INSTITUTE OF GEOLOGICAL SCIENCES

DEPARTMENT

INTERNAL REPORT

Overseas Development Administration Water/Livestock Development Mission to Tchad, November 1972

Supplementary Hydrogeological Report

by

J B W Day, B.Sc.

DATE April 1973

NATURAL ENVIRONMENT RESEARCH COUNCIL

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HYDROGEOLOGICAL DEPARTMENT

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Introduction

This report arises from an appraisal Mission to Tchad in October-November 1972 and follows an earlier more generalised version submitted on the Mission's departure from Tchad. It expands the section on availability of groundwater in the earlier report, and pays particular attention to the hydrogeological conditions prevailing along the particular trade cattle routes proposed for development, confirms the desirability of establishing alternative and cheaper means of well construction, examines the specific requests for aid, and suggests some possible alternatives. The question of well maintenance is also considered.

The Trade Cattle Route (Piste à bétail)

A number of such routes converge on the abattoirs at Fort Lamy from the outlying pasture areas; this report deals only with the routes serving the areas immediately north and north-east of Lake Tchad. Two tributary routes from Nokou and Rigrig converge on Mao; in theory these routes should receive cattle raised in the areas bordering Niger. From Mao the route runs south-south-east through Ngouri to Massakory where it is joined by a route from the administrative centre of Moussoro about 110 km to the north-east. From Massakory the route runs south-west to Massaguet, crossing the line of the main road, thence in approximately the same direction across country to Fort Lamy.

Topography and Present Climate

The entire area forms part of the internal drainage basin of Lake Tchad, the surface level of which approximates to 282 metres above mean sea level. The lake is fed by the River Chari and its tributary the Logone from the south (Tchad & Cameroun) and by the Komadugu Yobe from the west (Nigeria). The lake now has no outlet, and the more or less constant level is achieved from equilibrium between inflow via rainfall and rivers, and outflow through evaporation from the lake's surface and the low-lying sandy margins of the lake.

The climate is Sahelian with a rainfall varying from 200 mm around Nokou and the northern edge of the lake to about 600 mm at Fort Lamy; July and August are the wettest months. There is considerable annual variation in rainfall, and cycles of wet or dry years can give rise to a variation in lake level of several metres. During the wet season short rainstorms of high intensity are common; the sandy surface of the land north of Massakory absorbs the rainfall without surface runoff and infiltration to the water table occurs. South of Massakory less permeable surface silts give rise to temporary small lakes and ponds during and immediately after the rains.

Climatic History

The evidence of strand lines and fossil lake margins shows that there have been great climatic variations in the relatively recent past. The lake reached its maximum extension around 19000 BC when it covered some 330 000 sq km at an elevation of 320-325 m (Schneider 1966 pp 4-5), subsequently the lake shrank with strand lines at various levels. During the final retreat stages the lake overflowed north-eastwards towards the low country of the Bodele depression via the now dry channel of the Bahr-el Ghazal.

Geology

Lacustrine deposits varying in age from Oligo-Miocene to recent Quaternary entirely fill the Lake Tchad sedimentary basin and overlie an igneous basement complex. The depth to basement varies over the area but is said (Schneider 1966 p3) to reach 1500 m near the border with Niger where subsidence has played an important role. At Fort Lamy the basement is believed to lie at about 550 m below surface.

Immediately overlying the basement there may be a few metres of Tertiary sediments (Continental Terminal) but these measures, if present at all, would be too thin to constitute an aquifer. By far the greater thickness of the sediments comprise clays, sandy clays and clayey sands of Pliocene age; above these lie, north of latitude 13°N (through Massakory) 40-70 m of sands with clay intercalations forming the great sand-mass ('Erg') of Kanem. Wind action has redistributed the upper part of these sands into dune forms with frequent lower-lying interdunary depressions in the bottoms of which are thin (commonly 1-4 metres) of shaly, flood deposits; shallow flood water (commonly less than $\frac{1}{2}$ metre) may accumulate temporarily during the wet season. Several metres of recent flood-deposited shales are present along the floor of the Bahr-el Ghazal and associated ramifying depressions. Lake-deposited diatomaceous earths are also found in the depressions.

