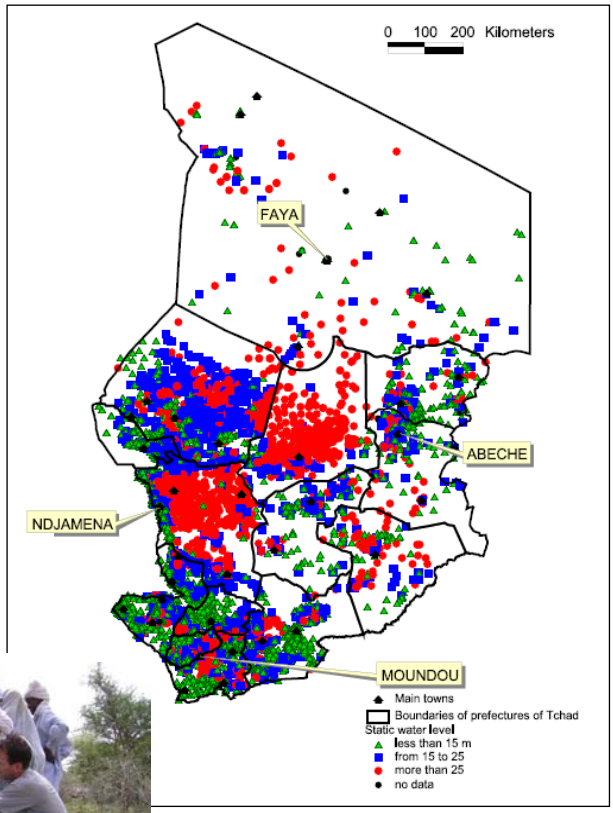
PRACTICA

Foundation

Report Phase I

Assessment of the feasibility of manual drilling

in Chad



N'Djamena, September 2005

In association with unicef, Chad and Oxfam GB

Illustrations on cover:

Chadian map of static water levels and

photo; training of a drilling team to assist in a test drilling

in the village of Djakberé

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1 Introduction

1.1 Background on the assignment

'In Chad, the proportion of the population with permanent access to safe water in rural areas was 17% in 2000; the proportion implementing environmental health measures was 7%. In towns equipped with a drinking water supply, only 9.7% of the population have a connection, while 27.5% obtain water from a public stand-pipe and 63% have to draw water from (often traditional) wells. On the whole, permanent access to drinking water is limited to 23% of the Chadian population. None of the towns has a functioning wastewater sewerage system and the collection networks are dilapidated. Less than 2% of city-dwellers have sanitary facilities with running water, while latrines are almost non-existent in rural areas.' (resource: The integrated plan for Chad's water development and management 2003 – 2020 (SDEA)).

Current machine drilled 'shallow' boreholes by Chadian enterprises, cost in Chad between $12.000 and $ 15.000 and although large 'water' budgets are available (EU, UN, AFD (Agence Française de Développement), African Development Bank, NGO's, etc.) towards the year 2015, most of the new planned water wells will be constructed for communal use in villages with more than 300 inhabitants. Nevertheless, 35% of the Chadian population lives in villages with less than 300 inhabitants and remain deprived in means of safe drinking water. Currently people in these villages have to walk long distances (one hour or more) to a pump or they obtain their daily water from rivers, 'wadis', ponds and dug holes.

To drill 'shallow' water wells (up to 35 meter on average) also low cost options exist, reducing the price of a well by a factor 10 compared to a machine drilled borehole. This cost reduction will not only able the NGO's to construct more water wells, but also 'opens the door' to villagers, schools and small communities to have a well constructed independently through the private sector (including villages with less than 300 inhabitants). Low cost, manual drilled wells equipped with a hand pump are suitable for save drinking water and small scale irrigation.

In Senegal *UNICEF* has a positive experience with manual drilled wells. To assess if manual drilling could be used for water well installation in Chad, the *Practica Foundation* was invited by *UNICEF* to make an assessment of the feasibility of manual drilling in Chad. This report describes the set-up and results of this project, which took place between the 18th of August and the 16th of September 2005.

1.2 Objectives of the project

The overall objective of this project is to study all aspects related to the potential of manual drilling for construction of save drinking water wells. Important is to compile all existing information on geology, hydrology and water quality to be found at governmental and non governmental level, 'water related' organizations and drilling enterprises. Besides this information existing structures (i.e. existing drilling enterprises and NGO's which are currently involved in drilling) and history in drilling are studied which can be useful for possible future training set-ups. If results of the assessment of the feasibility of manual drilling in Chad are positive, a strategy will be proposed with the aim to introduce and professionalize manual drilling in the private sector to reduce the costs of a borehole and make water wells assessable for larger group of people on both, communal and household level.

1.3 Summary

To realize this feasibility study a project team of three members was brought together:

Sílvia Gaya	Consultant *UNICEF Chad*
Fabio Fussi	Geo-hydrologist with *Oxfam GB* and consulted by *UNICEF*
Arjen van der Wal	Associate of the *Practica Foundation*.

During the first week a lot of existing geo-hydrological information and maps where collected. Several interviews took place with the Direction de l'Hydraulique, UN and EU consultants, UNICEF employees and owners of drilling enterprises. Further, materials for construction of a drilling set were purchased and a 'Rota sludge' drilling set locally constructed (please see appendix D for information on this drilling technique).

In the second and part of the third week a drilling team was formed and trained in the village of Djakbere, 2 hours North of N'Djamena. Several drilling attempts took place in the village with the Rota sludge drilling method (please see paragraph 3.5).

During the third week results and gathered information were evaluated and in the fourth week travels were made to the South (Pala and Moundou) for an inventory of existing manual drilling enterprises, used drilling techniques and well designs. Several drilling enterprises and NGO's were interviewed and drilling sites visited (please find Itinerary in appendix C).

In Chad, although not compiled, a lot of information on geo-hydrology is available and already a number of manual drilling enterprises exist. Maps, geo-hydrological data and interviews indicate that manual drilling could be feasible in about 50% of the country's surface in the most populated parts of Chad. Although in the past a lot of wells were drilled manually, a lot of problems occurred in water quality and discharge of the wells (well design) and installed pumps.

At the end of the project an evaluation took place with UNICEF and a draft proposal and training strategy (to improve well and water quality by professionalizing the manual drilling sector) was drawn up. On the last day the proposed strategy was discussed with UNICEF, Oxfam GB, UNDP and EU 'water' consultants. The mentioned organizations are positive on the proposed strategy and offer their assistance in the set-up of the proposed phase II – phase IV projects (please see chapter 6).

2 Geo-hydrology

2.1 Available data

Some years ago the Chadian government, the 'Direction de l'Hydraulique', started the collection of data from water points in Chad. A country wide survey was made and since then drilling enterprises were requested to fill out a drilling log and questionnaire of each well they had accomplished. They were asked to return this information to the Direction de l'Hydraulique, who put the information in a data base. By now this data base contains more than 10.000 water points since recording has started, providing a lot of useful information on the position of the wells, geology of the aquifer, depths of water tables, etc. (please find a selection of the information in this data base in appendix B). Most of the wells and boreholes recorded in this data base were accomplished in the past 15 years, although some of these wells date all the way back to the early 60's. Of all water points the GPS coordinates are available. Together with the geo-hydrologist of Oxfam GB a map was created showing all water points, divided in different colors depending on the depth of the static water level (please see paragraph 2.3).

At the consultancy agency 'Antea International' a data base (of the Fed EU Program) was found containing the chemical analyses of a selection of these water points, giving a better view on the water quality in different regions and on different well depths. For example, this data base show in some areas high levels of Manganese, creating corrosion on galvanized pipes (influence on color and taste of the water). In these areas stainless steel pumps have to be installed. Also analyses of Nitrates and Nitrites can be found, indicating vertical migration of infiltrated (rain or 'leak') water into the aquifer or borehole.

Furthermore, a lot of data can be collected from drilling enterprises and water related organizations. The UNHCR, for example, is collecting information of wells constructed in Eastern Chad. Probably, in Chad, there is a lot more existing information available, but unfortunately not all of this information is compiled and available to all water related organizations and enterprises. A lot of this existing information can be made 'visible' to 'users' (i.e. water related organizations and drilling enterprises) by combining relevant information and maps in, for example, sheets or books, classified per province or per region.

2.2 Geology

The general geo-hydrological map of Chad and information from the known data bases indicate that manual drilling could be possible in 50% (on estimation) of the most populated parts in Chad. The most suitable soft formations can be found in West- and Southern Chad. This includes the following regions:

- *Kanem and Lac:*
  Ogolian sands; mainly fine sands, in Lac diversified with thin clay layers.

- *Hadjer Lamis, Mayo Boneye and large parts of Dababa and Baguirmi:*
  Western Pleistocene; mainly fine sands and clay layers.

- *Tandjile Ouest and Est, Logone Occidental, Mandoul, Bahr Koh and parts of Kabia, Mayo Dala, Logone Oriental, Lac Iro and Salamat:*
  Southern Continental Terminal; mainly sandy clay and fine sands.

