

Institute of Geological Sciences  
Hydrogeological Department



## Hydrogeological report of the Overseas Development Administration's water/livestock development mission to the eastern region of Niger, June 1973

By

J. B. W. Day, B.Sc.

Exhibition Road London  
1973

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HYDROGEOLOGICAL REPORT OF THE  
OVERSEAS DEVELOPMENT ADMINISTRATION'S  
WATER/LIVESTOCK DEVELOPMENT MISSION  
TO NIGER, JUNE 1973

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## C O N T E N T S

	Page
Conclusions .. .. .	i
Recommendations .. .. .	iv
Introduction .. .. .	1
Members of the Mission .. .. .	1
The Mission's Initial Activities in Niamey .. .. .	1
Current Aid Activity in the Water/Livestock Field .. .. .	2
The Mission's Visit by Road to the Eastern Region .. .. .	2
Definitions of Area Described .. .. .	9
Topography and Climate .. .. .	9
Geology and Hydrogeology of Area .. .. .	10
Well Construction .. .. .	13
Well Maintenance .. .. .	14
References .. .. .	15

## I L L U S T R A T I O N S

- Figure 1 Sketch map of Eastern Region of Niger.
- Plate 1a Supplies of cattle fodder for drought relief being unloaded at the Veterinary Station, Zinder.
- Plate 1b Well maintenance by OFEDES at Boulangouyakou.
- Plate 2a The borehole at Kelakam, drilled in Nov-Dec 1971 and financed by British aid funds.
- Plate 2b The remains of two boreholes, sunk during the early 1960's and financed by British aid funds, at Mainé Soroa.
- Plate 3a Traditional well in interdunary depression north of Mainé Soroa.
- Plate 3b The artesian public supply borehole in the market place at Diffa.
- Plate 4a Artesian borehole and irrigated crops in the Watchman's garden at Adjikoyari, Plaine du Kadzell.
- Plate 4b Irrigated garden at Kabit.
- Plate 5a Village cattle being watered from the artesian borehole at Mamari, Plaine du Kadzell.
- Plate 5b Kuri (Lake Tchad) cattle on the shores of the lake at N'guimi.

## Conclusions

1. Additional water sources in the area of the Dillia Valley are unnecessary as there are enough already.
2. I do not have sufficient detailed information to state positively that each or all of the 115 pastoral zone wells proposed as aid-worthy are not required, but my general impression is that their sites have been plotted on a grid basis without regard to effects on surrounding pasturage and in most cases without taking account of existing traditional water sources.
3. Over-grazing is rife in the areas of eastern Niger visited and there is no reason to suppose that conditions are appreciably different in the remainder of this part of the Sahelian pastoral zone.
4. Over-grazing is due mainly to an increase in numbers of cattle and other domestic animals in recent years. At the same time pasturage has deteriorated because of continuing partial failure of the annual rains since 1966.
5. Increases in the numbers of stock beyond the maximum for optimum utilisation of pasturage are due to a number of factors, one of which appears to be the unco-ordinated provision by various donors, including the British, of artesian boreholes, puits forage and modern wide-diameter cemented wells. All of these enable water to be drawn much more rapidly than from single-bucket wells of traditional design. Traditional wells evidently provide a regulator to the numbers of stock carried by a particular area.
6. I agree with Mr Davie's conclusion that if there still are substantial areas of under-utilised pasturage where the constraint is lack of water, then such areas should be reserved for future ranching, and not grazed by nomads.
7. To date the provision of boreholes and wells in eastern Niger from British aid funds has been executed by a single contractor, Messrs Balakhany Ltd, without British technical supervision in the field. It appears that such schemes have been originated mainly by Balakhany Ltd, and promoted by the President's office without proper reference to the relevant Government Department. Maintenance

problems have resulted, and 2 recently drilled expensive boreholes now stand abandoned, their pumps broken.

