HYDROGEOLOGY

INSTITUTE OF GEOLOGICAL SCIENCES

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INTERNAL REPORT

Overseas Development Administration Water Development Mission to Mauritania, November 1972

Supplementary Hydrogeological Report

by

J.B.W. Day B.Sc.

DATE.....

NATURAL ENVIRONMENT RESEARCH COUNCIL

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OVERSEAS DEVELOPMENT ADMINISTRATION
WATER DEVELOPMENT MISSION
TO MAURITANIA, NOVEMBER 1972
SUPPLEMENTARY HYDROGEOLOGICAL REPORT

by

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January 1973

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C O N T E N T S

ILLUSTRATIONS

ODA WATER DEVELOPMENT MISSION TO MAURITANIA, NOVEMBER 1972

Supplementary Hydrogeological Report

Introduction

The following stems from a visit to Mauritania in November 1972 by three members of an ODA Mission sent to investigate requests for aid in the water/livestock sector, and follows a previous report written at Dakar dated 28 November 1972. It expands the original section on 'Hydrogeology (general)' and comments in greater detail upon the five projects for which aid has been requested by the Mauritanian Government in an undated document included in the Mission's original report as Appendix 1. Briefly, the five projects referred to are as follows.-

I Establishment of wells in North-Western Mauritania with

(a) a hydrogeological survey to determine sites with greatest potential, and

(b) groundwater exploitation by means of boreholes or shafts according to local conditions

II The equipment of two well-construction and maintenance units, based on Nouadibou and Akjoujt.

III Establishment of nine pumped wells, with large yields, in south-western Mauritania, that is

(a) drilling and equipment of five boreholes and

(b) equipment of four existing boreholes

IV Provision of a mobile maintenance workshop for pumping installations.

V Supply of ten Land Rovers, equipped with two-way radios.

It will be convenient to deal with the proposed projects in detail, in the order listed in the previous paragraph.

Project I - Survey and provision of wells in North-West Mauritania

Towns - communications - industry. This request concerns the area bounded to the east by the 15th Meridian, to the south by the 19th parallel, to the west by the Atlantic coast and to the north by the international boundary with Rio de Oro. The area is almost totally without roads except for the Nouakchott-Akjoujt road which crosses the extreme south-east corner and off which there is a sand-track to the village of Bennichab. In the coastal area access is along the beach. Just south of the Rio de Oro border runs the Federik-Nouadibou iron-ore railway. Vague tracks, running mainly north-south - are marked on some of the larger scale maps.

The iron-ore exporting port of Nouadibou (formerly Port Etienne) is the only major town in the area, which is situated on the eastern side of the southern end of the Cape Blanc peninsular. The fishing industry here is assuming major proportions, being mainly japanese owned and financed; there is said to be a fish cannery, and numerous trawlers are based on the port. 65 km north-east of Nouadibou is the village of Bou Lanouar, alongside the railway.

Between Nouadibou and Cape Timiris to the south there appear to be no major coastal settlements, but immediately south of the Cape lies Nouamghar, said to be an important fishing village. Just north of the 19th parallel lies the small coastal village of El Mhaijrat. Towards the south-east corner of the area lies the 'important' village of Bennichab, but within the interior lie only nomadic settlements centered on the principal Oueds (occasional streams).

Topography. The area is one of low relief; in the belt of country inland from the coast heights rarely exceed 40-60 metres, but towards the north and north-west elevations gradually rise to around 160 metres. The highest point, 175 metres, occurs on the Adam Bissinnein hills, near the railway at longitude $15^{\circ}31'W$. In the western and north-western part of the area are a number of low rocky eminences, but most of the area, particularly towards the coast, consists of silt or sand. Immediately inland from the coast are a number of 'sebkas' or 'chotts' i.e. salt marshes.

The area is crossed from south-west to north-east by two tracts of sand dunes; the southerly tract is known as Akchar and the northerly as Azefal. They enclose the 'vale' of Tijirit. North of Azefal, the region of rocky eminences is known as Tasiast.

Climate. Inland from the coast the climate is saharan; except for the extreme southeast corner mean annual rainfall is thought everywhere to be less than 100 mm (Roussel 1968b). Within the area there is one climatological station at Nouadibou (mean annual rainfall 31 mm); bordering the area to the south and east, the stations at Nouakchott, Akjoujt and Atar have recorded comparable figures of 130, 102 and 105 mm respectively. Most of this rain occurs as strong showers or storms during the months August-October.