In Central and Eastern Chad the geology consists of Pliocene and Eastern basement formations, containing rock layers. On the time of writing, not enough data is collected yet to determine the depth of these rock layers and the sediment layers on top of these formations. Although shallow water levels (see the next paragraph) are common in parts of Eastern Chad, further research on available data (drilling logs of existing wells, for example the UNHCR data base) is needed to determine the potential suitable areas for manual drilling (please find the geo-hydrological map of Chad in appendix A).

2.3 Hydrology

Throughout Chad the depth of the groundwater table differs a lot from region to region due to the variety of geological and geographical structures in different parts of the country. Using the available data and GPS coordinates of existing wells, collected in the data base of the Direction de l'Hydraulique (moreover 10.000 water points), a clear view on static water levels could be created in the most populated parts of Chad. During this project all the existing water points in this data base were put on the country map of Chad, divided by colors into three different static water levels (please find this map in appendix A).

The map shows large areas with a shallow water table in among others Northern- *(i.e. Kanem and Lac)*, Western border *(i.e. Hadjer Lamis),* Southern- *(i.e. Mayo Boneye, Kabia, Mayo Dala, Tandjile, Logone, Mont de Lam, Mandoul, Bahr Koh and Lac Iro),* Central- *(i.e. Guera)* and Eastern- *(i.e. Biltine and Assongha)* parts of Chad. Unfortunately, so far no studies are know showing seasonal changes (difference in water level between dry- and wet season) in the static water level. However, experts indicate a maximum fluctuation of 5 meters (dry season 1-4 meters and 5 meters during droughts). The static water levels of the water points in the mentioned data base were measured in both, dry and wet season. Therefore this hydrological map with water points should be red with a tolerance of 5 meters. Most of these measurements are 'recent' and took place in the past 6 years.

Maps showing the pH and conductivity are available for parts of the country (Fed EU program). At the consultancy agency 'Antea International' a data base (of the Fed EU Program) was found containing chemical analyses of a selection of water points, giving a better view on the water quality in different regions and on different well depths. This database can provide useful results of, for example, Manganese levels. However, analytic results on Nitrates, Nitrites and E. coli bacteria represent vertical migration of infiltrated (rain or 'leak') water into the aquifer or borehole and don't necessarily represent the water quality of the area's aquifer. In Chad, often a lot of mistakes are made during well installation (please see paragraph 4.3, 'no sealing….'), which is the main reason for vertical migration of Nitrates, Nitrites and bacteria into the well, contaminating the aquifer just on the spot of the well.

2.4 Suitable areas and maps

The combination of the geo-hydrological map and the map of static water levels indicates suitable areas for manual drilling in:

North:	*Kanem and Lac*
Western border:	*Hadjer Lamis and Mayo Boneye*
South:	*Tandjile Ouest and Est, Logone Occidental, Mandoul, Bahr Koh and parts of: Kabia, Mayo Dala, Logone Oriental, Lac Iro and Salamat*

In Central- *(i.e. Guera)* and Eastern- *(i.e. Biltine and Assongha)* parts of Chad with shallow ground water levels, further research is needed (see paragraph 2.2).

By combining the hydrological map (statistic water levels), showing all the existing water points, with the general geo-hydrological map of Chad on province level, a better indication, on the areas suitable for manual drilling, can be created. The creation of these maps, using a smaller scale, combined with the Chadian 'road map' (showing roads and villages) would make a selection of the available information easily assessable for water related organizations and drilling enterprises. Such maps could be made on province or region level of all populated areas in Chad, bound in a hardcover and distributed to organizations and enterprises.

Please find a selection of maps in appendix A;

- Map of Chad
- Geo-hydrological map of Chad
- Map of statistic water levels in Chad
- Examples of combined (geo-hydrological and statistic water levels) maps of: *Kanem, Chari Baguimi and Mayo Kebbi.*
- Maps of pH and Conductivity in groundwater

3 Manual drilling

3.1 History of manual drilling in Chad

According to available information, in 1965 the 'Peace Corps' started the introduction of a drilling technique (the sludge method) in Chad. After drilling took place, a 63 millimeter casing was installed (no gravel pack) with the piston of the pump directly installed in the casing (which then directly served as the 'raising pipe' for the pumps). The Peace Corps drilling and well program continued up till (as far as known) 1977, but unfortunately most of the installed wells and pumps stopped functioning after 3 to 6 months of use, due to the inflow of fine sands in both the well screen and the piston of the pump (pumps got blocked). In 1988 'CARE Tchad' reintroduced the 'Peace Corps method' experiencing the same problems. 5 years later CARE changed to the installation of 3-inch PVC casings with a 'wrap' filter (no or little gravel pack), still installing the (plastic) piston directly in the well casing. However, the plastic pistons damaged the PVC casing pipes and stopped duty after several months/years (depending on the user intensity). In 1997 and 1998 UNICEF provided a training on, among other things, manual drilling to the Direction de l'Hydraulique, but at the time of writing no further technical details were available.

Nowadays between 20 to 30 (estimated) manual drilling enterprises are active in Chad, using different manual drilling techniques.

3.2 Existing manual drilling enterprises

Interviews with drilling enterprises and water organizations indicate the existence of 20 to 30 (on estimation) manual drilling enterprises in Chad. In a first inventory already 10 manual drilling enterprises were identified and 8 of them interviewed. Most of these enterprises are found in N'Djamena *(i.e. Arimfor, Barabele, Silas, Nguema Dji, Monalta, Sadia (NGO) and two without name)* and, so far, two were found in the South; in Pala *(the NGO Belact)* and Bissimafu *('Organisation Populaire', trained by the Cameroon based NGO CRS (Catholic Relief Service)).* The interviewed enterprises are currently working in the areas: *Kanem, Lac and the South.* Drawing up an additional inventory will create a better view on the existence of enterprises and drilling activities (i.e. used drilling systems, capacity, professional level, etc.) of the whole manual drilling sector.

3.3 Currently used drilling techniques and prices

In general in Chad (as far as known) two manual drilling systems have been universally adopted, namely; the 'sludge method' and 'jetting'.

- The sludge method is used in sandy soils and sand diversified with thin clay layers with an average drilling depth of 30-35 meter, reached in two to four working days. The diameter of the borehole varies (among the different enterprises) between 4.5- to 7-inches and a 4-inch (diameter 110 mm) PVC casing is installed. In general no or little gravel pack is used (see chapter 4). Prices vary between US$ 1500,- and US$ 3000,- including a Indian mark pump (US$ 1000,- on average).

- The jetting method is often combined with a rotation movement and some times used in combination with the sludge method and a maximum drilling depth of 45 meter is reached in one or two working days, in sand and clay soils. The borehole diameter and diameter of the PVC casing don't differ much from the sludge method. Prices vary between US$ 2000,- and US$ 3000,- (including a pump).

- Besides manual drilling, three of the drilling NGO's *(i.e. Sadia, Belact and the Organisation Populaire)* use a small semi-mechanized drilling rig, transportable on a pick-up car. These rigs perform 'percussion' and 'rotary (jetting)' drilling with a maximum drilling depth of 40-70 meter (depending on the geology), reached in one to five working days. The borehole diameter varies between 6- and 9-inches and a 4- or 5-inch PVC casing is installed, including a proper gravel pack. Prices vary between US$ 4000,- and US$ 6000,- (including a pump).

With the sludge and jetting methods, natural clay, 'Foragum' and 'Bentonite' are generally used to create a drilling fluid. Bentonite (US$ 80/bag) and clay will partly remain in the drilling hole (having small influence on the discharge of the well), while Foragum (US$ 220/bag) is completely biodegradable. Using the percussion method, no drilling fluid is required.

Please note that prices of materials in Chad are high and up to twice as expensive as in a number of other African countries! (for example, the price of a 50kg bag of cement in N'Djamena costs around US$ 12,- and in the South up to US$ 20,-).

In Chad the manual and semi-mechanized drilling crews drill between 30 and 40 wells each year. During the rainy season, no drillings are made (roads not assessable).

3.4 Current well designs

Currently most of the manual drilling enterprises drill boreholes with a (in practice!) 4- to 6-inch diameter. In all cases now a 4-inch (110 mm) PVC casing is installed with no or little gravel pack installed around the filter screen. The length of filter screens differs. Some of the enterprises run experiments using 'wrap' filters, but no long term results are available yet. In general no drilling logs are made and no 'seal' is constructed to block off impermeable layers which were drilled through and prevent vertical migration of Nitrates and harmful bacteria. In practice the upper 50 cm to 5 meters are filled with concrete. In all cases a concrete slab is constructed and an Indian mark pump installed. Quality of the pumps (partly imported and partly locally constructed) and its installations differs a lot between different enterprises, some times installed by the drilling enterprise itself, but often by a nearby 'pump' enterprise (please see chapter 4 for a problem analyses).