8. The state-owned well maintenance organisation known as the Office des Eaux du Sous Sol (OFEDES) is efficient, and competently directed at both central and regional levels. It has the capability to sink new shafts and construct associated surface works, but does not possess drilling facilities.
9. On the Plaine du Kadzell the provision of deep artesian (overflowing) boreholes from British aid funds appears to have created a particularly serious situation. The wells provide large supplies of potable water at the turn of a tap, and in some instances are as little as 5-6 kilometres apart. As a result all grazing has disappeared and remaining resident cattle are dying around the wells. By contrast, further north in the more truly desertic area, we saw a herd of cattle in relatively good shape around a relatively remote well, indicating that in this neighbourhood at least, some standing pasture remained within grazing distance.
10. Groundwater, commonly of good chemical quality and at shallow depth, is available in the superficial dune sands and/or underlying upper sandy layers of the Tchad Formation virtually throughout the area. This groundwater body is periodically recharged by infiltrating rainfall. By contrast, abstraction from confined artesian aquifers at greater depth is at the expense of the resource. In the north Goure' area the main aquifer is the sands of the Cretaceous Tegama Series.
11. Groundwater storage in the superficial aquifer is sufficient to meet existing and foreseeable demands in the public supply and livestock sectors. Large scale abstraction, ie for agricultural irrigation, might however exhaust supplies locally. Supplies should, however, be adequate for small-scale local irrigation projects.
12. There appears to be scope for growing vegetables and possibly animal feed using limited irrigation on suitable soils within interdunary depressions, where shallow water table conditions exist.

13. The absence of an official interpreter during the visit to the Eastern Region inevitably resulted in a loss of much relevant information because of our inability to communicate adequately with local officials and inhabitants.



### Recommendations

1. The Overseas Development Administration should not support the request by the Nigérien Government for the provision of aid funds in respect of 3 boreholes in the Dillia Valley.
2. The Overseas Development Administration should not support the request for aid funds in respect of a blanket "programme d'équipement hydraulique de la zone pastorale" involving the provision of 115 wells.
3. Favourable consideration should be given to any request for provision of improved town supplies in eastern Niger (although I understand that the Canadians have recently offered aid in this respect).
4. Consideration should be given to initiating a small-scale medium to long-term technical assistance project at village level for the growing of vegetables and animal feed by irrigation. Social, land ownership and local marketing factors need to be borne in mind, and it is suggested that as a first step an agricultural (soils) expert should visit the area with a view to determining what work has already been done in this field and, if appropriate, how and where best to implement the project. I draw attention to the IBRD Niger Economic Report dated June 1st 1972, paragraph 110, page 35.
5. On future visits to Francophone West Africa, Overseas Development Administration advisory personnel should, unless there are good reasons to the contrary or unless they are fluent in either French or a local dialect, be accompanied by an interpreter.

HYDROGEOLOGICAL REPORT OF THE OVERSEAS DEVELOPMENT ADMINISTRATION'S  
WATER/LIVESTOCK DEVELOPMENT MISSION TO NIGER, JUNE 1973

Introduction

The Mission visited Niger to investigate projects in the livestock/water development field proposed as aid-worthy by the Nigérien Government. These projects were situated in the eastern region of the country and concerned the provision of wells or boreholes for watering livestock, mainly cattle. More specifically two projects were envisaged, the first involving the construction of 115 wells in the pastoral region between Zinder and the frontier with Tchad, and the second the sinking of 3 boreholes to be equipped with mechanical pumps in the Dillia valley north-west of Lake Tchad.

The Members of the Mission

The Mission was led by Mr J Davie, Deputy Animal Health Adviser to ODA, accompanied by Mr N B Hudson, Senior Economic Adviser to ODA, and Mr J B W Day of the Hydrogeological Department, Institute of Geological Sciences. Whilst in Niamey the Mission was accompanied by Mr M Blick of Embassy, Abidjan.

The Mission's initial activities in Niamey

Day arrived in Niamey early on the 4 June and was met by a car provided by the Nigérien Government. He later met Mr Tafarielli, Honorary British Consul, at lunch. Davie, Hudson and Blick arrived during the early afternoon. Later a meeting was arranged at the Ministry of Development and Co-operation at which details of the proposed projects were given and a proposed itinerary for the remainder of the Mission's stay. A visit to the eastern region between 8th and 20 June was included. It was regretted that no interpreter could be provided, despite a previous agreement to do so. The Mission would, however, be accompanied in the field by M. Ayaga and M. Jacques Morey of the Direction du Géologie et Mines.