South of Massakory, sands of Quaternary age and Pliocene sands and silts have been planated by retreat stages of the lake. The silts are poorly permeable and give rise to persistent ponds during and just after the rainy season.

Fort Lamy and its immediate surroundings are underlain by the recent alluvial flood plain deposits of the Rivers Chari and Logone; these consist mainly of fine silts.

Hydrogeology

The Quaternary sands forming the great Erg of Kanem provide an important unconfined aquifer north of Massakory, and throughout the Massakory, Moussoro and Mao areas the water table lies at fairly shallow depths, particularly beneath the bottoms of the interdunary depressions where levels of 1 to 5 metres below surface (bs) are common. Between Mao and Nokou depths up to 8 metres bs are recorded,

and on parts of the route between Moussoro and Massakory the water table may lie as deep as 10 metres beneath the bottoms of interdunary depressions. Between Mao and Ngouri the depth to water table may slightly exceed 10 metres.

Traditional wells consisting at best of brushwood-lined holes in the ground with an arrangement of Doum palm logs to form a rudimentary sill at the surface are often to be found in the interdunary depressions where the presence of shade makes the site attractive to herdsmen. The water is raised - commonly by young boys - by means of goatskin buckets and discharged into a mud-walled pool. Conditions around the well top are far from sanitary and encourage the spread of bovine and possibly human parasites. Nevertheless, partly because of their situation, herdsmen evidently prefer such traditional wells to more modern deep wells of concrete; on two occasions the Mission saw concrete wells - sited on the dunes rather than in the depressions - that had been allowed to silt up and then abandoned. The presence of a deep water column in concrete wells is a further factor which may mitigate against their use; a dropped goatskin bucket cannot easily be retrieved and it is not unknown for herdsmen to deliberately introduce sand. Maintenance of deep wells presents therefore a considerable problem.

The level of the water table is said to fluctuate up to 40 cm seasonally in response to infiltration from rainfall; allowance for this factor should be made when shallow wells are designed to penetrate the water table by not more than 1-2 metres.

The chemical quality of groundwater within this aquifer is good throughout the area. Within the triangle Mao-Nokou-Rig Rig, mineralization is everywhere less than 0.25 grammes per litre (g/l); elsewhere it does not exceed 3 g/l and is commonly much less.

Whilst unconfined conditions are generally present, at least in the upper layers of the Pliocene sands and sandy silts which occupy the areas between Massakory and Fort Lamy, locally confined conditions may occur at depth. At Naala alongside the main road, 20 km west of Massaguet, the water table in an open shaft (disused) lies at 38 m, but a recent nearby deep borehole (now in use) encountered over-flowing artesian conditions. Between Massakory and Massaguet the level of the water table varies between 15 m bs at the former and 40 m bs at the latter; in this general area are a number of drilled boreholes equipped with motor pumps. Along the direct route between Massaguet and Fort Lamy (south of the main road) the depth of the water table steadily reduces from 40 metres to 10 metres at Fort Lamy.

Well Construction

An unconfined shallow aquifer is present throughout the area. Further deep boreholes fitted with pumps would appear to be unnecessary and in fact none are requested. The requirement is for open dug wells suitable for abstraction by hand

or animal power. Existing proposals favour 1.8 metre diameter shafts of concrete construction incorporating 5 metre 'filter columns' also of concrete, below the water table. Such wells are expensive to construct and install, largely due to the high cost of cement which has to be imported. Other disadvantages are the concentrations of animals which inevitably occur around the well-head leading to insanitary conditions - one 1.8 metre diameter well can accommodate up to 6 buckets at the same time - and of course the excessive depth of water in the well makes cleaning and silt removal difficult, also leading to loss of buckets which may be accidentally dropped.