3.5 Test drillings in Djakbere

In order to asses if the so called 'Rota sludge' method could be used in the fine sands of the Northern areas in Chad, test drillings took place in the village of Djakbere, two hours North of N'Djamena and half an hour North-West of Mani. The Rota sludge drilling method is based on the 'sludge' principle, but a rotation is added to be able to drill through sand-, clay-, loam- and consolidated rock layers. The Rota sludge is stronger and able to drill larger diameter boreholes, compared to the normal sludge method (please find more information on the Rota sludge in appendix D).

A Rota sludge drilling set was constructed (out of local available materials) in a workshop in N'Djamena. In the village of Djakbere, where 100 inhabitants depend on turbid water from the river 'Chari', a useful location for the test drilling was selected near the school and a drilling team was formed. The drilling team was trained in the use of the Rota sludge and drilling took place. During the sludge drilling, no casing is used and the borehole stays open by water pressure. This water pressure does not exist in the first meters of the borehole (however in most soil type's water pressure is not required in the 'dry' zone during drilling). Unfortunately the top layer in Djakbere consisted of very fine sands, acting as quick sand in the drilling hole. Caving in of this top layer could not be prevented by water pressure and drilling fluid, and the top layer collapsed during drilling. Three attempts took place to respectively 6, 11 and 7 meters.

In general, four different manual drilling techniques can be distinguished. For each soil type the optimal technique has to be applied. The lesson learned is that the very fine sands in the top layers of Northern Chad are unstable during drilling with water. Therefore the percussion method (using a temporary casing), jetting method (using a high flow of water, transporting the caving sands rapidly to the surface) or a combination of percussion (installing a temporary casing in the first 5 meters) and sludge has to be applied in Northern Chad.

In Southern Chad (top soils in the South contain sandy clay) the Rota sludge might increase the drilling speed, compared to the traditional used sludge method. However, it is not the aim of the project to introduce new techniques when no advantage of the new technique is proved. Therefore it is recommended to make a comparison of all existing drilling techniques in Northern and Southern Chad during an additional inventory.

4 Problem analyses

4.1 Negative image

Although manual drilling can be applied in many of the populated areas in Chad and is much cheaper than a machine drilling, it has a negative image among NGO's and water agencies. None functioning wells in the past (paragraph 3.1), low water quality and discharge and wrong well designs (paragraph 3.4) lie at the bottom of the fact that currently none of the water agencies is contracting manual drilling enterprises for the installation of their wells, although large 'water budgets' are available.

4.2 Education

In general machine drilled wells in Chad are of a good quality. For a shallow well up to a depth of 40 meter the Chadian drilling enterprises are charging a price between US$ 12.000 and US$ 15.000. Because of the large cash flow within these companies the employees are well educated and have knowledge on relevant subjects for drilling and well installation (i.e. soil types and their behavior, drilling logs, well design, hygiene, gravel packing, sealing, well development, etc.).

The manual drilling enterprises on the other hand often employ low educated people and have a lack of knowledge on these subjects. As a result a number of problems can occur in water quality and discharge due to a lack of knowledge on geology, hygiene and well installation and its development.

Although manual drilling has a negative image, the main problem is not the drilling technique itself (if the borehole is drilled with a 6-inch diameter or larger, there is no difference between a machine- or a manual drilled borehole). The main problem is a lack of knowledge on the relevant subjects, needed for a proper well installation (please see paragraph 5.3).

4.3 Well designs, water quality and discharge

Currently manual drilled wells in Chad often have a low discharge and poor water quality, because of various reasons:

- No drilling logs are made during drilling; the drilling team is not able to create a 3-dimentional image of the borehole while drilling. Important features necessary for a good well installation are therefore unknown (i.e. proper soil description; depth and type of different soil layers, depth of impermeable layers which have to be 'sealed' again after drilling, depth of the right (permeable) aquifer, etc.)

- Some wells are not constructed deep enough; wells might have a low discharge in dry season due to a lack of knowledge on groundwater fluctuation. Water quality might be low due to the presents of Nitrates, Nitrites and bacteria in a very shallow aquifer.

- No or little gravel pack is installed; especially in areas where the aquifer consists of fine sands, a decent gravel pack is needed to avoid the inflow of fine particles into the filter. Now, filters often fill-up with fine particles creating a low discharge, poor water quality and worn-out pump pistons (please see paragraph 4.4).

- No sealing to block off impermeable layers which were drilled through; this allows vertical migration of Nitrates, Nitrites and harmful bacteria into the borehole, contaminating the aquifer just on the spot of the well, creating a poor water quality.

- Lack of knowledge on well development; wells are often not well developed creating a low discharge and chance on turbidity.

- Lack on hygienic aspects; no site selection of the position of wells in relation to nearby latrines or 'waste' areas.

4.4 Drilling systems and well design in relation to geology

One of the practical problems in Chad are the very fine sand particles. For example, the NGO 'Belact' (a high skilled and professional drilling NGO) experienced a lot of problems with fine sands entering the filter screen of the well. In the past 80% of the wells had to be redeveloped (by airlifting to remove fine sands from the inside of the filter screen) after 3 to 4 years of use. Now Belact runs experiments to avoid the inflow of fine sands;

In their experience fine sands are entering the well when the filter screen has a slot size which exceeds 1 mm, even though a proper gravel pack is installed. Now 'wrap' filters (nylon cloth seamed around the filter screen) are used on filter screens with a slot size larger than 1 mm (these slots are made by saw blades and therefore cheaper) in combination with a proper gravel pack. These experiments are recent and no long term results are available yet on the use of wrap filters. However, when a slot size of 0.75 – 1 mm is used (more expensive and made in PVC factories in Nigeria or Cameroon) in combination with a proper gravel pack (size 1 – 2.5 mm) no problems occur with the inflow of fine sands.

Currently half of the existing manual drilling enterprises drill boreholes with a diameter less than 6-inch which is and too small for the installation of a proper gravel pack. However, with little adaptations to the equipment and the choice of the right drilling system in relation to the geology, bigger boreholes can be made. Each type of soil (i.e. the fine sands in the North and the clay sands in the South) might require its own drilling system.

4.5 Pumps

In the past a variety of pumps were used in Chad, but nowadays for communal use Indian mark pumps are installed. Critical parts of these pumps are imported while the other parts are locally made. The pumps are then assembled in Chad. There is a huge variety in the quality of the installed pumps (due to the material and the installation procedure) and a lot of pumps break down within a period of 3 years after installation. Pumps are generally not installed by the drilling companies, but by small private 'pump' enterprises.

4.6 Standardization

In 'the Integrated plan for Chad's water development and management 2003 – 2020', validated by the Chadian government, the use of manual drilling techniques is recommended. However, the quality of these manual drilled wells should be ensured.

Currently the UNDP is assisting the Chadian government in the standardization of well designs, installation- and well development procedures. Once the Chadian well standards are introduced, 45 independent technicians (government or consultant) will be trained (coming 5 years) in supervision of the quality standards and accreditation of drilling enterprises. The technicians will be integrated among the private sector, consultant- and water agencies and NGO's. Some of these technicians could monitor the manual drilling sector in future (please see chapter 6).

Besides these activities the UNDP will stimulate the Direction de l'Hydraulique to play the leading part in data collection. In Chad a lot of data on 'water' are available, but unfortunately not al agencies and enterprises are sharing these data. It is advised that data will be compiled at a central point, easily assessable for water organizations and enterprises.

It is advised to integrate a quality standard for pumps and its installation in the program.

Please see chapter 6 for recommended strategies to upgrade and professionalize the manual drilling sector.

5 Conclusions

5.1 Geo-hydrology

In Chad there are a lot of data available on geology, hydrology and water quality, captured in data bases, archives and logs of the government and various water related organizations, agencies and enterprises. Unfortunately most of these valuable data is not collected at a central point and not easily assessable to organizations, agencies and enterprises which need the information for the implementation of their programs. A lot of organizations try to re-invent the wheel, while information already exists.

The general geo-hydrological map of Chad, the 'static water level information' from the known data bases and interviews with the drilling sector indicate that manual drilling could be possible in 50% (on estimation) of the country's surface in the most populated parts of Chad, namely;

North:	*Kanem and Lac*
Western border:	*Hadjer Lamis and Mayo Boneye*
South:	*Tandjile Ouest and Est, Logone Occidental, Mandoul, Bahr Koh and parts of: Kabia, Mayo Dala, Logone Oriental, Lac Iro and Salamat*

5.2 Manual drilling

Manual drilling already exists in Chad. Interviews with drilling enterprises and water organizations indicate the existence of 20 to 30 (on estimation) manual drilling enterprises, using different manual drilling techniques. Drillings are accomplished with an average depth of 30 to 35 meter. Currently, prices vary between US$ 1500,- and US$ 3000,- including a pump.

Besides manual drilling, 3 semi-mechanized drilling rigs are operational, drilling boreholes with a maximum depth of 40 up to 70 meter. Prices vary between US$ 4000,- and US$ 6000,- incl. a pump.

