than 28 m deep in the vicinity of Gori Banda (K 117), and two were boreholes redrilled at positive sites discovered by BRGM* in 1974. Among the 15 boreholes, five successfully yielded from 3.3 to 12 m^3/h of water. The best yields were obtained from layers of jaspilite (jaspe), where they are brittle and fractured and lie below the water table. In this regard, borehole K 123 B near Moussala, produced 8.6 m^3/h of water from jaspilite at the depth of 29.0 m. Another borehole, K 123 A, in the same vicinity and 55.9 m deep, produced only 0.9 m^3/h from a water-bearing zone in mudstones at a depth of 38.0 m. Except for the jaspilites, the best yields from boreholes in the Pelite Series are obtained in fracture zones associated with dolerite dikes (filons). Yields from boreholes located away from such

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* Bureau de Recherches Geologiques et Minières

fractures are generally quite small, that is, of the order of 0.1 to 0.3 m^3/h or less. The chemical quality of the deep groundwater in the rocks of the Pelite Series has generally been found to be good to excellent. The open wells which tap shallow groundwater in rocks of the Pelite Series has generally been found to be good to excellent. The open wells which tap shallow groundwater in rocks of the Pelite Series generally produce yields in the magnitude of 2.4 to 7.2 m^3/d at the beginning of the dry season and about 50 percent or less by the end of the dry season. The chemical quality of water from such open wells is also generally good to excellent.

2.6 Dolerite

Dolerite, of presumed Permian age, and existing in both extrusive and intrusive phases, is associated chiefly with rocks of the Pelite Series. Extensive flat-lying layers of dolerite, (presumably lava flows), but also possibly sills, cap the high, dissected plateau to the east of the Yélimané-Tambacara area. These layers of hard dense dolerite form vertical cliffs extending from as much as 50 to 100 m high and resting on softer, slope-forming sedimentary rocks -- chiefly slates, mudstones and argillites of the Pelite Series. Also small dolerite plugs and/or dikes are found cross-cutting rocks of the Pelite Series at several localities in surface outcrops in the eastern part of the area. Dolerite, intrusive into rocks of the Pelite Series, has also been encountered in open wells at Bandiougoula and Sakaradji. The dikes were commonly intruded along existing fracture lines in the country rock, thereby inducing further fracturing and comminution of the adjacent rock. These zones of fracturing have a much higher permeability and capacity for storing and yielding water to boreholes than do the adjacent unfractured country rock. It is for this reason that much time and effort are expended in pinpointing drilling sites through geophysical surveys, so that boreholes can be drilled which will yield 1 m^3/h or more. Dolerite, however, is virtually impervious. When dolerite is encountered in drilling a borehole or excavating a well, it is generally considered advisable to abandon the site and move to a new position.

2.7 Alluvium

The alluvial valleys of the Kolimbiné and Terekolé Rivers are underlain by unconsolidated deposits of sand and silt with some gravel of Quaternary age. Extensive surficial clays are also present in some intermittently flooded areas. Alluvial deposits also underlie some of the bench lands adjacent to the river valleys. Where they are sufficiently thick and permeable, the alluvial deposits are the best potential sources of village water supply among all of the rock groups of the Yélimané-Tambacara area. Villages favorably situated to tap

groundwater in alluvial deposits are Marana, Yélimané, Yélimané Sebe, Dougoubara, Diabguela, Dionkoulane, Tongou, Sanbaga and Doroféré and Kersignané. However, in most cases the headwalls (margelles) of such wells would have to be raised a meter or two above the natural land surface to provide protection of the well sites against intermittent flooding during the rainy season. Such wells, however, would be much more reliable sources of water during the dry season than wells drawing water from the older rocks of the area. Where properly sited such open wells tapping 5 m or more of saturated sandy alluvium could normally be expected to yield up to 20 to 25 m^3/d and about half this in the dry season. The groundwater in the alluvium is generally of good to excellent chemical quality.

Virtually no test drilling has yet been done in the alluvial valleys in connection with the Kayes-Nord Project. However, a few boreholes have been drilled in the Terekolé River valley near Yélimané and also at Niougomera about 9 km to the east. Well No. 7 (DNHE S17) drilled by BRGM in 1974 reached a depth of 50 m. Located about 200 m southwest of Niougomera. The borehole encountered sand and sandy clay throughout its full depth, without encountering hard rocks. The well is screened from about 16 to 32 m, yields 10.3 m^3/h, and has a 3.1 m drawdown from a static level of 7.1 m. The borehole is equipped with a submersible pump set in 6-inch PVC casing with a powerline running to an electric generator in the village. The pump is broken down at this time. When operational, the pump lifts water to a distribution tower in the village. One hour of pumping per day is sufficient to provide for the 24-hour requirements of the village. The water quality is excellent with only 592 mg/l (milligrams per liter) of total dissolved solids. This borehole was apparently drilled into an ancient "thalweg" (buried valley) of the Terekolé River.

Just south of Yélimané, the BRGM in 1974 drilled another borehole (well No. 6, DNHE S14) to a depth of 50.5 m in the Terekolé River valley. This borehole yields 10.4 m^3/h with a 4.5 m drawdown, from a static level of 11.8 m, and is screened from between 19.5 to 31.5 m. The borehole is equipped with a submersible pump set in a 6-inch PVC casing and powered with an electric generator. The water is pumped to a water tower in Yélimané for distribution. The pump was repaired in May 1981 but is now broken down again. The water is of excellent chemical quality with only 296 mg/l of total dissolved solids. No log is available for well No. 6, but it is possible that it taps alluvium in a buried valley similar to well No. 6 near Niougomera.

In view of the evidence provided by wells Nos. 6 and 7 the writer suggests that a few geophysical traverses across the valleys of the Kolinbiné and Terekolé Rivers would be worthwhile to determine whether or not a continuous thalweg exists in these valleys. If the geophysical survey indicates good

prospects, favorable sites could be test drilled for verification. The yields from boreholes drilled in the thick alluvial deposits of a thalweg can be expected to be much greater than from the thin alluvium that underlies these valleys elsewhere.