On the 5th, 6th and 7th June further meetings took place in Niamey -

1. At the Veterinary Laboratory;
2. At the Ministry of Economic Development;
3. UNDP;
4. FED;
5. USAID;
6. OFEDES.

When Davie and Day departed for Zinder by air on the afternoon of the 7th,

Mr Hudson and Mr Blick remained in Niamey for further discussions.

#### Current aid activity in the water/livestock field

Nine boreholes have recently been sunk, financed by FED funds, in the pastoral zone north of Gouré in connection with a State-managed ranching scheme, which ran into difficulties with the nomads who, considering that they had been displaced from their hereditary grazing grounds, resorted to active sabotage. Now only five mechanically pumped boreholes are operational. Two regional schemes are currently proposed for the blanket provision of open wells in the pastoral zone — one involving 110 wells in the Tahoua area of western Niger, and the other, 115 wells in the pastoral zone east of Zinder. To date aid funds have not been forthcoming for either scheme, and British aid is now requested in respect of the latter.

**There is also a continuing large-scale programme**, again under the auspices of FED for the modernisation of village wells. Modern-style cemented wells are planned for each village in Niger whose population exceeds 200. Of 9000 such villages, 3500 already have modern wells leaving a balance of 5500. It is planned that the State-owned Office des Eaux du Sous Sol (OFEDS) should construct 1058 wells within the next three years, using village labour. The Canadians have recently agreed to finance 107 of these wells in the Mainé Soroa district.

#### The Mission's visit by road to the Eastern Region

Messrs Davie, Day, Ayaga and Morey were met at Zinder and taken to the Préfecture where they were dined and later accommodated in the Government Resthouse. Next day after a visit to the local Abattoir and discussions with the Préfet, and later the officer in charge of the local branch of OFEDS, preparations were made for the field trip. Two Land Rovers, one of which was provided by the President's Office, appeared to be in good condition and well maintained. We were positively assured that enough fuel was being carried for the entire trip.

At 6 am on the 9th June we set out for Mainé Soroa, a distance of 385 km.

En route we visited two boreholes drilled and equipped by Messrs Balakhany during 1971, and paid for by British Aid Funds, at Goudoumaria and Kelakam. Both bores were out of use; at Goudoumaria the shaft drive to the pump was loose and one handle missing, and at Kelakam both handles had been removed. A number of pre-existing cemented wells were still in use at both towns (water levels respectively 15 - 20 m and 10 - 15 m below surface), and appeared to be providing adequate supplies by manual abstraction. It appeared that both boreholes may have been unnecessary. In each case they had been in use only for a limited time.

Between Kelakam and Mainé traditional wells in interdunary depressions were examined with water levels between 4 and 8 m below surface. There were many such depressions throughout the region, evidently with groundwater at shallow depth. Only rarely was there evidence of irrigated crops in these depressions but where attempts at "gardening" were being made the crops appeared to be healthy and growth was lush.

On arrival at Mainé Soroa we were entertained by the Sous-Préfet. Amongst other officials we met M. Guilpin, in charge of the local branch of OFEDES.

On the following morning (Sunday, June 10th) we were told that the petrol requirement for the trip had been miscalculated, and the Mission could not proceed beyond Mainé until authorisation had been obtained from Niamey for additional purchases. Asked if we could pay for a further 1000 litres of petrol we refused, regretting that we could not do so since it had clearly been agreed that the Nigérien Government would pay such expenses. We were then told that nothing could be settled before Tuesday since Government Offices were closed on Sunday and Monday. After protesting and threatening to return forthwith, radio contact was established with Duty Government Officer in Niamey and in due course (later that afternoon), authorisation was received. However, petrol had to be purchased the following day in Nigeria, so that our departure was delayed until the afternoon of Monday the 11th. Meanwhile on Sunday morning we visited the offices and workshop of OFEDES in Mainé and M. Guilpin explained