5.3 Problem analyses and education

At present, a lot of problems occur in water quality and discharge of manual drilled wells and installed pumps. Some of the manual drilling enterprises are very professional and perform good quality drillings and well installations while other enterprises have a lack of knowledge on relevant subjects, needed for the installation of a high quality well. Due to the history and variety in quality of manual drilled wells, it has a negative image among water related organizations and only some of them are contracting manual drilling enterprises for the installation of their wells.

In the near future well designs and installation- and well development procedures will be standardized by the Chadian government. Once the Chadian well standards are introduced, training programs can take place to professionalize the existing manual drilling sector. The set-up of a proper training program, a quality monitoring system and the certification of well trained professional enterprises will diversify the high skilled and professional drilling enterprises from the 'amateurs'.

At the end an expanding (and well monitored), professional manual drilling sector will increase the well drilling capacity in Chad, and will create a large cost reduction in the price of 'shallow' wells, making water wells assessable to a much bigger part of the Chadian population.

5.4 Evaluation meeting

At the end of this project an evaluation took place with UNICEF and a draft proposal and training strategy (to improve well and water quality by professionalizing the manual drilling sector) was drawn up. The proposed strategy was discussed with UNICEF, Oxfam GB, UNDP and EU 'water' consultants. The mentioned organizations are positive on the proposed strategy and offer their assistance in the set-up of the proposed phase II – phase IV projects (please see chapter 6).

6 Recommendations

Together with the UNICEF project team a proposal and training strategy to professionalize the manual drilling sector was drawn up. It is recommended to apply the following strategy;

6.1 Phase II: Identification, assessment and preparation

1. Inventory of all existing manual drilling enterprises and drilling NGO's and professional drilling enterprises which are interested in setting-up manual drilling teams.

2. Identification of activities, problems, used drilling techniques and professional level of drilling enterprises/NGO's (selection of enterprises/NGO's to participate in Phase III). Of each existing manual drilling technique a complete drilling and well installation will be monitored.

3. Detailed identification of all areas suitable for manual drilling based on the geo-hydrology. Existing data from government, water related organizations/agencies and drilling enterprises will be compiled. 'Combined maps' of the geography (road map), geo-hydrology and static water levels will be made on province or region level (please see paragraph 2.4).

4. Selection of a technical expert/independent consultant/NGO for quality management (QM) and follow-up training of enterprises which participated in Phase III. This agency (possibly assisted by Practica) will be responsible for quality monitoring during drilling and finished wells and coordinate certification (and announcements of this certification to government, NGO's and media) of the trained enterprises (and will participate in all Practica missions). Further, the QM agency will be responsible for 'social' marketing to potential customers (please see also paragraph 4.6).

5. Preparations prior to Phase III;

    - i) Supervision of 'purchase and construction' of drilling equipment, to be used in Phase III.

    - ii) Completion of the 'Drilling Manuals' by writing volume III (well design, drilling logs, hygiene, development, etc.) and translation of the three drilling manuals in French (i.e. 'Construction and Maintenance of Rota sludge drilling equipment', 'Operation of the Rota sludge' and 'Geo-Hydrology, Hygiene and well designs'. If necessary; translation of existing drilling manuals (i.e. 'jetting-', 'hand auger-' and 'percussion' drilling).

6.2 Phase III: Training prior to certification

- Training of drilling enterprises and NGO's (selected in Phase II) in all aspects of; manual drilling techniques in relation to the geology, hygiene, drilling logs and soil description, data management, well design, development, pumping tests, water quality tests, business skills and certification, etc. (practical and theoretical sessions).

    - Depending on the identification results of Phase II, Phase III might be repeated annually to cover the whole sector (a step by step approach is recommended in order to ensure quality. In the first year the most professional drilling enterprises will be trained. In later stage additional training of other drilling enterprises can take place).

- Training of NGO and 'water' agency employees in important aspects of manual drilling, well installation and explanation of the certification system.

- Provide a contract of 20 wells to each trained enterprise/NGO's to be implemented in the concentration areas of UNICEF programs. After these first 20 wells the enterprises will be certified (Phase IV) if the standards of quality are 'proven'.

6.3 Phase IV: Follow-up, certification and monitoring

- Follow-up training of all (in Phase III) trained drilling enterprises/NGO's
    - Aspects are based on requests and evaluation with the drilling enterprises/NGO's and evaluation with QM agency.
    - Visits to drilling enterprises/NGO's during drilling (monitoring of the drilling- and well installation process)
    - 'Field quality tests' on previous installed wells
    - Check on the database (drilling logs) of enterprises/NGO's
- Follow-up training of QM agency, based on evaluation
- Certification 'rounds'

6.4 Time frame

Completion of Phase II – Phase IV (incl. certification and 3 follow-up missions) is estimated to continue for a period of 2 years (based on one Phase III training program).

Phase	***Weeks (ind.)***	***Participants***	***Tasks***
Phase I	4	UNICEF Practica Foundation	Feasibility study September 2005 Completed September 2005
Phase II	5	UNICEF/others	Inventory of existing (manual) drilling enterprises and NGO's (prior to arrival of Practica) (1)
	8	Fabio Fussi, UNICEF	Detailed identification of suitable areas and production of maps (3) Supervision on purchase and construction of drilling equipment (5 i)
	5	Practica/UNICEF/others	Selection (and identification) of enterprises (2) Selection of (and arrangements with) QM agency (4) Supervision on purchase and construction of drilling equipment (5 i)
	8	Practica	Completion and translation of drilling manuals (5 ii)
Phase III	7*	Practica/UNICEF	Training of drilling enterprises/NGO's (theoretical and practical sessions) (*1 or 2 trainers, depending on subjects and areas)
	1	Practica/UNICEF	Training of NGO's and 'water' agencies
	x	UNICEF	Providing contracts (20 wells each)
Phase IV	3 visits of 4 wks	Practica/UNICEF/others	Follow-up training of drilling enterprises/NGO's Follow-up training of QM agency Certification
Phase III and IV	min. of 2 years	QM	See task description (4)
	?	Practica	Back stopping (e-mail/phone) to QM agency

Besides the proposed strategy it is recommended for UNICEF to pay attention to the quality of the installed pumps (a subject which might be discussed with the UNDP, please see paragraph 4.6) and community participation (with other NGO's) in places where pumps are going to be installed.

A special thanks for their cooperation to:

- *Sílvia Gaya, UNICEF*
- *Jean Baptiste Ndikumana, UNICEF*
- *Philippe Ankani, UNICEF*
- *Fabio Fussi, Oxfam GB*

- *Paul Hansbury, UNDP*
- *Saleh Mouhyddine, coordinator Gedel*
- *Ermanna Favareno Delacroix, head of 9eme Fed EU program*
- *Direction de l'Hydraulique*

Literature used:

- *The integrated plan for Chad's water development and management 2003 – 2020*

Appendix

A Maps

Geographical map (1)
Geo-Hydrological map (1)

Country map of static water levels (1)

Combined maps on province level (3)

pH and Conductivity maps (2)

B Data base

Selection of database information

C Itinerary

Short daily reports

D Product sheet Rota sludge

Information on the Rota sludge technique

Appendix A

Maps

Geographical map (1)
Geo-Hydrological map (1)