Temperatures normally reach their maximum in May and June - at Akjoujt mean temperatures in respect of these months are recorded as $42^{\circ}C$ and $41^{\circ}C$. On the other hand, the period November-February is relatively cool - average maximum temperatures being 30° or a little more.

Geology. A considerable amount of literature exists on the stratigraphy and structure of the area and only a brief account will be given here. Fundamentally, two groups of rocks are present of widely differing ages. The oldest - a suite of ancient Pre-Cambrian granites - intruded by later pegmatites and basic serpentines,

forms a mature basement complex which crops out in the Tasiast and north-east Tiferchai regions; this complex extends westwards beneath a second group of much younger (late Mesozoic and Tertiary) sediments which abut against the granites to the east and dip gently westwards towards the Atlantic Coast.

The sediments infill a depositional basin the trend of which parallels the coast of Mauritania, its width decreasing from 350-400 km in the extreme south of the country to 70-80 km at the northern border with Spanish territory. The oldest sediments - a sandy or sandy clay series - encountered in boreholes are Mesozoic (Cretaceous or Jurassic) in age, so that formations representative of the post-Pre-Cambrian - Pre-Mesozoic period are missing, and nothing is known of them in this area.

Above the basal sandy clays lie beds of Eocene (Tertiary) age which show a westerly change in facies from littoral sands, bordering the granite basement, through limestones to argillaceous marls. At Bou Lanouar (alongside railway, 75 km N.E. of Nouadibou) the Eocene is composed of 135 metres of marls and argillaceous sands. These beds do not crop out within the area, being overlapped to the east at depth by the succeeding Mio-Pliocene Continental Terminal formation. The latter however does crop out (see figure 1) to form a broad belt of country extending from Tiersioum in the north to the Bennichab area in the south-east and beyond.

The Continental Terminal consists of multi-coloured clayey sandstones and more-or-less argillaceous sands with some silts. There is a westerly increase in thickness of these beds: about 100 m have been proved at Bou Lanouar, increasing to more than 300 m at Nouadibou.

The structure of the sedimentary basin, although fairly well known in the south of Mauritania, is more poorly defined in the North. North of latitude $19^{\circ}30'N$ the basal granite complex seems to form a platform at a depth varying between 100 and 200 m below surface and extending to about latidude $20^{\circ}30'$. In this zone the Continental Terminal rests directly on the basement complex. Farther north, and west of meridian $16^{\circ}30'W$, there are zones where the basement appears to have subsided possibly in response to sediment loading, at any rate the depth to basement at Bou Lanouar is more than 600 metres and near Nouadibou 4000m.

The Quaternary and Recent deposits which cover much of the area reflect sedimentation resulting from various marine transgressions, flood run-off from the crystalline zones and wind action. Bordering the granite complex to the west is a belt of fluviatile alluvium or rag, whilst towards the Atlantic coast old marine alluvium is present. Overlying both and extending north-eastwards across the granites are the wind-blown dune masses of Azefal and Akchar. The total thickness of dune sands and the underlying alluvia appears to be of the order 30-60 m.

The courses of the principal 'Oueds' or occasional streams which carry run-off from theCrystalline zone are likely to be underlain by varying thicknesses of recent fluviatile alluvium of varying lithology.

Hydrogeology

1. The granite basement complex. Limited groundwater may be present in weathered and fissured zones. The depth of weathering depends upon a number of local factors but seldom exceeds 20 m (Roussel 1968a, p.10). Thus the thickness of the weathered zone is an important factor controlling the amount of groundwater in storage. With regard to basic rock, only large extrusions are likely to yield any water, since the numerous narrow dykes are rarely weathered at the surface. Qualitatively, the nature of the groundwater depends upon the chemical characteristics of the local 'aquifer' and there are said to be wide differences in the chemical qualities of water from wells within short distances of each other.

   In the Tiferchai regions ($15^{\circ}54'W$, $21^{\circ}10'N$) Plote (unpublished reports, 1960) considers that the preferential weathering believed to occur beneath the courses of occasional streams and temporarily flooded 'dayas' should result in local storage of groundwater. Elsewhere in Tasiast west of the 15th Meridian, little work has been done, although geophysical surveys are at present being made in the eastern region. In particular, nothing is known of groundwater conditions in the granites beneath the superficial dunes of Azefal. Similarly there is no knowledge of the groundwater conditions in the granites of that part of Tijirit west of the 15th Meridian, or where the granites are overlain by the dunes of Akchar.