Chapter 3

CRITERIA FOR GROUNDWATER DEVELOPMENT FOR VILLAGE WATER SUPPLY

3.1 Open Large-Diameter Wells versus Small Diameter Boreholes with Handpumps

There are both advantages and disadvantages to the use of large-diameter open wells versus the use of small diameter boreholes with handpumps. These are compared in the following summary:

Open Large-Diameter Well	Borehole with Hand Pump
1. The well does not require a pump for lifting water.	1. The borehole requires a hand pump for lifting water.
2. No pump maintenance is required.	2. The pump requires periodic maintenance at a recurring annual cost of about 10-15 percent of its original purchase price.
3. No pump maintenance and replacement infrastructure are required.	3. Pump maintenance and infrastructure replacement are required.
4. The well is vulnerable to pollution.	4. It is sanitarily protectable.
5. Four to six users can draw water simultaneously.	5. Only one water user can pump water at a time.
6. It has available a large volume for the accumulation and storage of water from a weak aquifer.	6. It has only a storage volume, and therefore it has to be sustained by a relatively strong aquifer.
7. The capital investment for one 25 m well complete with surface accessories is about $12,000.	7. The capital investment for one successful borehole 50 m deep plus hand pump is about $18,000.
8. The well is vulnerable to long dry periods or droughts.	8. The borehole is relatively less vulnerable to long dry periods or droughts.

In weighing the above factors, and taking into consideration the relatively weak infrastructure and remoteness of the Yélimané-Tambacara area, as well as the proposed financial participation of the villagers in the construction effort, it has been decided that the best choice for the village water supply at present is the large-diameter open well.

3.2 Water Use Requirements

It must be recognized that the water consumption of villagers is virtually inseparable from that of their animals. A combined figure of 60 l/d (liters per day) is generally accepted in Sahelian West Africa as the total unit requirement. Of this amount about 20 l/d is the human per capita use and the rest is for animals. Normally, the use of water from wells for watering livestock is minimal in the wet season and the early part of the dry season, when livestock obtain their water requirements from the residual surface water in the ponds and mares of the marigots. When these sources begin to disappear during the course of the long dry season, increasing demands are made on village wells for livestock watering, especially when itinerant herds are passing through the area on the way to market or to find better grazing lands.

However, this pattern of water use from wells is contrary to the natural availability of water from wells. Groundwater availability is greatest during the rainy season and the early part of the dry season. Toward the end of the dry season natural groundwater availability has declined to about 50% of that of the rainy season. It is because of this pattern of water use that many village wells become overstressed, dry, and temporarily fail at this time. Many larger villages simply do not have enough wells to provide for the increased water demands that prevail. One needs to take into account the fact that existing large-diameter open wells tapping weak aquifers of the area are capable of sustained yields in the range of 2.2 to 12.0 m^3/d in the rainy season and early dry season, but only about 1.1 to 6.0 m^3/d toward the end of the dry season. If the means of these extremes are taken as 7.1 and 3.5 m^3/d, respectively, and the maximum water demand 60 l/c/d, (liters per capita per day) it can be seen that the average well would theoretically be capable of serving a maximum of about 118 persons under favorable conditions, but only 58 persons plus animals under the stressed conditions at the end of the dry season. Thus a village of 580 inhabitants would theoretically need 10 wells to meet its full dry season requirments. In reality no village in the area enjoys this luxury, as water supplies from wells are generally supplemented by water taken from "puisards" (temporary water holes) excavated in the sandy channels of marigots during the dry season.

3.3 Well Deepening versus Construction of New Wells

To alleviate the problem of the reduced yield of an open well toward the end of the dry season, it is commonly believed that the yield of the well will be increased by deepening the well. Although it is possible that by deepening a well there is always the chance of intersecting a second and deeper water-bearing zone and thereby augmenting the yield of the first and uppermost water-bearing zone found in the well, in practice, however, deepening seldom pays off in increased yield. Nevertheless, it must be recognized that increased capacity is obtained for the accumulation of the limited groundwater inflows that occur during the dry season from the weak aquifers of the area. In a 1.6 m diameter open well, for example, there is some 2.0 m^3 (2,000 l) of storage for each linear meter below the water table. When one considers that the cost of one linear meter of a modern open well is about $439, the cost for storage capacity is expensive.

From the standpoint of groundwater hydraulics it would generally be better practice to construct a new well in the general vicinity of an existing well rather than to attempt deepening the latter in hopes of increasing the yield. If the new well is placed a sufficient distance away (about 50 m or more) from an existing well, the yield of the latter would be virtually unaffected by withdrawals from the former, particularly when considering the very low transmissivities of the rock aquifers. Also the stress on an existing well would be relieved as water users would have an additional water point available.

3.4 Well Siting

The criteria for selecting the site for a large-diameter open well are much less exacting than those for a successful borehole, that is, one yielding 1 m^3/h or greater. The sites for most existing wells can be said to be randomly selected, although the common sense views of the village elders have generally prevailed. It is generally observed that wells located near the marigots or their floodways have more stable yields than those located some distance away. This comes about because those wells located near the marigots benefit from the concentrated recharge to the aquifer provided by rainy season floods. More distant wells tap aquifers which are recharged much less intensely and frequently by the infiltration of rain from occasional regional storms. It is for this reason that the best sites for open wells are generally as near as possible to the floodways or to the seasonally flooded areas.

Chapter 4

GENERAL CONCLUSIONS AND RECOMMENDATIONS*

Where nearby large capacity boreholes are available, as at Yélimané (well No.. 6), Bandiougoula (K 101), and Niougomera (well No. 7), increasing efforts need to be made to establish the necessary operation and maintenance capability at the local level in order to keep the installed pumps, motors, and generators functioning effectively. Currently, these installations are down ("en panne") at least 75% of the time. Although borehole (K 101) at Bandiougoula is not yet equipped, those at Niougomera (well No. 7) and Yélimané (well No. 6) have sufficient capacity to serve quite adequately the entire population within a 5-km radius. Admittedly, piped distribution systems would be needed, but elevated storage tanks are already available. Recently, a borehole has been drilled at Tambacara which has the capacity to serve the entire village when it is equipped. Central to the successful use of large-capacity boreholes is a minimal capability for the operation and maintenance of installed equipment, as well as for the provision of essential lubricants and fuel.

The low-capacity open wells proposed for construction under the present project will ameliorate, but not eliminate, dry-season water shortages. The most beneficial effects will be felt in those villages having less than 500 inhabitants, with progressively less beneficial effects being felt in the larger villages. Realistically, villages with more than 2,000 inhabitants should seek to develop their own central water systems if adequate water sources can be found at a reasonable distance. Dionkoulane (population 3,820), for example, should seek to develop its water supply from large capacity boreholes located in the Terekolé Valley to the north of the village.