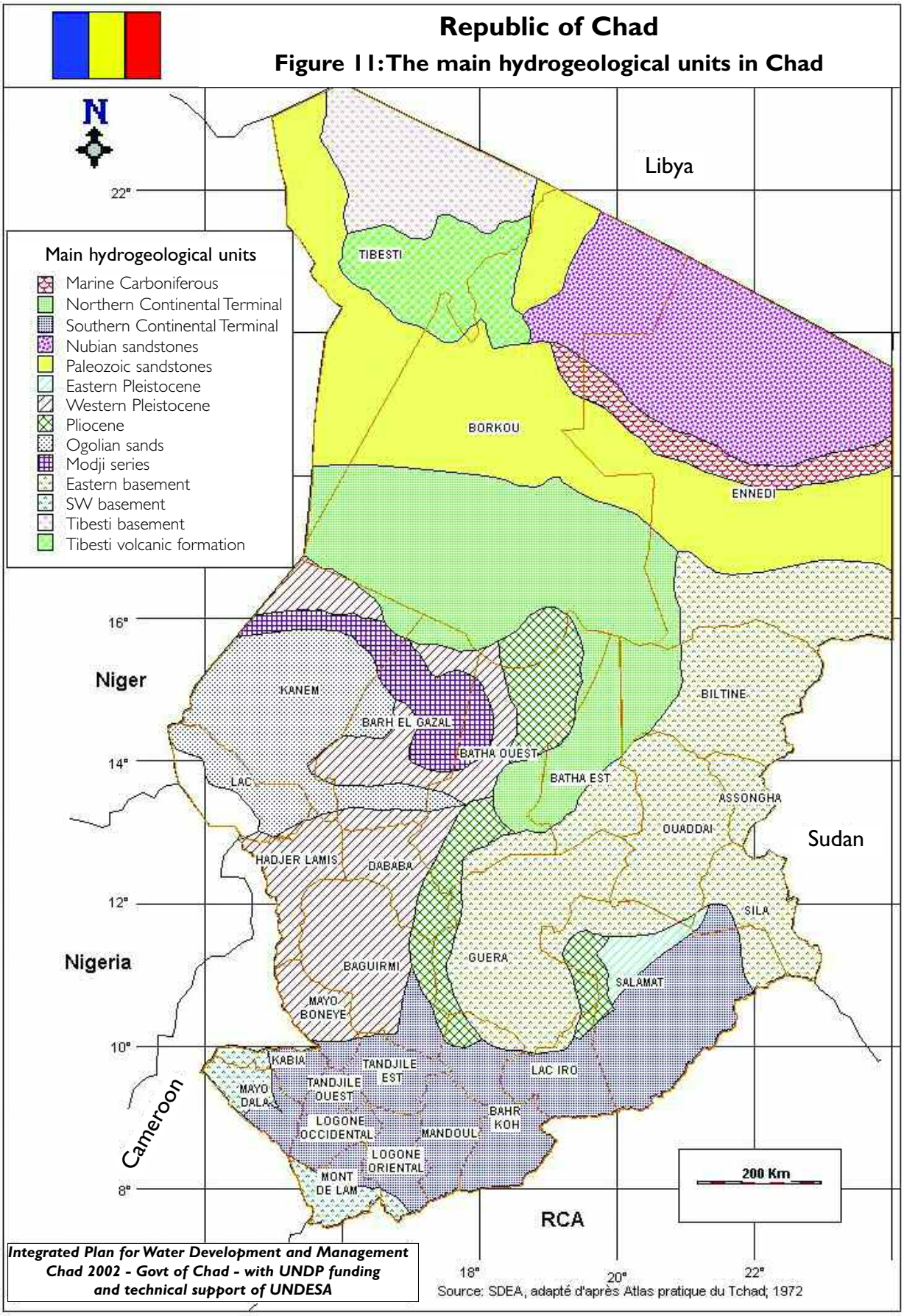
Country map of static water levels (1)

Combined maps on province level (3)

pH and Conductivity maps (2)

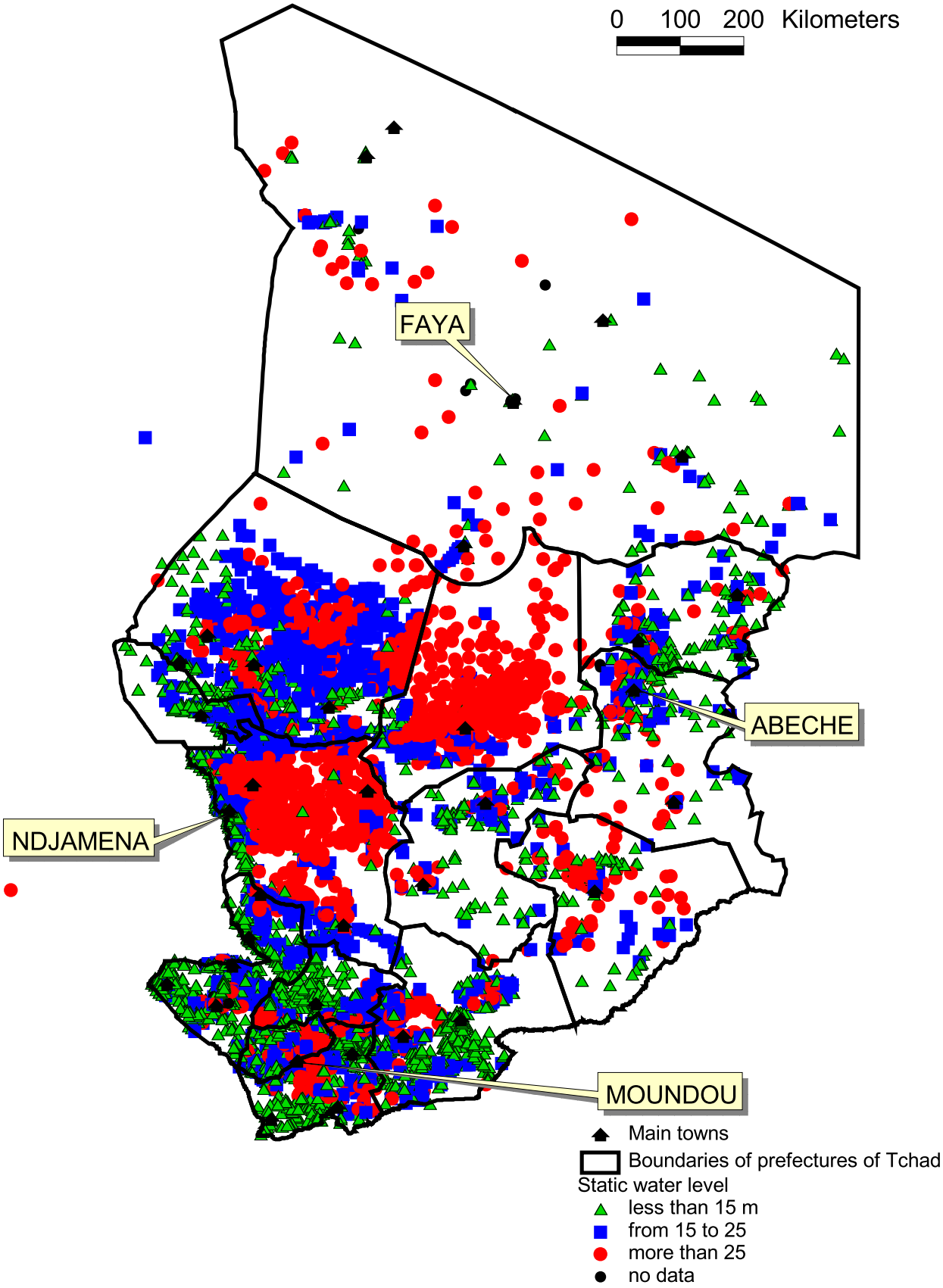
Map No. 3788 (F) Rev. 3 United Nations
October 2003