   Close observation of ground conditions allied to surface electrical resistivity techniques would seem likely to afford the best indications of potential drilling sites. Close geological control by drilling would however be essential to enable correct interpretation of resistivity data. However, it must be emphasised that large quantities of groundwater are unlikely to be found in these areas, and much of what little there is may be brackish or saline. For human supply, it would probably be necessary to rely upon traditional sources e.g. shallow wells in the Oueds ('Ogols') or rock cisterns ('Achguiges'), but as far as livestock are concerned it must be remembered that camels, for which the area provides much pasturage, can tolerate total dissolved solids concentrations of up to 6000 mg/l, and humans can drink the milk; the camel thus acts as a filter. Goats - an important source of protein - can also tolerate water with relatively high mineral concentrations. Initially, it would be prudent to concentrate drilling efforts on sites recommended by Roussel (1968a, pp 32-33).

2. The Pre-Quaternary Sediments. By contrast with the crystalline zones a good deal of information is available on the more westerly areas underlain by mezozoic or tertiary sediments. Two areas where substantial bodies of potable groundwater are known to exist in the Continental Terminal can immediately be identified: they are around Bennichab, in the south, where a number of wells have been drilled, and where reserves of potable groundwater have been estimated at 120 x 10^6 m^3, and in the north around Bou Lanouar where water from a number of wells penetrating Continental Terminal and the underlying Eocene is piped to Nouadibou. At Bou Lanouar the deepest sands - either basal Tertiary or Upper Jurassic in age - encountered in the boreholes between 500 and 600 m are water bearing but not exploited - they provide a reserve, for the groundwater is at present abstracted from Upper Eocene sands and the Continental Terminal. Further west at Nouadibou, deep boreholes have proved a similar but very much thickened succession; unfortunately no groundwater data was apparently obtained from these bores.

Between the extreme south and extreme north of the area there is a rise in the basement complex to between 100 and 200 m below surface and the Continental Terminal which rests on the granite is probably too thin to form a useful aquifer. At outcrop much of the formation lies above the saturated zone (away from the coast the water table may lie as low as 40 m below sea level, thus indicating evaporative discharge). To the west the groundwater generally becomes saline at depth so that potable water in the Continental Terminal is likely to be limited to an ill-defined N.N.W. - S.S.E. trending belt of varying width between a dry zone at and near outcrop in the east and a saline zone at depth in the west. Between latitudes 19°30' and 20°30'N the rise in the basement complex makes the presence of substantial bodies of potable groundwater problematical, although small supplies of brackish water suitable for cameline consumption may be available locally. Since the groundwater may be regarded as fossil, abstraction cannot be replaced; no appreciable replenishment from rainfall is likely in this extremely arid area.

Probably the most promising area for the exploitation of groundwater in the Tertiary sediments is that which lies south and south-west of Bou Lanouar towards the Baie de Levrier.

Detailed local groundwater studies have been made in the Bennichab region by Gravost (1965) and at Bou Lanouar by Putallaz (1962).

3. Quaternary Sediments. Recent alluvium in the beds of the principal Oueds is periodically recharged by brief surface flow resulting fron run-off from the crystalline areas. This groundwater, although strictly limited in quantity, is commonly of good quality and fit for human consumption. Little, if any, of the surface flow reaches the sea, and is subsequently accounted for by evaporation. Thus, in general the quality of this superficial groundwater is likely to deteriorate downstream towards the sea - recharge becomes less and evaporation results in increasing mineralisation. Exploitation is usually by means of shallow wells or 'ogols' which may or may not be usable all the year round.

If the periodic run-off in the Oueds could be retained or retarded by low earth barrages, the water so impounded would enhance recharge to a considerable extent; this possibility combined perhaps with subsurface barrages (clay puddle trenches) should be examined at suitable sites on the ground. Surface barrages have been constructed in the Akjoujt area, apparently with some success.

Little seems to be known about the possibility of groundwater within the dune-tracts of Azefal and Akchar, but it seems possible that some replenishment might occur around and within interdunary depressions, and this possibility requires investigation.

In the region of Nouamghar on the coast, the two dune-tracts of Azefal and Akchar coalesce. It is believed limited recharge here may give rise to thin shallow groundwater bodies resting on underlying salt water. At present exploitation is by means of shallow wells which yield potable water for varying periods after the rainy season; at other times of the year and when the rains fail, water for the coastal fishing villages (e.g. Nouamghar, Rguiba, El Mhaigrat) has to be imported. The feasibility of shallow groundwater exploitation by means of drain-trenches and collecting chambers should be investigated here.