Villages located along the edges of the Terekolé and Kolinbiné Valleys should consider construction of protected wells in the thicker, alluvial deposits of the valleys, that is, where there is about 5 m or more of saturated alluvium below the dry-season position of the water table. The basic problem is intermittent flooding during the rainy season. For this reason, protection of the well by elevating the well headwalls some 1 to 2 m above natural ground level would be required. In addition the provision of a sloping mound around the well and an armored carapace of slate slabs in mortar set on the slopes of the mound should be added. Admittedly, this would add to the basic cost of the well. At the same time, the dry-season viability of such a well would be considerably enhanced compared to that of the rock wells constructed on the bench lands

* Brief detailed descriptions and recommendations for each site studied are presented in Appendix D, pp. 25-38.

adjacent to the valleys. Opportunities for such a type of well would seem to exist near Diabougou, Doroféré, Sanbaga, Tangou, Dionkoulane, Dougoubara, Yélimané Sébé, Yélimané, Marana, and Niaratela.

There is a large zone in the southeastern and east-central part of the Yélimané-Tambacara area where the rocks of the Tillite Series contain brackish or saline groundwater, at depths ranging from near the land surface to 99 m below the surface. Locally, as at Diabougou and Guifi, small fresh-water zones apparently overlie the saline water; but these are not viable through the dry season. At Diabougou the best solution is to seek fresh ground water in the alluvial deposits of the Kolinbiné Valley to the north-northwest of the village. At Guifi the situation is more difficult; but the nearest potentially viable source of fresh groundwater would appear to be near Waloguela, east-northeast of Guifi.

The writer also concludes that there is a good possibility for the existence of a relatively deep, alluvium-filled thalweg beneath the Terekolé and Kolinbiné Valleys. In this regard the writer suggests that three or four electrical resistivity lines be run across these valleys, perhaps at natural constrictions to determine whether or not there is good evidence for the existence of such a thalweg. If these electrical resistivity surveys prove favorable, the promising sites can be test drilled for verification. It may be possible for this work to be undertaken as part of the Kayes-Nord Project.

REFERENCES

Agency for International Development, Yélimané-Tambacara Village Wells Project (USAID Project No. 625-0937, Project Identification Document, Washington, DC, 1981.

FAO/PNUD Project MALI 71/753, Amélioration de la Production et de la Commercialisation du Bétail et de la Viande, Etudes des Ressources en Eau des Zones Pastorales de Kayes-Nord, Office Malien du Bétail et de la Viande (OMBEVI), Ministère de la Production, Bamako, Mali, 1975.

Compagnie Générale de Géophysique (CGG), Projet de Développement de l'Elevage au Sahel Occidental, Reconnaissance Hydrogéologique par Prospection Géophysique, Office Malien du Bétail et de la Viande (OMBEVI), Ministère de la Production, Bamako, Mali, 1980.

BURGEAP, Projet d'Appui aux Operations de Développement de l'Elevage dans le Sahel Occidental - Volet Hydraulique (Financé par le Fonds d'Aide et de Cooperation), Rapport Final de Campagne 1980/81, Direction National de l'Elevage, Ministère de l'Elévage et des Eaux et Forêts, Bamako, Mali, 1980.

APPENDIX A

MEMORANDUM

October 20, 1981

Camp, Dresser & McKee, Inc.
WASH PROJECT
OCT 23 1981

WATER AND SANITATION FOR HEALTH (WASH) PROJECT
ORDER OF TECHNICAL DIRECTION (OTD) NUMBER 64

TO: Dr. Dennis Warner, Ph.D., P.E.
WASH Project Director

FROM: Mr. Victor W.R. Wehman, Jr., P.E., R.S.
AID WASH Project Manager

SUBJECT: Provision of Technical Assistance Under WASH Project Scope of Work for USAID/Mali

REFS:
A) BAMAKO 6234
B) STATE 261645
C) BAMAKO 03600
D) STATE 107022

1. WASH contractor requested to provide technical assistance to USAID/Mali as per REF. C, para. 1-4, scope of work. One hydrogeologist consultant, French fluency with expertise in Mali or in the Sahal preferred, if possible.

2. WASH contractor/sub-contractor/consultants authorized to expend up to fifty (50) person days effort over a three (3) month period to accomplish this technical assistance effort.

3. Contractor to coordinate directly with USAID/Mali (Lewis Lunce or Thomas Park), AID/Mali desk officer, AFR/DR/ENGR (Mr. J. Snead) and AFR/DR/HN (Dr. Shepperd or his representative). Contractor should keep above individuals appraised of ETA's and project progress as appropriate. Ensure individuals above receive copies of this OTD.

4. Forty-four (44) person days of international and domestic per diem is hereby authorized.

5. One (1) round trip from consultant's home base to Washington, D.C. (for briefing) to Bamako, Mali and return through Washington (for debriefing) to consultant's home base is authorized.

6. Local in-country travel is authorized as necessary to accomplish scope of work. If necessary, consultants authorized rental of local vehicles and conveyances, rental of local personal services (liaison, interpreter, typing, etc.) as necessary NTE $2,500 without approval and authorization by AID Project Manager.

7. Seven day work week is authorized if mission verifies 7 day work week necessary, certified by consultant and Project Director upon consultant return to WASH for debriefing.

8. WASH consultant requested to take 35 mm camera and film to take representative group of 35 mm slides to adequately portray environmental health situation in Mali for purposes of debriefing and educating other WASH CIC and consultant staffs.

9. Mission and consultant should be contacted immediately and technical assistance initiated as soon as possible or convenient to USAID/Mali. WASH CIC should ensure backstopping of consultants.