the organisation and working methods of his well maintenance staff. We were shown inter alia two crated diesel power units destined for the Balakhany wells at Goudoumaria and Kelakam; if funds were made available these were due to be fitted next year. We also visited the town wells in the low ground at Mainé. These consisted of two disused boreholes, originally both drilled by Balakhany in the early 1960's and since collapsed or corroded (remains of pumps and a pumphouse were still visible), a more recent (1962) 280 m deep 2 in pvc-lined sub-artesian borehole (also drilled by Balakhany) discharging at approximately one litre per second into a surrounding concrete-lined open shaft ("puit-forage") 30 m deep. We were informed that the shaft filled up overnight to the piezometric level about 2-3 m below surface (bs) so that a considerable amount of storage was created. In addition a short distance away there was an open shaft tapping the phreatic aquifer in which the water level was 40 m bs. The yield of this well was said to be better than that of the puit-forage, and 4-5 people could be seen hauling buckets at the same time. A record of the 1962 Balakhany borehole is available at IGS.

At the highest part of the town near the Préfecture is another open shaft for public supply containing very silty water, and a recent (1969) Balakhany borehole, converted into a covered puit-forage (with pump) by OFEDES. This well provides the hospital with a good-quality supply amounting to 24,000 litres per day. This pvc-lined borehole taps a thin, confined sand ("middle") aquifer at 289 m and is fitted with a total of 5 m of 3 in-diameter Johnson stainless steel screen. A record of this borehole, sunk under Crown Agents contract Q.516/1, is also held at IGS.

We eventually left for Diffa on Monday afternoon, accompanied by an additional (OFEDES) Land Rover driven by M. Guilpin and a local veterinary officer, M. Issa Ben Djeimat, both of whom had been instructed at short notice to accompany the Mission until its return to Mainé. Wells and artesian boreholes apparently all drilled by Balakhany (it was not known whether all were financed by British Aid Funds, but most probably were) were visited on the

Plaine du Kadzell, among them Malam Boukardi (puit-forage which was leaking and without proper drinking troughs), Chetimari, Kabit, Adjikoyari, Mamari, all of which were overflowing at the surface. With the possible exception of Malam Boukardi, all boreholes had been later relined with upvc tubing and appeared to be well maintained, without significant leakage. Most appeared to perform the dual purpose of village domestic supply and cattle watering point.

The administrative town of Diffa, population between 700 and 800, is the seat of the Préfet who is also responsible for the Sous-Préfectures of Mainé Soroa and N'Guigmi. Diffa adjoins the border with Nigeria, and many of the trade cattle which originate in the Lake Tchad area pass through en route for the abattoirs in Nigeria. The public water supply to Diffa consists of three small (effectively 2 in) diameter artesian (flowing) boreholes each approximately 1000 ft deep. The original bores have been relined with new pvc tubes in an attempt to prevent collapse of the linings through corrosion, and although the bores were in fact saved, a reduction in yield has resulted. Each bore is connected to a standpipe (see Plate 3b) and one to a simple distribution system serving the Préfecture, hospital and other nearby important buildings. However, neither the natural artesian pressure (about 12 m head) nor the yield of the bore is sufficient to maintain constant supplies even in this limited distribution system, and there is clearly a need for a properly constructed borehole of appropriate depth and diameter (say 8 in to 12 in, 300 m), a pumphouse and storage tank, and a simple distribution<sup>system</sup>/to standpipes throughout the town.

On arrival we were entertained by the Préfet.

The following day (12th June) we visited wells and artesian boreholes in the Plaine du Kadzell, en route for N'Guigmi, at the following localities: Boulangouyakou, Waragou, N'Galewa, Toumour and Kolomanga. All boreholes were well maintained (by OFEDES) and in the charge of a local guardian, who usually kept a small but productive irrigated garden. The artesian waters were acidic and highly corrosive to metals due to high CO<sub>2</sub> content but otherwise appeared to be of good chemical quality. Most emerged at the surface at a temperature of

approximately 39 - 40°C.