The substitution of multiple single-bucket wells of approximately 1 m diameter and extending 1-2 metres only below the water table has the following advantages; (1) cost is likely to be less; (2) local unskilled labour can be used to dig the wells; (2) heavy concentrations of animals are avoided; (4) abstraction of groundwater is spread over an area; (5) dropped buckets can be retrieved and there is no temptation to artificially reduce the depth of water in the well; (6) maintenance and cleaning is simple; (7) if constructed in appropriate plastic, corrosion problems should be minimal.

In areas where rot-proof timber or suitable brick/stone is available, well-linings present no problems other than cost, but in this part of Tchad there are no materials locally available, although brushwood has been used with limited success.

With the aid of an ODA research grant, this Institute is currently designing and developing a sectional interlocking plastic well-lining for use in small shallow wells ("Minipuits"). If successful the design should find an immediate application in Tchad, where it should be possible to install Minipuits in groups of 4 or 5 in interdunary depressions. At present it is envisaged that Minipuits could be used at sites where the water table is 5 metres deep or less, but experiment may show that installation at greater depths may be feasible.

Probable Well Requirements and Costs Along the Piste à bétail

1. Fort Lamy - Massaguet, (distance - direct route - 60 km).
   The request relates to 3 wells on a longer route (80 km) via Adénou, Morgoum, Michdiré, Karkam and Gahui. I am not clear why such a roundabout route should be followed; on the direct route via Gaouil, Redina and Goz el Kanado, only 2 wells would be required to give a 20 km spacing between wells. Well A, sited at 20 km NE of Fort Lamy would encounter the water table at about 20 m bs and Well B, 40 km NE of Fort Lamy, at 30 m. Wells would have to be of conventional construction, i.e. of concrete and and 1.8 m diameter together with appropriate filter column, surface platforms and coamings, with troughs.

Cost of 2 wells (calculated on same basis used in request document)

Lined well, above water table (1 @ 30 m & 1 @ 20)

	50 m	@ 90 000 CFA	=	4 500 000
5 m Filter columns	2 m	@ 1 050 000	=	2 100 000
Platforms and Copings	2	@ 565 000	=	1 130 000
4 m troughs	12	@ 80 000	=	720 000
				8 450 000
		Contingencies + 10%	=	9 295 000
		Cost increase + 10%	=	10 225 000 CFA

The cost of 3 wells on the same basis would be 13 633 000 CFA

2 Massaguet-Massakory (direct distance 65 km, route quoted 102 km)

The significance of the route quoted in the request document is not understood, in particular, Am Sénété does not appear to lie on the route at all. The area is well served by pumped boreholes with tanks and troughs (6 wells were recently re-drilled by Balakhany). If the existing Balakhany borehole at Al Zarazir (20 km north of Massaguet) is used as a 'staging post' between Massaguet and Goz Dibek, the trail would remain on the north side of the main road and the longer trek (30 km) between Dapkaraye and Massaguet avoided. However, for reasons as yet unexplained the Al Zarazir borehole appears not to be in working order. At any rate there is no need for a well at Bir Barka midway between Goz Dibek and Dapkaraye as the distance between these existing operational boreholes is only 22 km.

One well only is required in this section of the piste midway between Goz Dibek and Massakory which are 32 km apart. This would have to be of conventional construction as the water table at the site is approximately 20 m below surface. The approximate cost of this well would be:

Lined well	20 m	@ 90 000 CFA	=	1 800 000 CFA
5 m Filter columns	1	@ 1 050 000	=	1 050 000
Platform etc	1	@ 565 000	=	565 000
Troughs	6	@ 80 000	=	480 000
				3 895 000
		Contingencies + 10%	=	4 283 500
		Cost increase + 10%	=	4 712 000 CFA