Costs of Project 1 according to Mauritanians - Comment

The following sterling costs assume an exchange rate of 600 CFA = £1.

		£
Sedimentary Zone	10 wells (shafts), 50 m deep @ £250 per metre (diameter not stated, but presumably 1.5 - 1.8 m)	125 000
	5 boreholes, depth 120 m, linings, screens, pumps etc. (diameter again not stated, but presumably 12" or thereabouts)	126 916
		251 916

Considering that it is apparently intended to drill the 5 boreholes with the Failing rig which the Mauritanians hope to inherit from the current IDA aid project,

the costs of drilling seem excessive even by local standards. The costs of digging the 10 shafts are probably about right. The bores could almost certainly be drilled by a British contractor for a lesser sum, and this aspect might be investigated.

		£
Crystalline Zone (Research)	40 trial bores, drilled with light drill included under 'equipment'	13 333
	Geophysical research team - 3 months	10 000
	Hydrogeological team - 6 months	15 000
		38 000

This sum does not include the cost of the drill, or of ancilliary equipment. Please see my remarks in a following paragraph.

	£
15 wells (shafts), depth 30 m (presumably of diameter 1.5 - 1.8 m)	112 500

This project would of course follow the survey. The cost is probably about right.

Ancilliary transport for Failing 1250 SS rig	£
1. 10 m^3 water tank wagon	11 666
2. 5 tonne transport	8 333
3. Radio-equipped Land Rover	4 000
4. Light (air-circulation) drill	20 830
5. Mobile workshop for light drill	8 333
6. Compressor for drill	10 000
7. Compressor Lorry	8 333
	71 500

The costs are high and appear to include import charges imposed at Dakar by the Senegalese. If material could be landed at Nouakchott (facilities restricted to a number of 5-ton cranes on a pier) or more conveniently, at Nouadibou where port facilities exist, I am sure a good deal could be saved. Items 1, 2 and 3 are required for use with the Failing rig at present being used by IDA - the rig will be presented to Mauritania on conclusion of the project, probably sometime in 1974. The remaining items would be used for the Tasiast survey, and their cost could usefully be included in the estimate for crystalline zone research i.e. £38 000 + £47 496 = £85 496.

Total costs for the whole of the first project are said to be 284 550 000 CFA, or £474 250.

Execution of crystalline zone survey - Recommendations

There appear to be four possibilities.-

(1) Simply to provide the sum requested and allow the Mauritanians to let contracts and organise the survey (in this case contracts would almost certainly go to the French);

(2) Let a contract to appropriate British Consultants;

(3) A survey by IGS;

(4) A combination of 2 and 3 above, with IGS acting as remote supervisor to operations in the field by consultants.

I consider that a proper survey of the crystalline zone might usefully be combined with a short survey of the lesser known areas of the sedimentary zone and of the possible superficial aquifers along the coast. Such a combined survey would be likely to take 6-9 months. Staff would need to consist of at least 4 Europeans plus a number of local labourers. If suitable professional counterpart staff are available, a training element could with advantage be introduced. Because of the difficult terrain the team would have to be self-sufficient over long periods and radio communication would be essential; logistics would require careful study and organisation.

Whilst I cannot give any undertaking that IGS could in fact undertake such a project (present commitments indicate that it could not) the following costs of an IGS survey/drilling party are offered as a guide.-

Personnel			£	£
Salaries:	1 PSO hydrogeologist/geophysicist	270 days @ £22.59 =	5 100	
	1 SO " "	270 " @ £13.25 =	3 580	
		Plus 45% overheads =	3 892	£12 572
	1 VSO driver/camp manager/radio operator for 270 days		1 000	
	1 driller, for 6 months	26 weeks @ £200 per week	5 200	
	Subsistence for PSO & SO, 540 days @ £10		5 400	£24 172
	Air fares, 5 @ £300 (1 supervisory visit)		1 500	£1 500
		Personnel Total		£25 672

£25 672

Equipment

	£	
Light drilling rig, air circulation, mounted on 4 x 4 Bedford	15 000	
Air compressor, Lorry mounted	8 000	
2 x Land Rovers, 109 pick-ups fitted with 2-way radio	4 000	
2 x Air conditioned trailer caravans	4 000	
Misc. Camping equipment	1 500	
Drilling tools, bore linings, test pumping equipment	10 000	
Surface Resistivity equipment	1 000	
Camp radio receiver and transmitter	1 000	
Shipping costs @ 6%	2 670	£47 170
Fuel	1 000	£48 170
10% Contingencies	4 817	£52 987
10% annual rise in cost	5 300	£58 287

At 1974 prices, staff and equipment Total £83 959

Project II - Equipment of two well maintenance and construction teams

The equipment of these units based within or near the Project I area will be essential if the exploitation phase of Project I is carried out. There are a number of existing wells and boreholes for the supply of both Nouadibou and Akjoujt so that some sort of locally-based maintenance organisation is desirable even at the present time. The implementation of this project could of course follow Project I.

