

FDWR / EDF WATER RESOURCES PROJECT

GROUNDWATER RESEARCH
DEPARTMENT
National Water Resources Institute
Kaduna

FINAL REPORT
Volume I
Text and Appendices

July 1986

This report consists of three volumes:

Volume I Text and Appendices

Volume II Borehole Completion Reports

Volume III Geophysical Data

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ABBREVIATIONS

api	aerial photograph interpretation
DHH	down-the-hole -hammer
EC	electrolytic conductivity
ECA	Experimental Catchment Area
EDF	European Development Fund
EEC	European Economic Community
EM	electro-magnetic
FDWR	Federal Department of Water Resources
FGN	Federal Government of Nigeria
FMAWRRD	Federal Ministry of Agriculture, Water Resources and Rural Development
FMWR	Federal Ministry of Water Resources
GCA	Government Coastal Agency
GI	galvanised iron
GO	government officer
GVTC	Government Vocational Training Centre
GWRD	Groundwater Research Department
ITD	Inter-Tropical Discontinuity
N	Naira
nd	nominal diameter
NDA	Nigerian Defence Academy
NOP	Nigerian Overseas Products Ltd
NRBDA	Niger River Basin Development Authority
NSWB	Niger State Water Board
NWRI	National Water Resources Institute
PVC	polyvinyl chloride
PAN	Peugeot Automobile Nigeria
STR	subject-to-regularisation
T	transmissivity
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNRBRDA	Upper Niger River Basin and Rural Development Authority
YES	vertical electrical sounding

SUMMARY

The Federal Department of Water Resources (FDWR)/European Development Fund (EDF) Water Resources Project was designed to fulfil an important role in the development of Nigeria's water resources : the establishment of a Groundwater Research Department (GWRD) at the National Water Resources Institute (NWRI) in Kaduna to carry out investigations into groundwater problems and to advise on planning and management issues.

A firm of consulting engineers (MRT) was engaged to assist with the procurement of drilling and geophysical equipment, and to provide the services of a chief hydrogeologist and geophysicist (32 manmonths) for the training of Nigerian staff and for the direction of a research programme. One of the conditions of the drilling rig manufacturer (Halco) was the provision of a master driller for 24 months to commission the equipment and to train the drilling staff.

The project was initiated in July 1982 and this report discusses the activities that were undertaken to the end of March 1986.

Two main phases to the work were envisaged at the start of the project:

- phase I (establishment);
- phase II (operations).

Phase I involved the procurement of the equipment and the physical establishment of the new department within the NWRI, including the recruitment of Nigerian staff. It was largely completed by the end of 1984.

Phase II activities got underway at the start of 1985 and field work was carried out in Kaduna, Plateau and Niger States. The programme started in the catchment of two small rivers near Kaduna, chosen to provide a convenient test bed for research into all aspects of water resources - it was hoped that the groundwater work would act as a stimulus to other research departments in the Institute. The catchment became known as the Experimental Catchment Area (ECA).

The main emphasis during the field programme was on practical, on-the-job training in the use and maintenance of the equipment and in the accurate collection and analysis of data. This was complemented by the preparation of a training manual on groundwater investigation procedures, and the provision of reference text books.

The bulk of the work was located on the Basement Complex, although part of the research investigations in Niger State involved drilling into sedimentary formations. Fourteen boreholes were drilled, to depths of up to 115m, and nearly all were tested for yield and water quality. Geophysical surveys - using both resistivity and seismic

refraction techniques - were carried out to site most of them, and to complement a photogeological mapping exercise in Niger State; data were analysed and interpreted on a microcomputer belonging to MRT.

By and large the project's field programme has been encouraging - the staff recruited for the department have worked well in the field and benefited from the training and experience, and much useful data have been collected. However, although there were technical problems and breakdowns to the equipment at times, progress was mainly constrained by several administrative and logistical issues:

- (a) **Travelling allowances and overtime.** Payment of these - which effectively double the income of junior staff, and hence are important incentives for field work - was always extremely slow; also, in some cases, justified claims were cut by the Accounts. This led to a lot of bad feeling in the department and action is needed if the Institute wants to retain the loyalty and goodwill of the field staff.
- (b) **Radio communication.** Soon after the deployment of the consultants in 1984 a local currency budget was prepared for operational expenses and the procurement of technical and field support equipment. However, although the budget was approved by the Federal Ministry of Agriculture, Water Resources and Rural Development, funds for capital expenditure did not become available until early 1986.