At N'Guigmi we were met and entertained by the Préfet. Later we met Mr Simon Nichol, an English teacher at the local school, who kindly agreed to accompany us on our projected trip to the Dillia Valley. Next day, after engaging a retired gardè nomade as guide, we drove up the Dillia Valley as far north as Lagané Peule, some 100 km north of N'Guigmi. In the topographic sense the term "valley" in this case is misleading; the Dillia consists of a fossil outpouring of sand and silt, probably as a thixotropic mass, from <sup>beyond</sup> the small Termit massif to the north-west. Its age appears to be late Quaternary. Now in the form of a low ridge flanked by higher wind-blown 'cordon' dunes — from which the impression of a valley is gained — the bottom of the Dillia lies at a higher level than some of the flanking ground in which there are a number of interdunary depressions, the bottoms of which may be as much as 30 m below the level of the floor of the nearby Dillia. Thus groundwater levels in the depressions are nearer the surface than they would be in the Dillia, which accounts for the absence of wells in the Dillia itself.

At Lagané Peulé there is a large deep depression lying to the west of the Dillia. A traditional well (category "B" of Greigert and Sauvel, 1970, annexe p 84. These categories are referred to in the section which follows on hydrogeology of the Eastern Region.) has potable water at a depth of about 16 m bs, and there were about 70 - 80 resident head of cattle and a number of goats being watered. Further south at Lagané a similarly-situated traditional well (category "C") was also watering a much smaller number of resident cattle. Here the water level was 12 m bs. There were also other wells in the same general area, and a modern concrete well at N'Gel Gagué (category "C", east of the Dillia) would have been visited had our guide been able to find it. At no point did we see standing pasturage — all was eaten to the ground. Trees had been partly or wholly lopped to provide fodder; many had died as the result or from other causes. We were reliably informed that even after a normal wet season the pasturage in the Dillia is almost totally consumed within three months of the end of the rains; it was

evident that the area was already overgrazed with existing watering facilities, which thus appeared more than adequate. Over much of its length the Dillia is no more than 5 - 10 km wide and even at its southern end where the width increases to about 20 km there are existing wells (N'gel Gagué is one) within easy grazing radius. A proposal for three pumped wells in the 'valley' itself cannot therefore be supported.

N'Guigmi (population believed to be approximately 2000 - 3000) derives its public water supply from three small diameter deep artesian boreholes (all category "E") which are connected in series to a simple piped distribution system with a number of public standpipes, only some of which are now in use for a few hours per day. Some of the more important buildings are connected to the mains but not all, eg the school, receive supplies as the yield of the bores has reduced as a result of relining the original steel tubes with upvc in order to combat corrosion.

All three boreholes were drilled by Messrs Balakhany and financed by British Aid; the latest, sunk in November 1963, is 379 m deep and taps a confined sand aquifer between 363 and 369 m at which depth there is a 1 $\frac{3}{4}$  in diameter (Johnson?) screen with slots of 0.375 mm. The original piezometric level stood at 19.66 m above surface (289 m above datum). The original yield at 0.91 m above surface was 15.9 m<sup>3</sup>/hr

We were informed that the yield from each borehole is now approximately 4 m<sup>3</sup>/hr and that the pressure head had fallen to about 15 m above surface. Clearly there is a need for a new borehole of appropriate depth and diameter (370 - 380 m, 8 in to 12 in diameter, lined with corrosion resistant tubes. The use of a 'Hagusta' type screen might be considered. There is a requirement for a storage tank and water tower. However, it is unlikely that a pump would be needed at present as there should be sufficient artesian pressure for a number of years.

There are at least three open wells in N'Guigmi (all category "E") which draw upon groundwater in the superficial aquifer; water levels do not exceed 5 m bs.



The itinerary originally included visits to wells in the Manga area (north of N'Guigmi and east of the Dillia Valley) but we were told that there was insufficient petrol for this trip which was therefore cancelled.