10. Appreciate your prompt attention to this matter. Good Luck!

ACTION COPY

Department of State

INCOMING TELEGRAM

PAGE 01 BAMAKO 06234 071051Z 7848 001387 AID6959

ACTION AID-35

ACTION OFFICE STHE-01

INFO AFFW-04 AFDR-06 AAST-01 ENGR-02 AFDA-01 RELO-01 MAST-01
AGEE-01 /018 A4 707

INFO OCT-01 /036 W

---115300 071338Z /46

R 061430Z OCT 81
FM AMEMBASSY BAMAKO
TO SECSTATE WASHDC 4218

UNCLAS BAMAKO 6234

AIDAC

EO 12065. N/A
SUBJ: HYDROGEOLOGIST CONSULTANT

REF: STATE 261645

MISSION STILL PLANNING FOR WASH VISIT MCD. NOVEMBER WITH SAME SCOPE OF WORK.
BORG

30 Sept 81

UNCLASSIFIED

Department of State

OUTGOING TELEGRAM

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APPROVED BY AID/ST/HEA:CPEASE
AID/AFR/SWA: LWERLIN (PHONE)
AID/AFR/SFA: HGRAY (PHONE)
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R 300552Z SEP 81
FM SECSTATE WASHDC
TO AMEMBASSY BAMAKO

UNCLAS STATE 261645

ADM AID (PASS TO: RURAL DEVELOPMENT OFFICER)

E.O. 12065: N/A

TAGS:

SUBJECT: HYDROGEOLOGIST CONSULTANT

REF. 03600 BAMAKO

1. HAVE IDENTIFIED POTENTIAL WASH CANDIDATES FOR HYDROGEOLOGIST POSITION STILL PLANNING FOR NOVEMBER 16 START DATE.

2. IS SCOPE OF WORK STILL THE SAME AS IN REFTEL?

3. HYDROGEOLOGIST MAY NEED TO COORDINATE EFFORTS WITH PERSON OR PERSONS RESPONSIBLE FOR WORKING WITH VILLAGE LEADERS OR WATER COMMITTEES EITHER FROM MISSION OR HOST GOVERNMENT.

4. AWAIT YOUR RESPONSE. THANK YOU. CLARK

Received ST/HEA (Wehman) 9/30/81

Passed to WASH 10/2/81

UNCLASSIFIED

ACTION COPY 16 June 81

UNCLASSIFIED

Department of State

INCOMING TELEGRAM

PAGE 01 BAMAKO 03600 161129Z 9754 028752 AID4110
ACTION AID-35

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INFO AAAF-01 AFSA-03 AFFW-04 STA-10 AADS-01 DSHE-01 CH8-01
AFDA-01 RELO-01 MAST-01 /030 A4 816

INFO OCT-01 /036 W
025524 161129Z /34

P 160900Z JUN 81
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TO SECSTATE WAHSDC PRIORITY 2907

UNCLAS BAMAKO 3600

AIDAC

FOR AFR/DR/SWAP SIMMONS; DS/HEA/EH

E.O. 12065: N/A
SUBJ. WATER AND SANITATION FOR HEALTH PROJECT (WASH) CONSULTANCY REQUEST FOR MALI

REF: WASH PAMPHLET

1. PROBLEM: USAID/MALI REQUESTS THE TDY SERVICES OF A WASH CONSULTANT GEOLOGIST WHO WILL MAKE RECOMMENDATIONS ON THE SITING OF APPROXIMATELY 25 WELLS PLANNED FOR JOINT FINANCING BY MALIAN VILLAGERS AND AID IN THE FIRST REGION OF MALI UNDER THE PROPOSED YELIMANE/TAMBACARA VILLAGE WELLHSA.I.P. (625-0937). SUBJECT A.I.P. IS CURRENTLY UNDERGOING PREPARATION OF PID AND REPLY AS TO CONSULTANT AVAILABILITY WILL ESPEDITE PID COMPLETION.

2. SCOPE OF SERVICES REQUIRED: CONSULTANT SHOULD BE A QUALIFIED GEOLOGIST WITH EXPERIENCE IN SITING OF HAND-DUG WELLS USING AERIAL PHOTOGRAPHY, SOIL RESTIVITY TESTS AND SOME INVESTIGATIVE DRILLING. DURATION OF PROPOSED DUTIES SHOULD BE APPROXIMATELY FIVE WEEKS TENTATIVELY BROKEN UP AS FOLLOWS: REVIEW OF AERIAL PHOTOGRAPHS IN BAMAKO (ONE WEEK); INVESTIGATIVE PRELIMINARY CONSULTATIONS WITH GRM HYDRAULICS OFFICE !;9,3 233 0; CONSULTATIONS WITH REGIONAL GRM WELL-DIGGING AUTHORITIES AT REGIONAL CAPITAL OF KAYES (THREE DAYS); VISITS TO WELL SITES (TWO WEEKS); CONSULTATIONS WITH LOCAL WATER COMMITTEE IN YELIMANE (THREE DAYS). CONSULTANT SHOULD IDEALLY HAVE PRIOR SAHELIAN EXPERIENCE. FSI RATING OF 3 IN FRENCH IS HIGHLY DESIRABLE.

3. COORDINATING ORGANIZATION/CONTACT PERSONS: USAID/BAMAKO; LEWIS ~~LUNCE~~, DEO, THOMAS PARK, GDO/HLS.
~~LUCE~~ LUCKE
4. TIMING: IDEAL CONSULTANT ARRIVAL SHOULD BE NOVEMBER 16 THROUGH DECEMBER 18, 1981.

5. PLEASE ADVISE CONSULTANT AVAILABILITY.
WAUCHOPE

Craig Haffner
WASH Project
pick-up.

UNCLASSIFIED

MALI

25 Apr 81

UNCLASSIFIED

Department of State

OUTGOING TELEGRAM

PAGE 01 STATE 107022 8402 064682 AID2040
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INFO OCT-00 AS-01 /036 R

DRAFTED BY AID/AFR/DR/SWAP: RJSIMMONS: EDB
APPROVED BY AID/AFR/DR: NCOHEN
AID/AFR/DR/SWAP: JRMCCABE
AID/AFR/DR/ENGR: ATUMMARELLO (INFO)
DS/H: JALDEN (INFO)
AID/AFR/SWA: LWERLIN (PHONE)

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FM SECSTATE WASHDC
TO AMEMBASSY BAMAKO

UNCLAS STATE 107022

AIDAC: BOB SHOEMAKER AND TOM PARK

E.O. 12065: N/A

TAGS:
SUBJECT: MALI WATER ANDSANITATION FOR HEALTH PROJECTS

1. AID/W PROJECT OFFICER WAS RECENTLY VISITED BY DR RAY ISELY AND MR. CRAIG HAFFNER OF WATER AND SANITATION FOR HEALTH PROJECT, 1611 NORTH KENT STREET, ROOM 1002, ARLINGTON, VIRGINIA 22209. TELEPHONE NUMBER 703-243-8200, TELEX NO. WUI64552, CABLE ADDRESS, WASHAID. AS YOU PROBABLY AWARE, DS/HEALTH FUNDS THIS ACTIVITY.