Department of Public Information
Cartographic Section

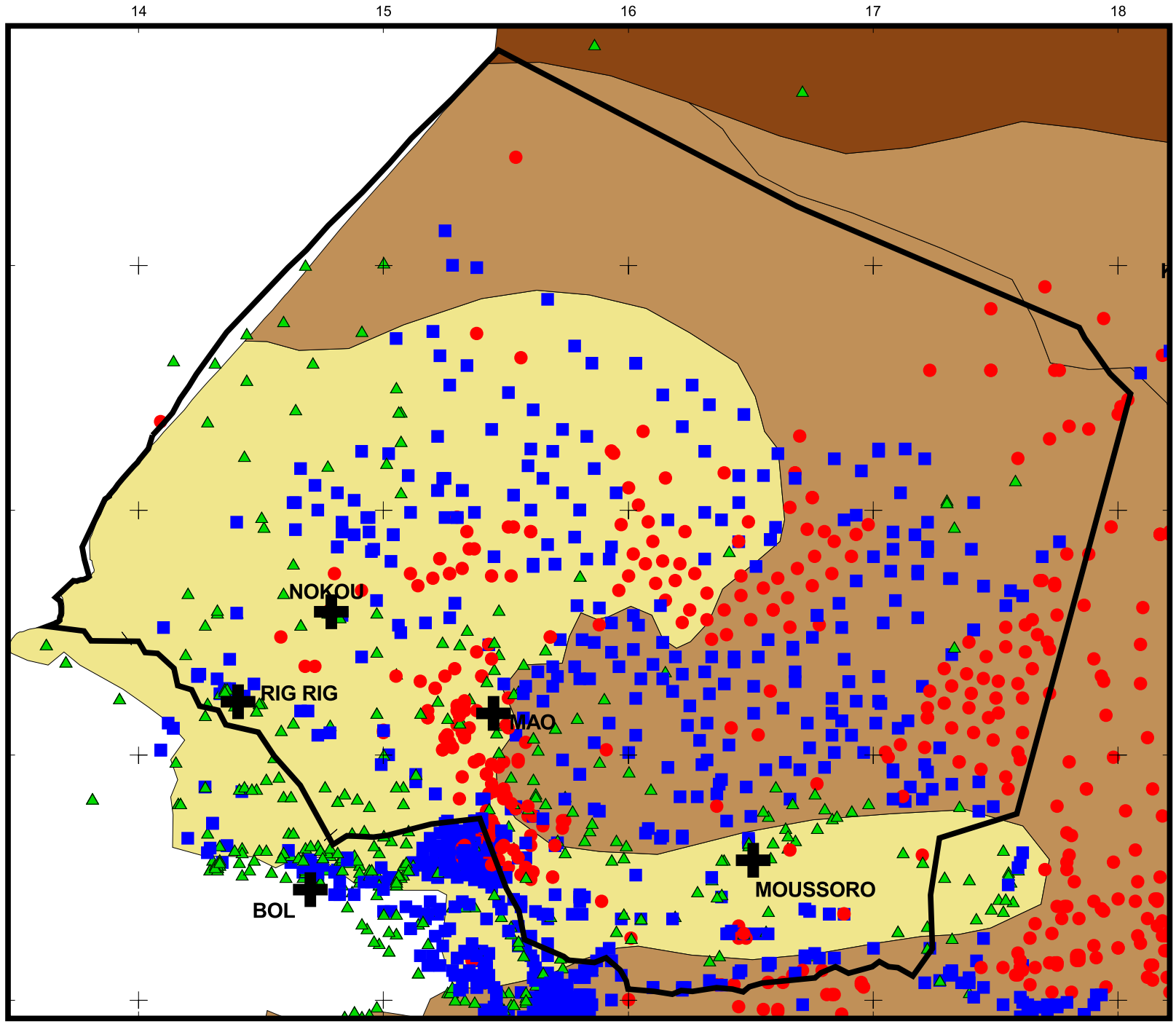

Republic of Chad
Figure 11: The main hydrogeological units in Chad
N
Libya
Sudan
Niger
Nigeria
Cameroon
RCA
22°
16°
14°
12°
10°
8°
18°
20°
22°
Main hydrogeological units
Marine Carboniferous
Northern Continental Terminal
Southern Continental Terminal
Nubian sandstones
Paleozoic sandstones
Eastern Pleistocene
Western Pleistocene
Pliocene
Ogolian sands
Modji series
Eastern basement
SW basement
Tibesti basement
Tibesti volcanic formation
TIBESTI
BORKOU
ENNEDI
KANEM
BARH EL GAZAL
BATHA OUEST
BATHA EST
BILTINE
ASSONGHA
OUADDAI
LAC
HADJER LAMIS
DABABA
SILA
GUERA
BAGUIRMI
SALAMAT
MAYO BONEYE
KABIA
TANDJILE EST
TANDJILE OUEST
MAYO DALA
LAC IRO
LOGONE OCCIDENTAL
MANDOUL
BAHR KOH
LOGONE ORIENTAL
MONT DE LAM
200 Km
Integrated Plan for Water Development and Management
Chad 2002 - Govt of Chad - with UNDP funding
and technical support of UNDESA
Source: SDEA, adapté d'après Atlas pratique du Tchad; 1972

Map of Static Water Level
(recorded in existing wells database)

Scale 1:9000000



Hydrogeological Map - Kanem



KANEM

Main towns

Static water level

- less than 15 m
- from 15 to 25
- more than 25
- no data

Hydrogeological units

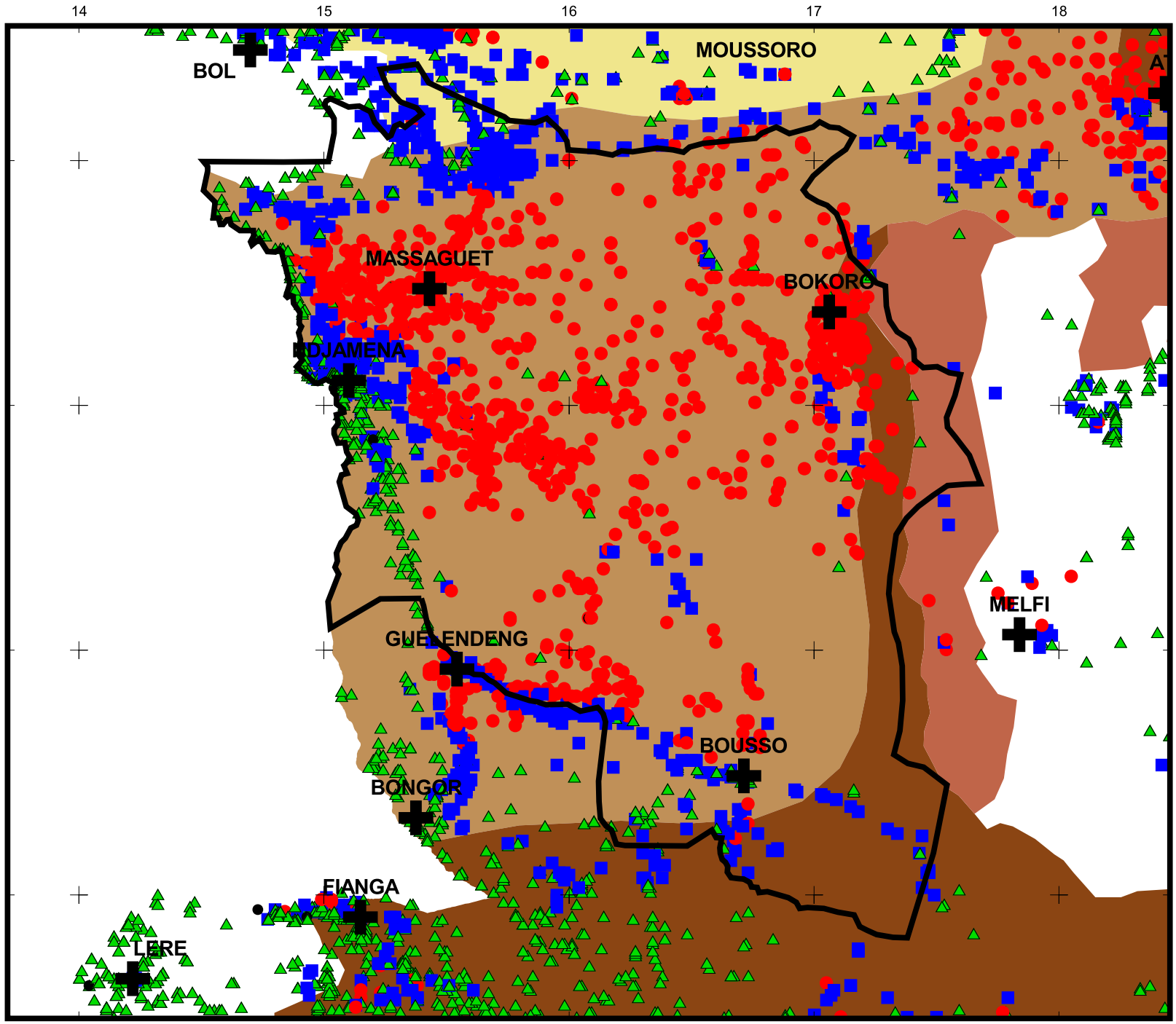
- Sables éoliens généralement bien classés
- Série fluviolacustre
- Série fluviolacustre du CT

Scale 1:2500000

0 40 80 Kilometers

N

Hydrogeological Map - Chari Baguirmi



CHARI BAGUIRMI

Main towns

Static water level

- less than 15 m
- from 15 to 25
- more than 25
- no data

Hydrogeological units - chari baguirmi.shp

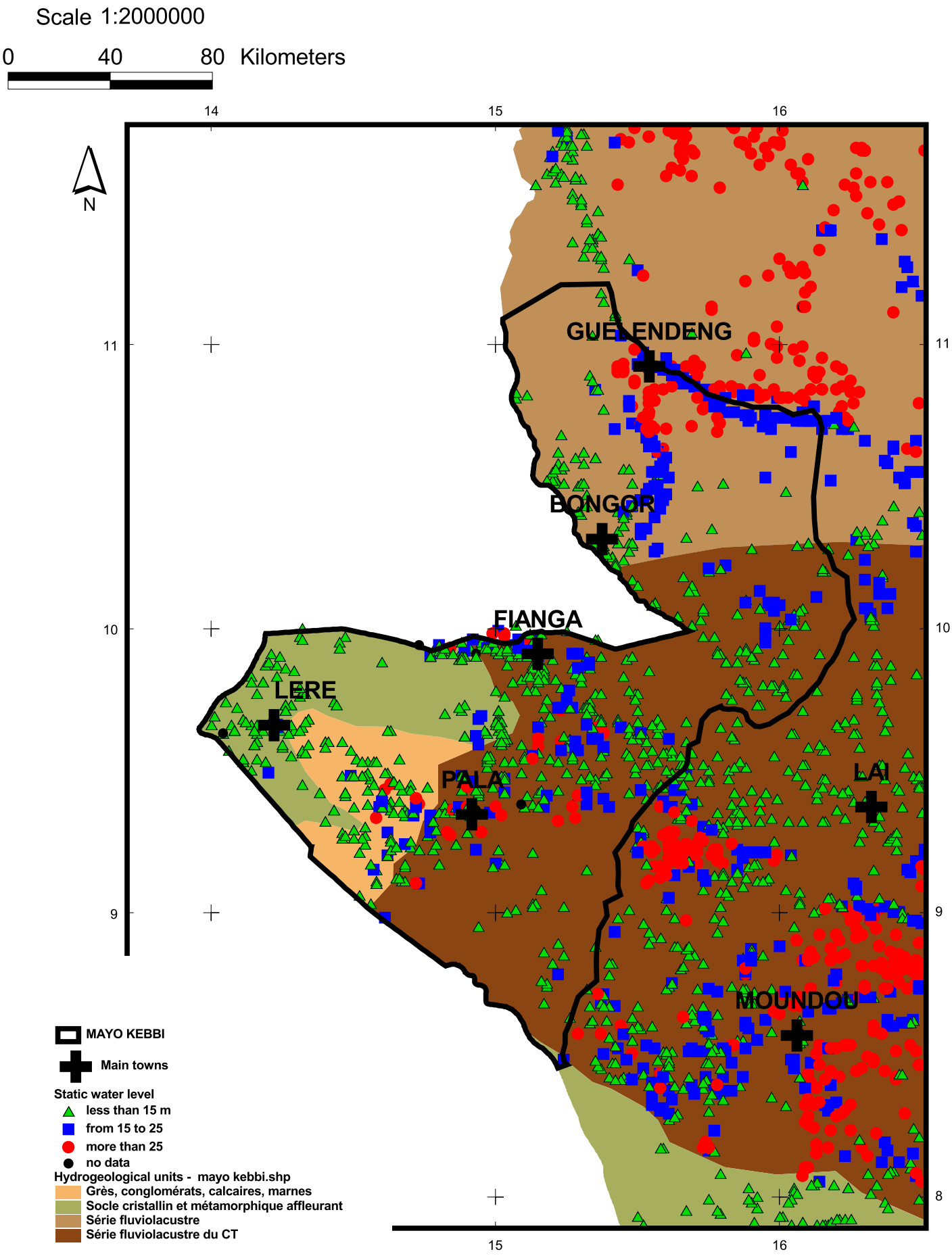
- Dépôts tertiaires et quaternaires reposant sur le socle
- Sables éoliens généralement bien classés
- Série fluviolacustre
- Série fluviolacustre du CT