This was most serious in the case of radio communication sets; without them the field teams had no direct contact with the Kaduna base. Fortunately, however, this problem will soon be resolved since the installation of radio sets began in March 1986.

- (c) **Field accomodation.** Although tents were provided as part of the project equipment it was thought that, given the number of field staff recruited (25), it would be better if accomodation was provided by the beneficiaries of the drilling and geophysical programmes, especially since no charge was being made for the resulting boreholes. However, the standard of this accomodation at most locations was very disappointing and led to a lot of privation and illness amongst both the expatriate and counterpart staff.

Clearly the field teams have to be entirely self sufficient, but extra equipment is needed for this. Caravans are the only satisfactory answer to this problem, and it is recommended that they be included in any future procurement of imported items.

In response to questionnaires sent out in early 1985, 24 proposals for research projects in all parts of Nigeria were received. These should ensure that the department is kept busy for many years to come.

However, in order to keep the department operational there will be a need to replenish spare parts and to provide extra equipment to overcome some of the problems previously mentioned and to enhance existing capabilities. The total cost is estimated to amount to some Pounds Sterling 116,288.

In addition, a provision needs to be made for the purchase of transport, office equipment and other capital items included in the local currency budget prepared in 1984, as well as for the replenishment of drilling consumables and borehole components. The total cost is estimated to amount to some N 162,360.

CHAPTER 1

INTRODUCTION

1.1 Background to Project

A financing agreement (2503/NIG) was signed in Brussels on 18 July 1980 between the European Economic Community (EEC) and the Federal Government of Nigeria (FGN) to provide technical assistance under the Lome 1 Convention. A major part of the assistance was for building-up and strengthening the organisations responsible for the exploration, development and monitoring of Nigeria's water resources by providing funds for equipment and consultancy services.

An important aspect considered was groundwater which, since the early 1970s, has been increasingly exploited in an effort to satisfy the needs of urban and rural populations, and industrial and agricultural developments. However, this emphasis on exploitation, though laudable, invariably overshadowed the routine collection of data necessary to properly evaluate the potential and limitations of the groundwater resources being used.

In recognition of the urgent need to make up for this lapse the Federal Department of Water Resources (FDWR)/European Development Fund (EDF) Water Resources Project NIG/400/78 was set up; an Agreement for Engineering Services to execute the project was signed between the (then) Federal Ministry of Water Resources (the Administration) and MRT Consulting Engineers (Nigeria) Limited (the Consultant) on 20 July 1982.

The aim of the project was to train Nigerian staff in the collection of reliable groundwater data by means of hydrogeological and geophysical investigations and a drilling programme, using equipment procured for the project. The project was based at the National Water Resources Institute (NWRI), Kaduna, where a Data Bank had been established to store and analyse water resources information for the whole of Nigeria. A new department was established within the Research Centre of the Institute - the Groundwater Research Department (GWRD) - to implement the project.

The Consultant was required to:

- (a) draw up technical specifications and tender documents for the supply of a drilling rig, ancillary equipment, two support trucks, three personnel carriers and geophysical equipment in accordance to EDF guidelines. One of the conditions was for the drilling rig manufacturer to supply the services of a driller mechanic (master driller) for 24 months;
- (b) assist with the tender evaluation, award of contract and inspection and acceptance at the manufacturers' works;
- (c) provide the services of a hydrogeologist (project co-ordinator) and a geophysicist for 20 and 12 months

respectively in Nigeria, to train the Nigerian technical staff recruited for the GWRD, to supervise the field research programme and to produce reports on the various aspects of the work accomplished.

This draft final report summarises all the work that went into the execution of the project, the results of the field programme to the end of March 1986 and requirements for the future.

It consists of three volumes:

- Text and Appendices (Volume I);
- Borehole Completion Reports (Volume II);
- Geophysical data (Volume III).