3 Massakory-Moussoro, (route quoted 121 kms)

Five wells are requested, average depth 20 m. At present the route followed by the herdsmen south from Moussoro is via Kalatio, Doum Doum, Chedra, thence down the Bahr el Ghazal to Massakory. The proposed route via Eglei Yoroso and Ridjil Haz (where there are disused, and partially filled-in cement wells installed by the French (FIDES) during the 1950s) would revert to a former piste, believed abandoned because of thieves. Careful selection of a route to include interdunary depressions for installation of groups of Minipuits should substantially reduce costs in this section, but allowance should be made for 1, possibly 2, conventional wells averaging 15 metres depth (not 20 m as stated in the request document). In the following calculations, the cost of a single Minipuit (including surface works) has been assumed to amount to 360 000 CFA and a group of 5 to 1 800 000 CFA. However, it is possible that the use of Minipuits may be appropriate throughout this section.

Conventional wells:

Lined wells	(2 @ 15 m)	30 m	@ 90 000 CFA	=	2 700 000 CFA
4 m Filter columns		2	@ 910 000	=	1 820 000
Platforms		2	@ 565 000	=	1 130 000
Troughs	(2 x 4)	8	@ 80 000	=	640 000
					6 290 000

Minipuits:

3 groups of 5					5 400 000
Troughs		15	@ 80 000 CFA	=	1 200 000
			All wells		12 890 000
			Contingencies + 10%		14 179 000
			Cost increase + 10%		15 597 000 CFA

In addition there is the cost, detailed in the request document, of partially equipping the existing new borehole at Moussoro.

4 Massakory-Mao (route quoted 149 km)

Five new wells are requested in this section plus complete equipment for an existing new borehole at Ngouri which would supply the town as well as the cattle trail.

As with the previous section, careful selection of route to include suitable interdunary depressions should enable Minipuits to be used at points south of Ngouri, but between Mao and Ngouri two conventional wells, average depth about 12 m may be required. However both this and the previous section

(Massakory-Moussoro) need to be surveyed on the ground before sites are finally selected - use of Minipuits may prove feasible throughout the routes with resultant savings in costs. Probable costs in this section are as follows:-

Conventional wells:

Lined well	(2 @ 12 m)	24 m	@	900 000 CFA	=	2 160 000
4 m Filter column		2	@	910 000	=	1 820 000
Platforms		2	@	565 000	=	1 130 000
Troughs	(2 x 4)	8	@	80 000	=	640 000
						5 750 000

Minipuits:

3 groups of 5				5 400 000
Troughs	15	@	80 000 CFA	= 1 200 000
			All wells	12 350 000
			Contingencies + 10%	13 585 000
			Cost increase + 10%	14 944 000 CFA

Plus cost of complete set of equipment for Ngouri borehole (see request document).

5 Mao-Nokou (quoted route 84 km)

Three wells, average depth 12 m, are asked for, plus equipment for existing borehole at Nokou.

Use of Minipuits may be possible throughout the route, but allowance for 1 conventional well, depth 10 metres, should be made for the area immediately south east of Nokou.

Conventional wells:

Lined well	(1 @ 10 m)	10 m	@	90 000 CFA	900 000 CFA
4 m Filter column		1	@	910 000	910 000
Platforms		1	@	565 000	565 000
Troughs		4	@	80 000	320 000
					2 695 000 CFA

Minipuits:

2 groups of 4	2	@	1 440 000	2 880 000
Troughs	8	@	80 000	640 000
			All wells	6 215 000
			Contingencies + 10%	6 836 500
			Cost increase + 10%	7 520 000 CFA

Plus cost of equipment for existing Nokou borehole (see request document)

6 Mao-Rig Rig (quoted route 112 km)

Six wells, average depth 10 m, are requested.

Installation of six wells would mean an average spacing of 16 km only; 5 wells would appear to be more realistic. One conventional well, depth 8 m, would probably be needed on this stretch of the piste; Minipuits are likely to suffice at the remaining 4 water points, given careful selection of interdunary depressions en route.