2. THE QUOTE WASH END QUOTE PROJECT APPARENTLY CAN PROVIDE TECHNICAL ASSISTANCE AT THEIR EXPENSE TO SUPPORT THE DESIGN, IMPLEMENTATION AND EVALUATION OF WORK IN THE FIELD. IF MISSION CONTEMPLATES WELLS PROJECTS OR COMPONENTS OF OTHER PROJECTS IN THIS FIELD, THE WASH ORGANIZATION APPEARS TO BE APPROPRIATE SOURCE OF SUPPORT. THIS INFORMATION IS SENT IN LIGHT OF SOME DISCUSSIONS IN DECEMBER OF 1980 RELATING TO RURAL WATER SUPPLIES EFFORTS. HAIG

Camp, Dresser & McKee, Inc.
WASH PROJECT

MAY 5 1981

APPENDIX B

Itinerary

Nov. 14	Left Washington, DC (National) at 3:55 p.m. by TWA 556.
	Arrived in New York, NY (JFK) at 5:05 p.m.
	Left New York, NY at 7:30 p.m. by TWA 800.
Nov. 15	Arrived in Paris, France (Charles De Gaulle) at 9:00 a.m.
Nov. 16	Left Paris by RK 047 at 12:00 noon.
	Arrived in Bamako, Mali at 5:00 p.m.
Nov. 17-18	At Bamako - Briefed by Lewis Lucke, DEO, USAID/ Bamako on Village Wells Project. Visited offices of DNHE* and NU/PNUD Project MLI/76/004* for technical discussions and to obtain data on existing boreholes and hydrogeologic reports in the Yelimané-Tambacara area. Visited offices of USAID/TAMS PIRT project for technical discussions and to obtain false-color LANDSAT imagery of the area. Purchased topographic maps of the area at IGN/Bamako.
Nov. 19	Travelled from Bamako to Yélimané by charter flight of Mali Air Service in company with the Mali Rural Health Project Evaluation team.
Nov. 20-30	Hydrogeologic field reconnaissance of the Yélimané-Tambacara area in company with Roy Speed of the Mali Rural Health Project.
Dec. 1	Travelled from Yélimané to Kayes by Land Rover. Performed field work en route.
Dec. 2	At Kayes - Held technical discussions with principals of OMBEV Kayes-Nord Project.
Dec. 3	Travelled from Kayes to Bamako by rail (13 hours).
Dec. 4-14	At Bamako - Discussed hydrogeologic problems in the Yélimané-Tambacara area with principals at the DNHE* and the OMBEVI.* Prepared report, typed first draft, and proofread typed material.

* See "Appendix C: Officials Interviewed."

Dec. 15-16	Prepared and duplicated sketch of map to accompany report.
Dec. 17	Held pre-departure discussions and debriefing of the findings of the mission with USAID/Bamako officers.*
Dec. 18	Left Bamako, Mali at 9:00 a.m. by UTA 852.
	Arrived Paris, at 6:00 p.m.
Dec. 20	Left Paris at 12:45 p.m. by TWA 811.
	Arrived in Washington, DC (National) at 5:45 p.m.

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* See "Appendix C: Officials Interviewed."

APPENDIX C

Officials Interviewed

Direction National de l'Hydraulique et de l'Energie (DNHE)
- S. Traoré , Director
- Geögy Traoré (Feher), Hydrogeologist
- J.P. Sasmayoux, Hydrogeologist

NU/PNUD, Projet MLI/76/004, "Exploitation des Eaux, en Milieu Rural"
- S. Traoré, Country Director
- L. Moullard, International Director
- A. Guerre, Hydrogeologist
- A. Bouvier, Geophysicist

USAID/TAMS, Projet Inventaire de Ressources Terrestres (PIRT)
- Gaossou Traoré, Country Director
- John Buursink, Project Manager
- Madia Sidoro, Hydrogeologist
- Roy Martin, Range Ecologist
- Raymond Laurin, Pedologist

USAID/Harvard University, Mali Rural Health Project
- Loel Callahan, Project Manager
- Roy Speed, Field Representative, Yelimané
- Jacques Bauduy, M.D.

FAC/BURGEAP/OMBEVI, Projet d'appui aux Operations de Developpment de l'Elevage dans el Sahel Occidental - Volet Hydraulique
- Dominique Fougeirol, Project Chief

USAID/Bamako
- David Wilson, Country Director
- Thomas Park, Public Officer
- Lewis Lucke, Development Officer

APPENDIX D

Descriptions of Local Water Supplies and Potentials for Improvement

General Statement

This chapter provides brief descriptions of the writer's findings of visits he made to 24 villages. His examinations of the local hydrogeologic conditions at typical existing open wells in or near each village and his recommendations for the location and depth of proposed new wells and/or the deepening of existing wells are given. Each village is described serially in the order in which it was visited in the field.

For the sake of brevity the following notations are used to describe the characteristics of each open well visited.

No.	Serial number of well
Loc.	Location, approximate direction and distance of well, in meters, from center of village
D/W	Depth to the water level in the well, in meters, below the measuring point
Depth	Depth of the well measured below the measuring point, in meters
Date	Date of measurement, 1981
MP	Measuring point, in meters above ground level. The measuring point is always the highest point on the headwall (margelle) of the curbing
Diam	Approximate well diameter, in meters
Geol	Geologic formation of the aquifer

GD	Grès de Daba
Ti	Tillite Series: t, tillite member; a, argillite member
P	Pelites of Nara-Nioro
al	Alluvial deposits (sand, silt and/or clay)

Lith	Lithology of the water-bearing zone (aquifer) in the well
Taste	Taste of water and general acceptability for human consumption

In addition to existing large-diameter open wells, the sites of several boreholes, recently identified as part of the Kayes-Nord Project or as part of the BRGM drilling campaign in 1974, were visited. These have already been referred to in the text and are mentioned only where especially relevant, under the village descriptions.

Dougoubara

Population (1980) - 260. Villages have requested one (1) new well of an estimated required depth of 23.1 m.

Existing wells examined:

No.	2
Loc.	SSW 100, in alcove at north edge of Terekolé River Valley
D/W	15.85
Depth	16.00
Date	Nov. 21
MP	0.9
Diam	1.6
Geol	al and/or P (?)*
Lith	al and jaspilite
Taste	good

Recommend location for a new well to be in an area about 150 to 250 m due south of the village, with the well's necessary depth being about 20 m. Well would pass thorugh al and end in al and/or P.