1.2 Project Execution

Project execution is illustrated on Figure 1.1. Two main phases to the work were envisaged at the start of the project:

- (a) Phase I - Establishment
- (b) Phase II - Operations

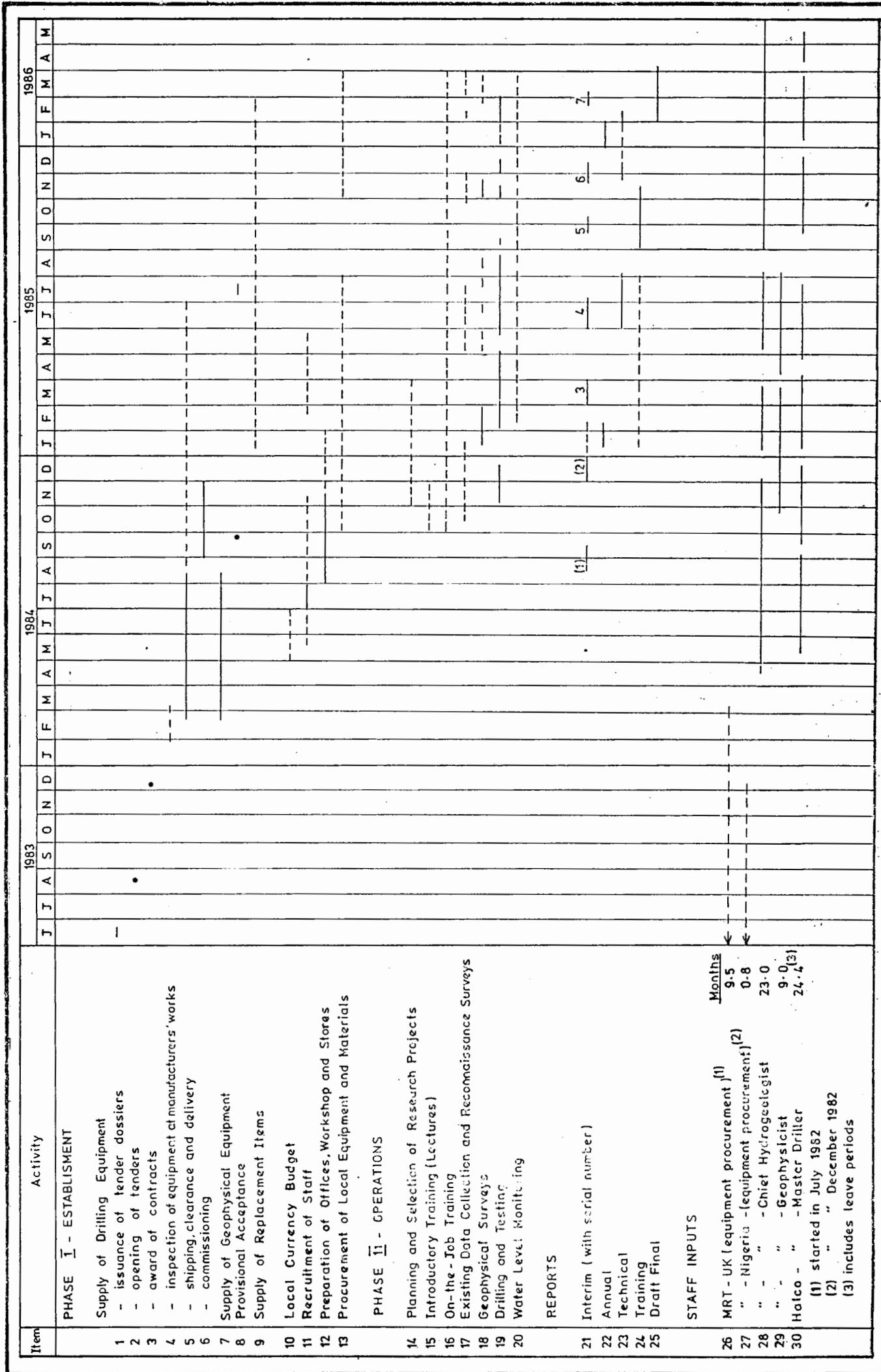
Phase I involved the procurement of the equipment; and the physical building up of the GWRD in terms of the provision of office and workshop space, recruitment of Nigerian staff, provision of staff accommodation and the supply of locally available materials. In addition, a local budget for capital and operating expenses was prepared as part of a planning and cost exercise.