Scale 1:2500000

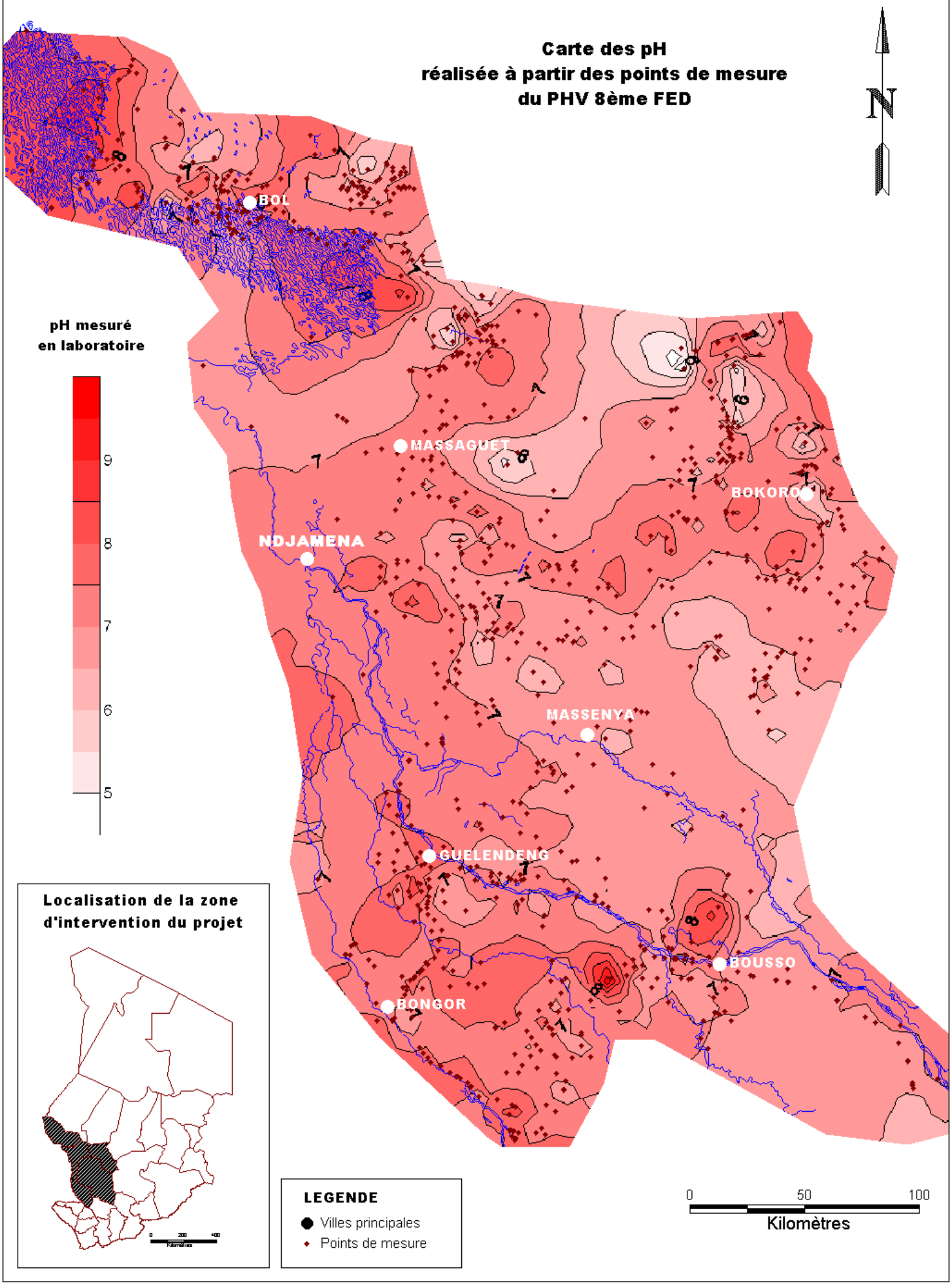
0 40 80 Kilometers

N

Hydrogeological Map - Mayo Kebbi

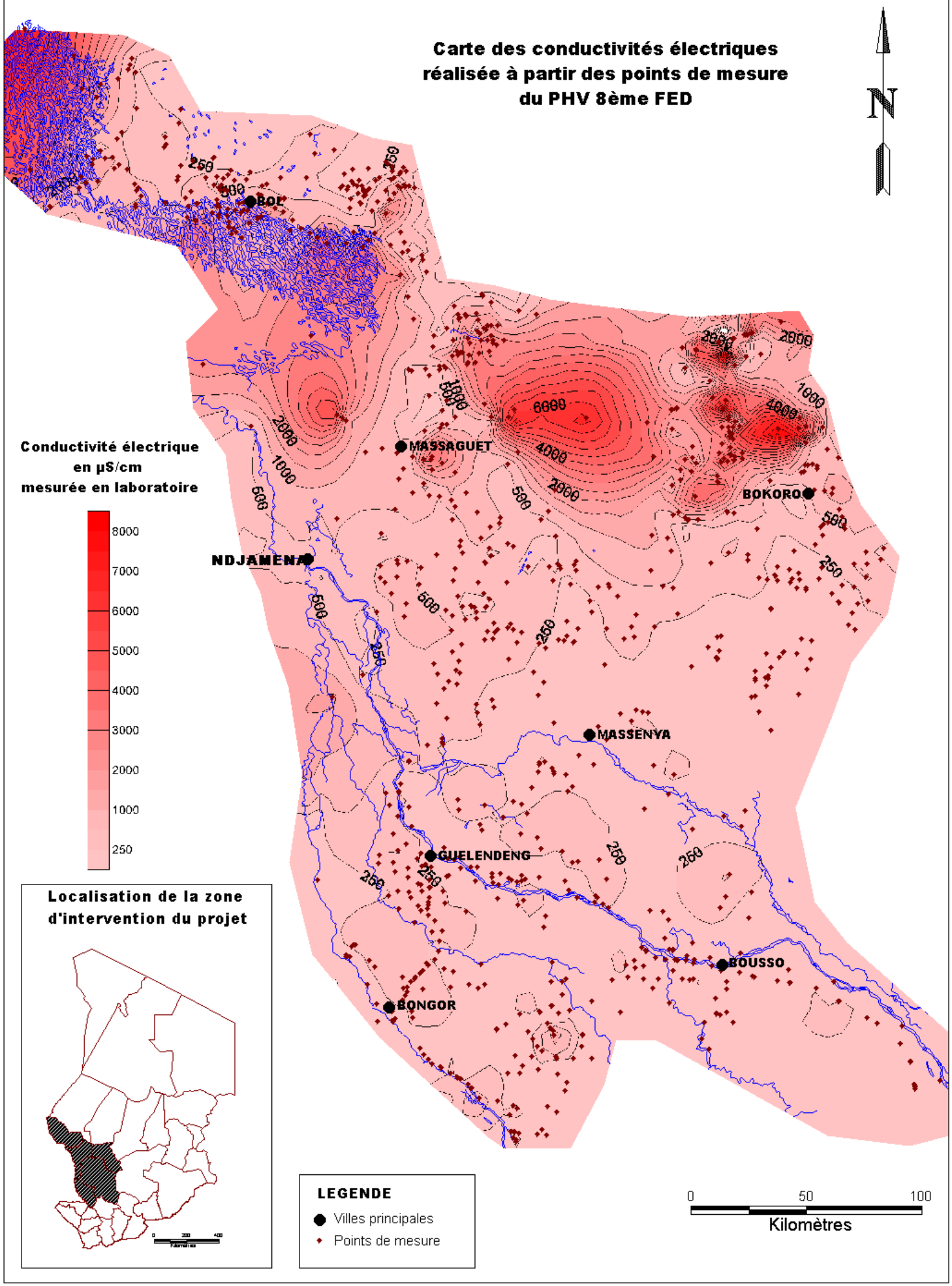


PROJET D'HYDRAULIQUE VILLAGEOISE du 8ème FED au TCHAD



C LOTTI / BCEOM

PROJET D'HYDRAULIQUE VILLAGEOISE du 8ème FED au TCHAD



C LOTTI / BCEOM

Appendix B

Database

Selection of database information

Appendix B Selection of database information

Some years ago the Chadian government, the 'Direction de l'Hydraulique', started the collection of data from water points in Chad. A country wide survey was made and since then drilling enterprises were requested to fill out a drilling log and questionnaire of each well they had accomplished. They were asked to return this information to the Direction de l'Hydraulique, who put the information in a data base. By now this data base contains more than 10.000 water points since recording has started, providing a lot of useful information on the position of the wells, geology of the aquifer, depths of water tables, etc.