Conventional wells:

Lined well	(1 @ 8 m)	8 m	@ 90 000 CFA	=	720 000 CFA
4 m Filter column		1	@ 910 000	=	910 000
Platform		1	@ 565 000	=	565 000
Troughs		4	@ 80 000	=	320 000
					2 515 000

Minipuits:

4 groups of 4	4	@1 440 000	5 760 000
Troughs	16	@ 80 000	1 280 000
		All wells	9 555 000
		Contingencies + 10%	10 510 500
		Cost increase + 10%	11 562 000 CFA

Plus cost of partially equipping existing borehole at Mao.

The probable total costs for new wells (conventional and Minipuits) along all the project routes therefore amount to:-

Fort Lamy-Massaguet	2 conventional wells	10 225 000
Massaguet-Massakory	1 " "	4 712 000
Massakory-Moussoro	2 " "	
	3 groups of minipuits	15 597 000
Massakory-Mao	2 conventional wells	
	3 groups of minipuits	14 944 000
Mao-Nokou	1 conventional well	
	2 groups of minipuits	7 520 000
Mao-Rig Rig	1 conventional well	
	4 groups of minipuits	11 562 000
	Grand Total	64 560 000 CFA

If, as the Mission report recommended, wells are not to be sunk at present on the Mao-Nokou and Mao-Rig Rig sections of the piste, the approximate cost of the remainder of the scheme would amount to 45 478 000 CFA.

The above costings assume inter alia that there is some latitude for well site selection, and that the route of the piste would follow the wells, rather than vice versa. The importance of careful site selection on the ground cannot be over emphasised, sociological as well as hydrogeological factors are involved. Site selection should not be left to a contractor. Proper siting of wells will not only lead to considerable savings in cost, but should also ensure their optimum use.

Equipment for Existing Boreholes

The Mission recommended in its original report that the equipment requested in respect of four existing boreholes should be supplied forthwith. The possible exclusion of the Nokou-Mao section of the piste from the project should in no way negate the provision of equipment for the Nokou borehole, which would also provide a badly-needed public supply for the town. Consideration should be given to providing diesel-powered shaft-driven turbine pumps in place of the electric submersibles usually supplied on the grounds that the former should prove initially cheaper and subsequently easier to maintain.

Constructional details and test results of the boreholes should be checked with the Tchadian authorities before orders are placed.

Maintenance of Wells and Running Costs of Boreholes

In the present state of the Tchadian economy, it would be wise to make financial provision, over a limited period (say 5 years), both for the maintenance of any open wells which may be provided and for the running costs of pumped boreholes. The figures quoted in the request document appear to be reasonable, and I have no reason to disagree them. It should be noted however that the provision of Minipuits in quantity should reduce the well maintenance costs to some extent. It should also be noted that we are now asked to contribute to the running costs of only two (Dapkaraye and Massakory) of the six boreholes recently drilled and equipped by Messrs Balakhany. Goz Dibek was sunk with the aid of FAO funds and Massaguet by the West Germans. No mention is made of the remaining four Balakhany boreholes (see following section).

The existing stations at Massakory, Dapkayare and Massaguet are known to be, and the station at Goz Dibek thought to be, maintained to a high standard by resident mechanics, and presumably full-time caretaker/mechanics will have to be appointed to the remaining stations at Mao, Mossoro, Nokou and Ngouri once these are equipped and operational. If the UNDP training scheme (see final section)

is implemented according to programme, some trained maintenance staff should be available in about 2 years time. It should be emphasised that the provision of mechanically-pumped boreholes without financial provision for their maintenance cannot be recommended under the present circumstances.