Yélimané Sébé

Population (1980) - 706. Villagers have requested one new well of an estimated required depth of 23.1 m.

Existing wells examined:

No.	3	4
Loc.	W 25	S 50
D/W	17.35	8+
Depth	17.5	10+
Date	Nov. 21	Nov. 21
MP	0	1.5
Diam	1.0	1.6
Geol	P	al
Lith	jaspilite	al
Taste	good	good

---

* "(?)"-indicates that the author is uncertain as to definite geologic formation.

Recommend location for new well to be in area south of Yélimané Sébé, in vicinity of well No. 4, but at least 50 to 75 m distant from any existing, heavily used well. Necessary depth is 15 to 20 m, with well mostly in al but possibly with some P in bottom.

Yélimané Grand

Population (1980) - 1405. Villagers have requested one new well of an estimated required depth of 16.2 m.

Existing wells examined:

No.	5	6B	6C
Loc.	S150	SSW 150	SSW 100
D/W	5.85	12±	10±
Depth	8.8	15±	15±
Date	Nov 21	Nov. 21	Nov 21
MP	0.8	1.0	0.8
Diam	1.6	1.6	1.6
Geol	P	al and P	al and P
Lith	jaspilite	al and slate	al and slate
Taste	excellent	excellent	excellent

Recommend location for new well to be in area south of Yélimané, but at least 50 m distant from wells No. 5, 6, 6A, 6B or 6C. Necessary depth is about 15 m, with well mostly in al and some P (slate or jaspilite) in bottom.

Diabguela

Population (1980) - 405. Villagers have requested one new well of an estimated required depth 14.0 m. There are no existing wells in or near this village. Villagers take water from the flooded areas in the wet season and water holes in the dry-season.

Recommend location for new well to be about 500 m south of village, just above the limit of wet season flooding. Well should be dug at least 5 m below position of dry season water table. Necessary depth required is about 20 to 25 m with well in al at top, and P (slate) at bottom.

Topokoné (Topoloné)

Population (1980) - 195. Villagers have requested one new well of an estimated required depth of 24.8 m. There is only one existing well in this village.

Existing well examined:

No.	8
Loc.	SSW 100
D/W	10.20
Depth	20.4
Date	Nov 23
MP	0.8
Diam	1.6
Geol	P
Lith	slate
Taste	good

Recommend two options: (1) location of a new well to be about 5 m south-southwest of well No. 2, with the well all in P (slate) and having a required depth of 25 m; or (2) construction of an open large-diameter well 20 to 25 m deep, near the site of the Kayes-Nord borehole (K 116 B) about 1 km from Topokoné, where a yield of 1.5 m^3/h has recently been obtained at a depth of 20 m. Option (2) is favored by the writer because of the greater probable dry-season dependability.

Marana (Makana)

Population (1980) - 900. Villagers have requested one new well of an estimated required depth of 17.5 m. There are two existing public wells and one private well in the village.

Existing wells examined:

No.	9A	9B
Loc.	N 25	N 75
D/W	8.34	9.20
Depth	13.3	12.0
Date	Nov 24	Nov 24
MP	1.1	1.0
Diam	1.8	1.8
Geol	P	al and P
Lith	slate	al and slate
Taste	good	good

Recommend locating the new well in an area about 50 m west of well No. 9A. The necessary depth required is about 15 to 20 m, with the well ending in P (slate).

Bandiougoula

Population (1980) - 2462. Villagers have requested two new wells of an estimated required depth of 16.6 m each.

Existing wells examined:

No.	11	12	13	14
Loc.	NE 500	W 25	SSE 25	SE 25
D/W	3.58	11.24	10.30	10.30
Depth	6.75	20.6	10.8	12.75
Date	Nov. 25	Nov. 25	Nov. 25	Nov. 25
MP	0.5	0.8	1.0	1.0
Diam	2.0	1.8	2.0	1.8
Geol	al	P	P	P
Lith	al(sand)	slate w/ dolerite	slate	slate
Taste	good	fair	good	good

Recommend deepening wells Nos. 11, 13 and 14 to a depth of 15 m each. All are favarably situated for local recharge from the Babassang River floods. Additionally, well No. 10 (DNHE S17), which was recently redrilled (K 101) by the Kayes-Nord Project, is located on the northeast edge of the village. The borehole is 6 inches in diameter, has a D/W of 8.90 m, and a depth of 50.5 m below the top of the casing, which is 0.45 m above ground level. The borehole yields 3.4 m^3/h from sandstone of the Pelite Series. If equipped with a submersible pump, a generator, and a water tower for storage, this borehole could easily provide plenty of water for the entire village. The water is of fair quality with 932 mg/l of total dissolved solids.

Kodié

Population (1980) ± 2350. There are six to eight wells in the vicinity of the village. The villagers have requested the deepening of four wells by 5 m each, for a total of 20 m.

Existing wells examined:

No.	15	16	17	18	19
Loc.	SE 75	W 75	NW 500	NW 150	SW 100
D/W	11.05	6.75	5.65	6.60	7.50
Depth	13.2	7.95	9.15	0.75	11.40
Date	Nov. 25	Nov. 25	Nov. 25	Nov. 25	Nov. 25
MP	0.0	1.0	1.0	1.0	1.0
Diam	2.0	1.8	1.8	1.8	1.8
Geol	P	P	P	P	P
Lith	slate	slate	slate	slate	slate
Taste	good	good	good	good	good

Recommend deepening wells Nos. 16, 17, 18 and 19. All are fairly-well situated to receive recharge from the Sambehoui River during floods. Each well should be deepened to a depth of 15 m.

Niaratela (Niakatela)

Population (1980) - 219. Villagers have requested a new well at an estimated required depth of 18.0 m.

There are no existing wells in or near this village. The villagers take water from the Terekolé River during the wet season and from puisards excavated in the sand of the stream channel during the dry season.

Recommend locating a new well to be about 100 m south-southeast of the village at a required depth of about 20 m, and/or about 5 m below the dry-season position of the water table. The well will probably end in P (slate).

Dionkoulane

Population (1980) - 3,820. Villagers have requested a new well at an estimated required depth of 12.4 m. This is one of the largest villages in the Yélimané-Tambacara area. There are reported to be six to eight wells in or near the village.