Unless I have misunderstood, there appear to be two errors in the table of equipment on p.5 of the request document (Appendix 1). These are in respect of Land Rovers (total should read 6, not 7) and poste de radio (total should read 6, not 9). Allowing for these errors, the total cost, at Mauritanian prices, of this project would be 62 350 000 CFA, or £103 916.

Again, the prices quoted are about double U.K. prices, and I suspect that costs could be substantially lowered by supplying UK material and shipping direct to Mauritania.

Project III - Drilling and/or equipment of nine high-yielding boreholes in South-West Mauritania

This request for immediate aid has arisen because of the failure of winter rains for the third successive year. The resulting southerly migration of livestock, herdsmen and their families has created a demand for water which the few existing wells cannot cope with. Disaster is inevitable before the next rainy season, but conditions could be much alleviated and many lives saved by provision of pumped boreholes as requested. These bores would form part of a general relief programme and would also fit in with longer-term developments planned for the area, which is generally south of Boutilimit. There would be no overlap with the IDA project at present being implemented further east (north of Kaedi) but the Boulilimit region does lie within a wider area considered in the 1971 IDA report (p.7).

The area is underlain by Tertiary sediments which include two, possibly three, aquifers. The detailed siting of the five new boreholes requested could be left to the Mauritanians and their advisers; the hydrogeology of this area is fairly well known.

There appears to be some doubt whether 3 or 4 existing boreholes need to be equipped; while the main request states '4', the breakdown of costs (p.6) allows for only 3. Assuming the true number to be 4, the total cost of equipping 4 boreholes would amount to 4 x 4 700 000 = 18 800 000 CFA or £31 333.

The total cost of drilling and equipping the five new bores would amount to (5 x 13 600 000, not 13 700 000 as stated) 68 000 000 CFA, or £113 333. The total cost for the whole of Project III thus amounts to £144 666.

Once again, these are local prices, and execution of all or part of the work by a British Contractor should result in much lower expenditure. However, as has been emphasised in the main body of the Mission's report, this project, to be effective, requires immediate implementation. Attention is also drawn there to the order of priorities in Mauritanian eyes as between Projects I and III.

Project IV - A mobile workshop for maintaining deep borehole pumping installations

The Mauritanian Government evidently foresees the need to create special maintenance facilities for deep borehole pumps and ancilliary equipment, with specialist staff. This workshop would presumably be equipped to undertake major repairs beyond the capability of the local 'Brigades'.

The cost is stated to be 7 000 000 CFA or £11 666.

Project V - Miscellaneous equipment

1. The Mauritanians insist that any radio equipment supplied should be of 'Racal' manufacture. There is an obvious need in this desert country where road or telephone communications may not exist to equip vehicles with two-way radio both for control and safety purposes.

2. I have no information as to how badly these vehicles are needed.

Note on port facilities in Mauritania

The only harbour affording port facilities and shelter is Nouadibou (formerly Port Etienne) which exists mainly for exporting iron ore brought by rail from the mines at F'derick (Fort Gouraud). There are no roads connecting Nouadibou with the remainder of the country but there are desert tracks suitable only for four wheel drive vehicles. Mobile equipment - land rovers, lorries, drilling rigs etc - intended for work in the Tasiast area could with advantage be landed at Nouadibou.

Material intended for use in the southern half of the country might be landed at Nouakchott, but facilities are restricted to a number of (approximately) 5 ton cranes on an unsheltered pier, where there is commonly a ground swell and fresh winds. Unfavourable weather or sea conditions might cause lengthy delays in unloading. It is therefore suggested that if the quantities of vehicles and material warrant it, an approach might be made to the Ministry of Defence with a view to shipment and landing by beach landing vessel for which conditions are ideal.

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FIG. 1 GEOLOGICAL SKETCH MAP OF PART OF THE ISLAMIC REPUBLIC OF MAURITANIA