This database contains, among other things, the following information per well:

Position of the well:

Region
Sub-region
Canton
Name of the village
Longitude
Latitude
Suburb
GPS coordinates

Well information:

Project (incl. financed by….)
Drilling enterprise
Type of well (i.e. hand dug well or drilling)
Status (working or dry)
Use (communal, private, other)
Date of well installation
Diameter
Total depth

Other:

Infiltration test
Geomorphology
Name and type of the aquifer
Soil type of the aquifer
Statistic water level (and date of measurement)
Pumping test (inclusive date, duration and date)
Type of maintenance system
Type of installed pump
Date of installation
Use (potable, irrigation)

Appendix C

Itinerary

Short daily reports

Appendix C Itinerary

19/08 Arrival
First acquaintance with the 'project team' and evaluation of available geo-hydrological information. Start collection of preforma's and materials for research and for construction of the drilling equipment.

20/08 Introduction to UNICEF staff members. Collection of preforma's and materials and start with construction of the drilling equipment. Collection and evaluation of geo-hydrological data. Discussion with the owner of a drilling company.

22/08 Meeting with the 'Direction de l'Hydraulique'. Construction of drilling equipment. Further collection of preforma's and materials, etc. Processing of geo-hydrological data.

23/08 Meeting with Mrs. Ermanna Favareno (EU consultant, head of mission 9eme Fed EU program). Construction of drilling equipment. Interview with a manual drilling enterprise, N'Djamena. Processing of geo-hydrological data and collection of materials and equipment. Administrative delays.

24/08 Meeting with Paul Hansbury (UNDP) and Saleh Mouhyddine (coordinator Gedel). Visit to a manual drilling enterprise. Collection of the drilling equipment at the workshop. Administrative delays.

25/08 Processing of geo-hydrological data. Evaluation and discussion with the project team. Administrative delays.

26/08 Travel: N'Djamena – Mani – Djakbere. Visit to Mani to locate a drilling site. Inventory of existing drilling holes. Visit to the head of the village of Djakbere. Drilling site selection, request for 'employees' from the village and unloading of materials.

27/08 Selection of 'employees'. Explanation on the Rota sludge drilling technique. Installation of the drill rig. Training of the employees in manual drilling and start of the drilling.

28/08 Training of villagers in the use of the Rota sludge. Continuation of the drilling.

29/08 Training of the villagers in the use of the Rota sludge. Continuation of the drilling, repositioning of drill rig, inflow of sand from the top and broken equipment. Collection of water samples (river and existing well).

30/08 Return to N'Djamena. Discussion and evaluation on geo-hydrological data and processing of maps with Fabio Fussi. Departure of Fabio Fussi. Collection of preforma's for additional materials.

31/08 Repair and purchase equipment. Administrative delays.

01/09 Purchase last equipment. Processing of data. Return to Mani and Djakbere.

02/09 Attempts to free the drill bit with jetting (drilling with water pressure). Removal of drilling pipes. Return to N'Djamena for purchasing material for construction of a new drill bit.

03/09 Construction of a new drill bit. Processing of geological data.

04/09 Travel: N'Djamena – Djakbere. Installation of the drilling rig. Start drilling and installation of temporary casing.

05/09 Training of the villagers and continuation of the drilling.

06/09 Collection of drilling equipment in Djakbere. Return to N'Djamena.
Visit to the Direction de l'Hydraulique.

07/09 Visit to the Direction de l'Hydraulique. Visit to Ermanna Favareno (EU consultant, head of mission 9eme Fed EU program). Visit to university. Processing of data.

08/09 Processing of data. Work out of a future training strategy. Preparations for mission to the South.

09/09 Preparations for mission to the South. Administrative delays. Travel: N'Djamena – Bongoro.

10/09 Travel: Bongoro – Pala. Meeting and interviews with the NGO Belact, the coordinator of the UNDP Gedel program in the South and GTZ.

11/09 Set-up of proposed training strategy. Visit to a well drilling association in the village of Bissimafu (semi-mechanized drilling rig).

12/09 Travel: Pala – Moundou. Visit to and interviews with the NGO's Word Vision and Sadia (semi-mechanized drilling). Travel Moundou – N'Djamena.

13/09 Interviews with several manual drilling enterprises in N'Djamena. Evaluation of information.

14/09 Presentation for UNICEF employees. Final discussion with UNICEF on the proposed strategy.

15/09 Debriefing with UNICEF.
Presentation and discussion of the proposed strategy with UNICEF, UNDP, EU and Oxfam GB consultants.

16/09 Departure.

Appendix D

Product sheet Rota sludge

Information on the Rota sludge technique

Appendix D **Information on The Rota sludge**

PRACTICA foundation

Product sheet

Stone-hammer and Rota-sludge for harder soils

In addition to the existing methods for manual drilling, Practica has developed a drilling package consisting of the Rota-sludge and Stone-hammer. The Rota-sludge scrapes and hammers lightly, while the Stone-hammer hammers with considerable force. The Rota-sludge is used for soft and semi consolidated formations (i.e. sand stone, tuff stone and clay stone) the Stone-hammer is used for boulders. The Rota-sludge is based on the sludge or hand percussion method as practised in India but modified with a rotation.

Rota sludge drilling

How it works

Rota- sludge

The equipment consists of a column of 2 inch pipes, screwed together, with a cutter on the bottom end. This pipe column is lifted by a lever and dropped down sharply to hit the bottom of the well. A handle is attached to the pipe and at the moment of impact the pipe is turned about 45 degrees.

The cutter at the bottom is provided with teeth, which scrape away soil. So there is a hammering and scraping action.

When the pipe column is lifted, the driller closes off the top of the pipe and opens it at the beginning of the down-stroke. Because the well is kept full of water, this closing and opening at the right moment, causes the water to be pumped up through the drilling pipe. The water flow carries the cuttings with it.

To seal off the walls of the well, to prevent caving–in and facilitate the transport of cuttings, cow-dung is added to the water. This makes a sludge, hence the name Rota-sludge.

Stone-hammer

When boulders or hard clay are encountered, the Stone-hammer can be used. The hammer is a closed piece of pipe with an open-ended drill bit at the bottom. In the pipe a weight (hammer) is activated with a rope from the surface. Lifting and dropping the hammer drives the drill bit down. When 60cm has been drilled, the unit is pulled up to the surface to empty the hollow drill bit

Stone-hammer drilling

Economics

The investment cost for a complete set of Rota-sludge or Stone-hammer equipment is in the order of $800 in Africa and Latin America and about $ 150 in India. Machine drilled wells often cost $100-300 per meter (West Africa), dug-wells around $50/m (Nicaragua) and manually drilled wells cost in the order of $25/m (Nicaragua). In Chad prices are higher (please see the report).

Rota-sludge drill bit

Applicability

Experience gathered so far, shows that the Rota-sludge and Stone-hammer methods come in where the soil is too hard for jetting or augers.

Most developing countries have regions where these methods can work and are cheaper than other options. At present the PRACTICA manual drilling techniques have been introduced in India, Tanzania, Nicaragua, Ghana, Ethiopia, Senegal and Niger. In Chad it will be introduced in 2005/2006.

Introduction

To find out if and to what extent these methods of manual drilling are of interest for a country or region, PRACTICA usually carries out a feasibility mission. This mission comprises a study of the geology to have a first indication where it may be feasible, followed by fieldwork where the geological data are checked against the information in the field from existing wells, well diggers and visual information. To complete the mission, in the areas where chances of success are highest, some test wells are drilled. The duration of an identification mission is generally around six weeks. Based on the information gathered in this process, A decision can be made on how to proceed. If it is decided to proceed, PRACTICA can provide training and technical assistance. Manuals are available, both for the manufacture of the equipment and the drilling.

Stone-hammer drill bit

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