After a 0500 hours start on 14th June the Mission left N'Guigmi to visit wells in the Tioldé area north of the Plaine du Kadzell. Seven wells were sunk here by Messrs Balakhany during 1968/1969 under Crown Agents contract Q 516/1. It would have been quite impracticable to visit more than two of them, and even this slight departure from the planned schedule gave rise to intense discussion. In the end we visited Loé (borehole 331 m, 5 m of Johnson 3 in stainless screen, and N'Guel Dyabi (bore 286 m, 5 m screen) both of which were fully artesian and appeared to be in good condition under the charge of guardians. Small numbers of resident cattle were being watered at each. There appeared to have been no appreciable lowering of the slight artesian heads (2 $\frac{1}{2}$  m at Loé, 3 m at N'Guel Dyabi) since the bores were constructed. We were informed that of the remaining five boreholes, four were working well (two artesian, two in the form of puits forage) and one at Karga (category "D") producing at a very low yield only. None of these bores were fitted with pumps; all had resident guardians. We later visited artesian wells at N'Guel Dafaou and Sayam (category "A") before heading for Diffa where talks were held with the Sous-Préfet. Afterwards we met M. Abdoulaye Mohamed, Chef du Service Départemental de l'Agriculture de Diffa, with whom we had lunch.

After lunch we left for Mainé Soroa, spending a night there before continuing to Zinder. Next day we drove via Goudoumaria to Gouré, where the Sous-Préfet had prepared an extensive programme of visits to various wells in the area north of Gouré. By this time both of us were exhausted, the drivers tired and the remainder of the party was evidently suffering from the excessive heat and dust. We therefore asked to be excused from this part of the itinerary, and the Sous-Préfet very kindly concurred; we then continued our journey to Zinder. We deeply regretted any inconvenience caused to the Gouré authorities and were most grateful for their understanding attitude.

At Zinder we talked to the Sous-Préfet (the Préfet was absent) and outlined what we had seen during the trip and our conclusions, mainly to the effect that more wells were not appropriate in the Dillia Valley. We felt, however, that there was room for improvement in the town water supplies of Mainé, Diffa and N'Guigmi, and that this was an area in which British aid might be appropriate, and the Sous-Préfet agreed.

There was no available Civil flight to Niamey until the following Thursday, 19th June, so Day and Davie remained in Zinder and took the opportunity to start writing their reports. Meanwhile the Land Rover returned to Niamey with Messrs Ayaga and Morey.

After various delays, the scheduled flight on Tuesday, 19th June eventually reached Niamey on Tuesday evening to be met by M. Morey. On Wednesday morning at a meeting with all interested authorities at the Ministry of Planning, the Mission again outlined its recent activities and principal conclusions. M. Tafarielli interpreted. Messrs Leclerc and Lesroux signified their agreement in principle with all that we said.

Later that afternoon Mr Davie left Niamey for Paris, and on Thursday Day flew to Abidjan to meet the British Ambassador.

#### Definitions of area described

The following sections refer to that part of Niger east of the 10th meridian and south of latitude 15°30' north. The area more or less coincides with the portion of Niger considered in the various publications of the Tchad Basin Commission, one of which relates specifically to groundwater resources.

#### Topography and climate

The area is one of relatively low relief, the highest ground — above 400 m above datum — occurring north of Gouré towards the minor massif of Termit. Virtually the whole area falls within the internal drainage basin of Lake Tchad and levels fall gradually towards the lake where the mean water level approximates to 282 m above datum. The only permanent water course is that of the River Komadougou Yobe which discharges into Lake Tchad <sup>and</sup> which forms the Niger—Nigérien border east of Mainé Soroa. The only other physical feature of note is

the fossil shallow Dillia Valley which in the past has carried drainage past the Termit massif towards Lake Tchad.

Most of the area is covered by fixed dunes, but the area between N'Guigmi, Mainé, the River Yobe and the lake comprises the flattish Plaine du Kadzell at a mean elevation of about 300 m, which evidently marks a former extension of the lake.

Lake Tchad, although fresh at its southern end, is less so towards the north. It is fed mainly from the south by the River Chari and its tributary the Logoné which drain rain forest areas of central and southern Tchad. By contrast the Yobe contributes but a small proportion of the total inflow. The more or less constant level of the lake is achieved by equilibrium between river inflow and outflow through evaporation, but cycles of wet or dry years give rise to a variation in lake level of several metres.

#### Geology and hydrogeology of area

A detailed description of the hydrogeology of the area is given by Greigert and Sauvel, 1970 and it is not proposed to give more than a brief outline here. This comprehensive BRGM publication includes an atlas of maps at a scale of 1:200,000 on which are shown the sites of all wells both modern and traditional and boreholes known to be present in the pastoral zone. For convenience Greigert and Sauvel categorize them as follows:

1. Category A - Well capable of watering a thousand head of cattle or more per day.
2. Category B - Well capable of watering several hundreds of head of cattle per day.
3. Category C - Well capable of watering 100 - 200 head of cattle per day.
4. Category D - Well capable of watering a few dozens of head of cattle per day.
5. Category E - Well for domestic use.