Boreholes Recently Sunk and Equipped by Messrs Balakhany

Despite a further written request to the Tchadian authorities for information as to the present state of these 6 boreholes, no reply has yet been received and it must be assumed that only two are currently in action i.e. Dapkaraye and Massakory. I am unable therefore to add to the remarks in the appropriate section of the Mission's original report. Perhaps the Crown Agents or their contractors could shed some light, but as matters stand it is difficult to avoid the conclusion that the drilling or re-drilling of some of these boreholes may not have been strictly necessary. It may be significant that the present request makes no reference to the four boreholes known to be out of action, through partial or total lack of equipment. Attention has been drawn elsewhere in this report to the apparent desirability of utilising Al Zarazir (re-drilled by Balakhany in 1971) as a watering point in substitution for Dapkaraye, thereby shortening the route between Massakory and Massaguet by some 30 km.

Alternative Possibilities for Aid in the Water/Livestock Field

Although lack of water in the dry season is clearly a factor in the loss of weight suffered by cattle during their long treks to abattoirs, lack of pasturage along the route is also significant. In the case of Tchad, groundwater is locally abundant at shallow depths, so that the first is relatively east to rectify, but provision of fodder or improvement of pasturage is more difficult and likely to prove considerably more expensive. In my view the relative importance of each factor in this problem of loss of weight has yet to be established beyond reasonable doubt, but it may be that lack of food is the more significant. It would seem reasonable to assume that beasts on trek under arduous conditions expend more energy then they normally would, also that they are able to consume only a fraction of their normal diet. The resulting imbalance between calorie input and energy output inevitably leads to weight losses which the provision of additional water may alleviate to some extent.

Groundwater irrigation of fodder crops at or near watering points along the pistes would appear to be technically feasible; the shaley soils in many of the interdunary depressions seem to be cultivable and there is sufficient groundwater storage at relatively shallow depths to supply limited irrigation projects at low pumping costs. What appears to be needed is a pilot project at one or more points along the route, but the economics of the exercise would not be easy to determine.

The fattening/finishing of cattle on non-irrigated ranches in close proximity to major abattoirs has been recommended by the US Department of Agriculture

(Carter and McIeroy 1968 p46). However in view of the apparent suitability of the flat land around Fort Lamy for irrigation and the proximity of the Chari river as a vast source of excellent quality water, further consideration should be given to the possibility of producing fodder crops locally under irrigation. The introduction of water into the surrounding countryside via a canal system might be investigated, and the costs compared to those of pumping groundwater from boreholes; yields of 10-20 litres/second should be easily obtainable from 300 mm boreholes sunk to about 75-100 metres. Groundwater reserves in this area are considerable and have scarcely been drawn upon. Using irrigation, present stocking rates on enclosed land of 1 beast per 4 hectares should be more than doubled. For comparison the stocking rate on unenclosed, unirrigated land is said to be 1 beast per 10 hectares in Tchad.

Cattle are produced/fattened on enclosed but unirrigated land at the PRODEL ranch between Massakory and Massaguet; these beasts still have to be trekked to Fort Lamy approximately 100 kms distant with consequent weight loss en route.

Well and Borehole Maintenance Training School - UNDP

The fundamental importance of establishing efficient arrangements for well and borehole maintenance within developing countries such as Tchad has been stressed previously (eg Carter and McLeroy 1968, p46). UNDP has made proposals and is currently financing the greater part and overseeing the setting-up of a training school (believed to be at Fort Lamy) for well construction and maintenance personnel. Its detailed programme and objectives are set out in the attached memorandum supplied by M. Bonnevie of UNDP.

From this memorandum it appears that UNDP are providing all training personnel, material and equipment (including transport) for the school so that opportunities for bilateral aid in this field would appear to be limited in this case. However, the Tchadian Government are expected to contribute 30 million CFA over 3 years, mainly for the construction of offices and other project premises and for the salaries of trainees. Bearing in mind the present precarious financial situation in Tchad, their Government might welcome bilateral assistance in meeting part of these costs. Possibly an offer to meet the salaries and expenses of X number of trainees for the 2 year duration of their courses would prove acceptable to the Tchadian authorities.