Existing wells examined:

No.	20	21	22	23
Loc.	E 50	S 50	W 50	N 50
D/W	5.82	13.55	9.75	3.25
Depth	13.45	14.3	11.25	8.25
Date	Nov. 26	Nov. 26	Nov. 26	Nov. 26
MP	1.0	1.0	1.0	1.0
Diam	2.0	1.8	1.8	1.8
Geol	Tia (?)	Tia (?)	al	al
Lith	argillite(?)	argillite (?)	al (sand)	al (sand)
Taste	good	good	good	good

Recommend locating a new well in the vicinity of well No. 23, but at least 50 m away from it or any other well and as close as possible to the flood limit of the Terekolé River valley. Well would need to be about 15 to 20 m deep; it would begin in al and end in al and/or Ti (argillite ?).

Fongou

Population (1980) - 383. Villagers have requested one new well at an estimated required depth of 13.6 m. There are two existing wells serving this village.

Existing wells examined:

No.	24	25
Loc.	S 25	N 25
D/W	12.60	5.80

Depth	15.75	9.70
Date	Nov. 26	Nov. 26
MP	0.0	1.0
Diam	2.0	2.0
Geol	Tia	al
Lith	argillite and mudstone	al (sand)
Taste	good	excellent

Recommend locating a new well about 50 m away from well No. 25 and as close as possible to the flood limit of the Terekolé River valley. The well would need to be about 15 m deep and would probably be entirely in al.

Kardidi

Population (1980) - 191. Villagers have requested one new well at an estimated required depth of 21.5 m. There are two existing wells in Kardidi.

Existing wells examined:

No.	26	27
Loc.	SW 10	E 50
D/W	11.90	5.10
Depth	15.4	9.75
Date	Nov. 27	Nov. 27
MP	1.0	1.0
Diam	1.8	1.8
Geol	GD	GD
Lith	sandstone	sandstone
Taste	good	good

Recommend locating the new well north-northeast of the village between well No. 27 and a clump of date palms near the edge of the marigot flood line. Its necessary depth would be 15 to 20 m and would end in GD (thin-bedded sandstone).

Salara (Salaka)

Population (1980) - 168. Villagers have requested one new well at an estimated required depth of about 15.0 m. There are no existing wells in Salara. Villagers presently take water from a small "bas fond" about 75 m north-northeast of the village and from another, about 100 m south.

Recommend locating the well about 75 m north-northeast of the village, just south-southwest of the flood line of the marigot. The estimated necessary depth of the well is about 15 to 20 m, or 5 m below the dry-season position of the water table. Most of the well section would be in GD (sandstone).

Komodounde (Komodinde)

Population (1980) - 646. Villagers have requested one new well at an estimated required depth of 16.1 m. There is only one existing well in the village.

Existing well examined:

No.	28
Loc.	E 25
D/W	13.15
Depth	13.25
Date	Nov. 28
MP	1.0
Diam	1.8
Geol	GD
Lith	sandstone
Taste	good

Recommend deepening well No. 28 to a depth of 20 to 25 m or to 5 m below the dry-season position of the water table. All of the well section would probably be in white to buff, hard, fine-grained (GD) sandstone.

Kersignane

Population (1980) - 1,326. Villagers have requested one new well at an estimated required depth of 20 m and the deepening of another well by 3.1 m. There are reported to be six wells in or near the village, of which two are reported to have brackish water.

No.	29	30	31	32
Loc.	W 25	S 25	S 25	E 25
D/W	11.90	7.60	7.50	8.15
Depth	12.95	9.55	8.65	12.75
Date	Nov. 28	Nov. 28	Nov. 28	Nov. 28
MP	1.0	0.0	1.0	1.0
Diam	2.0	1.6	2.0	2.0
Geol	GD	al and GD	al and GD	al and GD
Lith	sandstone	al and ss	al and ss	al and ss
Taste	good	good	good	good

Recommend constructing one new well near well No. 30, as the present well is not worth repairing or deepening and should be closed and sealed. The estimated depth required for the new well would be about 15 to 20 m, or about 5 m below the dry-season position of the water table. The concrete rings (buses) should be perforated and gravel packed in the water-bearing alluvium above the sandstone with an open hole in the sandstone. Well No. 31 should be deepened to 15 m to increase dry-season storage and possibly to increase yield.

Diabougou

Population (1980) - 429. Villagers have requested one new well at an estimated required depth of 20 m.

Existing wells examined.

No.	33	34	35
Loc.	NE 25	NE 25	NE 50
D/W	15.05	11.20	14.60
Depth	26.6	13.3	24.6
Date	Nov. 28	Nov. 28	Nov. 28
MP	1.0	1.0	1.0
Diam	2.0	2.0	1.8
Geol	Tia	al	Tia
Lith	argillite w/gypsum	al (sand)	argillite w/gypsum
Taste	bitter	good	bitter

Recommend locating a new well about 1.5 to 2.0 km west-northwest of Diabougou within the flood-prone area of the Kolinbiné River valley. Well would have to be 10 to 15 m deep and entirely in al. The well should not be dug into the underlying Tia (argillite), which probably contains poor quality water. The headwalls of the well would have to be raised up onto a 1 to 2 m high mound, protected by slate and mortar slabbing against occasional flooding. Well No. 34 and another nearby shallow well should not be deepened. The deeper water is probably of poor quality.

Doroféré (Dorofery)

Population (1980) - 1,555. Villagers have requested one new well at an estimated required depth of 20.1 m. This large village has five wells in the vicinity.

Existing wells examined:

No.	36	37	38
Loc.	E 50	E 25	W 50
D/W	dry	14.70	11.45
Depth	collapsed	15.9	20.9
Date	Nov. 28	Nov. 28	Nov. 28
MP	---	1.0	1.0
Diam	2.0	1.6	1.8
Geol	tillite	tillite	tillite
Lith	Tit	Tit	Tit
Taste	good (?)	poor	good

Recommend location of a new well either (1) 75 m north-northeast of well No. 38 or (2) 75 m south-southwest and as near as possible to the flood limit of the Kolinbiné River. Well would

need to be about 20 to 25 m deep and would end in Tit (tillite).

Sanbaga (Sambaga)

Population (1980) - 1,713. Villagers have requested one new well of estimated required depth of 23.65 m.