These categories have been referred to elsewhere in this report.

Almost the entire surface of the area is covered by dune sands up to about 30 m thick and associated deposits of ages varying between Recent and Early Quaternary. Most of the dunes are stabilised by vegetation, and there are

frequent interdunary depressions bottomed by silts or diatomaceous earths. Below the Dune Sands are the clays, clayey sands, sandy clays and various grades of sand of the Tchad Formation, Tertiary to Quaternary in age and of fluvio-lacustrine origin. These Tchad Beds probably reach a thickness of some 400 m near the lake, but thin westwards to only a few metres in the area north of Gouré. At Kelakam, a recent British borehole proved 250 m of silts and clays before encountering basement rocks. Little is known about the measures beneath the Tchad Formation in this area, but immediately below there may be a few (probably less than 50) metres of sands, silts and clays of the Continental Terminal (these have been encountered at Maiduguri, Nigeria and in the Mao region of Tchad) before reaching measures of Cretaceous age which are known at outcrop in the area north-west of Gouré where they consist of a thick (500 - 600 m) sandstone ('Tegama') series overlain by silts and shales. Basement rocks beneath the Cretaceous in this area are believed to consist of granites or metamorphic rocks; at Goudoumaria the granite basement was encountered at 130 m immediately beneath clays and silts of the Tchad Formation, without any intervening beds.

Where the superficial Dune Sands are underlain by clays or less permeable silts of the Tchad Formation — and this is the case throughout most of the area discussed — these sands have a saturated zone up to about 10 m thick at their base which constitutes an important unconfined aquifer. Periodic and limited recharge may occur through infiltration (there is virtually no surface run-off) during some rainy seasons, so that the present small abstraction for domestic and stock-watering purposes does not appear to have caused any appreciable lowering of the water table. Natural outflow from this aquifer is entirely by evaporation (apart from seepage into the Komadougou Yobe in the south of the area) and in the vicinity of Lake Tchad excessive evaporation from the land bordering the lake results in groundwater levels below the level of the surface of the lake itself. Nevertheless the lake acts as base drainage level for the entire area and in general groundwater levels in the unconfined

(phreatic) aquifer rise gently with increasing distance from the lake's margins. Locally the River Yobe also acts as base level for phreatic groundwater.

In interdunary depressions the level of the water table is commonly only a few metres or less below surface, particularly in the southern districts close to the border with Nigeria and the River Yobe and rarely more than 25 m even in the north of the pastoral zone. At Lagané Peule alongside the Dillia Valley the observed level in the well was 15 - 16 m below surface.

When sands or permeable sandy silts are present at or near the top of the Tchad Formation these normally form a single unconfined aquifer together with the overlying Dune Sands. These upper Tchad Formation sands are underlain (in the N'Guigmi area) by 230 - 280 m of impermeable plastic clays — although thin beds of saturated sand may be present — which in turn are underlain by up to 30 m of sandy beds which to the north of and in the Plaine du Kadzell form a confined aquifer in which the level of the pressure surface lies above that of the unconfined upper aquifer. This "Middle" confined aquifer within essentially similar sequences has been proved north-east of N'Guigmi at Kaufey and Mitimi in Manga, and across the border in Tchad. Maximum recorded heads are about 20 m above surface at N'Guigmi but there is some evidence that pressures may be declining slowly as a result of abstraction. There is no recharge to this confined aquifer other than limited amounts probably derived from the compaction of clays, so that all abstraction is at the expense of the resource. However, present abstraction is small in relation to the amounts in storage in the aquifer, and provided that stringent precautions continue to be taken against waste, bores at present fully artesian should continue to be so for the foreseeable future, with the possible exception of bores near the edge of the overflow zone which now have pressure heads amounting to one or two metres only (Loé for example, and N'Guel Dyabi).