JOHN B W DAY
April 1973

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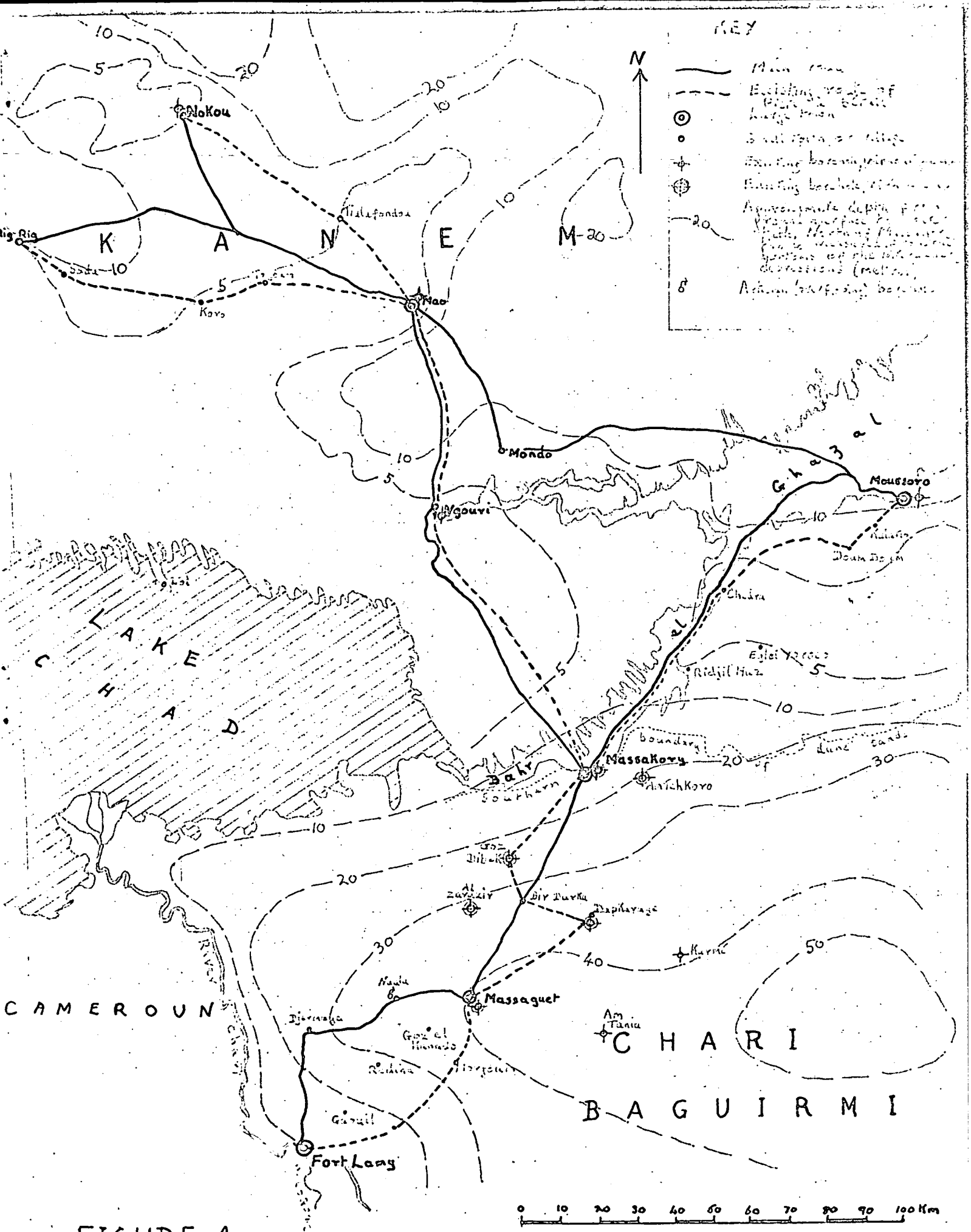

FIGURE 1

HYDROGEOLOGICAL SKETCH MAP OF PART OF THE REPUBLIC OF TCHAD