Existing wells examined:

No.	39	39A
Loc.	SE 25	W 25
D/W	18.15	14.90
Depth	19.4	16.5
Date	Nov. 28	Nov. 28
MP	1.0	2.0
Diam	2.0	2.0
Geol	al	al
Lith	al (sand)	al (sand)
Taste	good	good

Recommend location for a new well to be west of the village, near the edge the flood limit of the Kolinbiné River valley and about 75 m distant from well No. 39A or from any other heavily used well. The new well would have to be about 20 to 25 m deep and extend about 5 m below the dry-season position of the water table. As well as in al, the concrete rings should be perforated and gravel packed.

Guifi (Guiffi)

Population (1980) - 880. Villagers have requested one well deepened by 5 m. There are four wells in the village.

Exsiting wells examined:

No.	40	41	42
Loc.	NE 50	S 50	W 50
D/W	17.90	18.00	17.70
Depth	28.20	±30.00	25.3
Date	Nov. 29	Nov. 29	Nov. 29
MP	1.0	1.0	1.0
Diam	2.0	2.0	2.0
Geol	Tia	Tia	Tia
Lith	sandstone	argillite	argillite
Taste	good	slightly bitter	slightly bitter

Two boreholes have been drilled under the Kayes-Nord Project. Borehole K 121 B on the northwest edge of the village reached a total depth of 49.6 m in Tia micaceous sandstone and dark gray argillite. At 30 m the borehole encountered a water-bear-

ing zone which yielded 40 l/h of water having a very bitter taste. Borehole K 121 A, which is about 2 km east of the village, reached a total depth of 99 m. At 78 m a water-bearing zone was encountered which yielded 200 l/h of water also having a bitter taste. This borehole was also drilled in the argillite member of the Tillite Series.

The hydrogeologic conditions for discovering adequate supplies of potable groundwater in the immediate vicinity of Guifi are not promising. Only the very shallow groundwater near the village is potable, and this supply fails in the dry season. Any deepening of either well No. 40 or of the other nearby well of similar character, in the hopes of increasing water yield, is likely to result in impotable water similar to that of wells No. 41 and 42 and of boreholes K 121 A and K 121 B.

It is recommended, as one possible solution, that the construction of a potable water well in the vicinity of Waloguela about 4.5 km east-northeast of Guifi, the installation of a wind-powered pump and water tower at the well, and the construction of a gravity pipe line from the water tower to Guifi be undertaken. This is an expensive solution and may not be feasible owing to the capital and recurring costs for maintenance. Other more expensive solutions might be considered, but all of these seem to be beyond any reasonable hope of fulfillment.

Sakaradji

Population (1980) - 470. Villagers have requested one well be deepened by 5 m. There is one permanent well that exists now near the village, and one deep puisard is currently under construction for use during the 1981-82 dry season.

No.	43	44 (puisard)
Loc.	NE 100	NE 200
D/W	18.70	10.60
Depth	18.75	Under construction
Date	Nov. 29	Nov. 29
MP	1.0	1.0
Diam	2.0	1.0
Geol	P and dolerite	al and P
Lith	slate and dolerite	al and slate
Taste	good	good

Recommend that well No. 43 not be deepened as dolerite has been encountered in the bottom of this well, and there is very little probability of increasing the yield by digging deeper in this impervious rock. Three options seem possible. Construct a new well about 25 m deep in P (slates) either at (1) a site about 75 m northwest of well No. 43 or (2) at a site 75

m east of well No. 43. Either site should be near the flood line of the large marigot lying north of Sakaradji. Or (3) construct a complete well at or near the site of well No. 44. This well should be placed on a mound about 1 to 2 m high, protected by slate slabs set in mortar against flooding. The concrete rings should be perforated and gravel packed in the al (sand and gravel), with a hole left open in the underlying P (slate). Its required depth would be about 15 to 20 m. The writer recommends the latter option as the most viable.

Hamdallaye

Population (1980) - 250 approximately. Villagers have requested one new well at an estimated required depth of 24.9 m. There is only one existing well near the village.

Existing wells examined:

No.	45
Loc.	SW 200
D/W	18.80
Depth	21.6
Date	Nov. 29
MP	1.0
Diam	1.6
Geol	Tia
Lith	argillite
Taste	good

Borehole K 120A drilled near Hamdallaye under the Kayes-Nord Project encountered (Ti) argillite, tillite, pelite, and dolomite to a depth of 58 m, but no appreciable amount of water.

Recommend locating a new well site between well No. 45 and the southwest edge of the village. The well should be placed just above the flood line and about 100 m southwest of village. The required depth would be about 25 m, or 5 m below the dry-season low position of the water table.

Mounia (Mougna)

Population (1980) - 564. Villagers have requested one new well of an estimated required depth of 21.1 m. There are three existing wells in or near the village.

Existing wells examined:

No.	46	47
Loc.	SW 50	S 50
D/W	13.30	13.60
Depth	15.6	17.3

Date	Nov. 29	Nov. 29
MP	1.0	1.0
Diam	2.0	2.0
Geol	P	P
Lith	slate	slate
Taste	good	good

Recommend locating the site for a new well on the south side of Mounia either (1) at a site about 50 m west of well No. 46, or (2) at a site about 50 m east of well No. 47. The new well should be about 20 to 25 m deep, or about 5 m below the dry-season position of the water table.

Gawa

Population (1980) - 199. Villagers have requested one new well of an estimated required depth of 17 m. There are presently two wells near the village.

No.	48	49
Loc.	W 75	NE 50
D/W	4.30	6.10
Depth	11.0	8.6
Date	Dec. 1	Dec. 1
MP	1.5	1.0
Diam	1.6	1.6
Geol	P	P
Lith	slate	slate
Taste	good	good

Recommend locating the new well between well No. 48 and the village on the east side of the same marigot but just above flood line. The required depth about of the well is 15 to 20 m, or about 5 m below the dry-season position of the water table.

Mongoro

Population (1980) - 199. Villagers have requested the deepening of one well by 5 m. There is one existing well.

No.	50
Loc.	NNE 50
D/W	3.15
Depth	6.2
Date	Dec. 1
MP	1.0
Diam	2.0
Geol	P
Lith	slate
Taste	good

Recommend deepening this well to 15 m and raising the head-walls by 1.5 m so that the well is on a mound. The mound should be protected with slabs of slate set in mortar, as the area around the well is intermittently covered with about 50 cm of water due to during rainy season floods.