Permeable sands of the Continental Terminal may underlie the Tchad Formation in the N'Guigmi area where resistivity surveys indicate that their depth may approximate to 450 m. They are known to be absent towards the Nigerian border,

but were present in Nigeria at the Maiduguri borehole between 450 and 560 m. Similarly, nothing is positively known between the 11th meridian and Lake Tchad of the Cretaceous Tegama sandstones. Once again it is thought that, mainly on the evidence of the resistivity surveys, if present they would occur at N'Guigmi at a depth of about 1000 m. They form an important confined aquifer about 500 - 600 m thick in the area north and west of Gouré where the Tchad Formation is too thin to form a significant aquifer.

#### Well construction

Traditionally wells are dug by nomads to considerable depths wherever and whenever the need arises. Where these wells ("Puisards") are shallow or exploit seasonal groundwater of limited extent i.e. in the alluvial beds of wadis, the wells amount to simple holes in the ground which require re-digging after each seasonal replenishment, but when wells ("puits") penetrate an extensive permanent groundwater body (most traditional wells in eastern Niger are in this category) they are likely to be of a more permanent nature and incorporate some form of lining, commonly of Doum logs. Such primitive screening may lead to excessive siltation and collapse, particularly in the case of wells sunk in the Tchad Formation with its fine silts and sands which are difficult to exclude. Commonly, signs of former foundered wells can be seen around existing wells. The necessity to replace wells fairly frequently is a heavy financial burden on nomadic families, who frequently own wells not only for their own use but also as a source of income.

Traditional wells lack proper surface works and are thus liable to pollution by animals on the surface. It is common for the water to be discharged into leaky wooden troughs or mud-walled pools.

Modern cemented wells vary in depth and diameter but most penetrate at least 5 m below the unconfined water table where a "colonne filtrante", consisting of outer perforated concrete rings surrounding a slightly smaller but otherwise similar inner ring and enclosing an annular gravel filter medium, excludes fine sand and silt. In coarser formations the gravel pack and inner ring may be

dispensed with. Wells are commonly of 1.4 or 1.8 m diameter, and the latter size permits up to six herdsman to abstract simultaneously. Such manual abstraction can amount to 5 m<sup>3</sup>/hr from a depth of 60 m. The provision of a concrete platform at the surface and raised margin to a well is now considered mandatory, and there are usually metal or (preferably, because of corrosion) concrete troughs.

Puits-forage, sometimes known as puits-citerne or dumb wells, consist of a cemented shaft sunk alongside or around a borehole which has tapped a confined aquifer and from which water flows into the shaft via a connection made below the static water level in the bore. Abstraction from the shaft is manual, and no borehole pump is required. Where there is a possibility of encountering unconfined water at a reasonable level, it is advisable to sink the shaft first, since if shallow water is encountered during the sinking a deep borehole may not then be required.

Artesian (overflowing) boreholes are commonly fitted with taps for domestic users and a trough with a ball tap or similar device some distance from the well head. A raised concrete slab is usually present around the well head (see Plates).

Boreholes which do not overflow must be fitted with mechanical pumps. There is at present no call for pumped boreholes which would only pose difficult maintenance problems. Outside the North Gouré area, there are none in eastern Niger, although pump sets are available in store at Mainé for the Goudoumaria and Kelakam boreholes. Hydrogeological conditions within much of the settled zone in the southern part of eastern Niger favour the use, for village supplies, of the fibre glass sectional interlocking wells ("minipuits") currently being developed by this Institute with the aid of an ODA research grant. Possibly there is scope for their use under UNDP or FAO auspices in the current village well modernisation programme.

#### Well maintenance

All well maintenance in the rural areas of Niger is carried out by a State owned organisation known as OFEDES (Office des Eaux du Sous Sol) with its central direction in Niamey and a number of regional outstations, e.g. Mainé Soroa. In

1971 the organisation's total staff amounted to 354. Apart from well, pumping station and borehole maintenance, OFEDES also undertakes the sinking of new wells (shafts) and is adequately equipped for this purpose. This organisation is about to sink 107 wells, average depth 30 m in the Mainé administrative district, to be funded by Canadian aid (approximately 200m Cfa).

#### References

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