Equipment procurement was initiated in 1982 with the preparation of technical specifications and tender documents. Most of the equipment was delivered to the NWRI in June to August 1984, with a few items delayed until April and June 1985. Full details are given in Chapter 2. A ceremony to hand over the equipment from the EEC/EDF to the FDWR/NWRI was held on 25 March 1985; the EEC/EDF was represented by Dr Frisch (Director General of the Development Commission), the FDWR by Mr Hanidu (Assistant Director, Lagos), and the NWRI by Mr Abetianbe (Acting Director).

The establishment of the GWRD within the NWRI began with the arrival of the Consultant's hydrogeologist (project co-ordinator) in April 1984, and was largely accomplished by the end of that year (full details are given in Chapter 3). The stage was then set to begin field operations and on-the-job training (Phase II).

Phase II activities got underway at the start of 1985 and will continue until the end of the project in May 1986 (see Chapter 4 for details). Field work has been carried out in Kaduna, Plateau and Niger States, and may be initiated in Kwara State before the end of

Figure 1.1 Programme of Work



KEY : — Continuous activity /input
 - - - Intermittent activity /input
 • Activity took place on single day

the project.

1.3 MRT and Halco Staff Inputs

Inputs of MRT and Halco staff in Nigeria are summarised in Table 1.1. Those of the chief hydrogeologist and geophysicist deviated from the contract agreement as the result of a review of work loads and logistical requirements during a visit to Kaduna by Mr M.R. Tulett of MRT on 17-19 March 1985. MRT proposed that the geophysicist's input (Mr Cunningham's) be reduced by 3 months (completion at the end of July 1985), and this time be added on to the chief hydrogeologist's (Mr Jackson's) who would then complete at the end of May 1986. The main advantage of the proposal was that the completion in May 1986 would match the end of the assignment of the master driller supplied by Halco (Mr Rigg). The proposal was accepted by the FDWR, and Mr Cunningham completed his assignment on 4 August 1985.

Mr Tulett, from MRT's head office in the UK, paid a second visit to the project on 2 October 1985 and is due to pay a third visit in April 1986.

A major problem encountered during staff mobilisation concerned visas, mainly because only 3 weeks visitor's visas were issued which could not be processed by the Immigration Service in Kaduna because the visas did not entitle the holder to work in Nigeria and were not subject to regularisation (STR). Although 3 month extensions were granted by the Immigration Service, all the staff had to make trips to Lagos to enlist the assistance of the FDWR and EEC offices to apply for residence permits. The staff were eventually issued with government officer (GO) stamps (residence permits are normally only issued to those involved in business/commercial activities).

The Consultant sees no reason why for an EEC-aided project the Nigerian High Commission in London could not have been authorised to issue STR visas which would have enabled the Immigration Service office in Kaduna to process the applications for longer stay permits. This would have avoided a lot of the frustrations and time wasting that the staff encountered during the first few weeks of their assignments.

Table 1.1
MRT and HALCO Staff Inputs

Position	Name	Input Dates (1)	Total Input (30 day month)	Contract Input (Month)
Chief Hydrogeologist (Project Coordinator)	D.M. Ball)) (MRT)	18 Apr 84 - 25 Nov 84)))	23.07	20(2)
	R.S. Jackson))	9 Jan 85 - 9 Apr 85) 3 May 85 - 9 Aug 85) 1 Sep 85 - 7 Jun 86)		
Geophysicist	L.J.F. Cunningham (MRT)	21 Oct 84 - 20 Mar 85) 7 Apr 85 - 4 Aug 85)	9.03	12(3)
Master Driller	J. Rigg (Halco)	11 May 84 - 11 May 86	24.37	24(4)

- Notes: (1) includes travelling time UK/Nigeria/UK
(2) revised to 23 months as a result of MRT's proposal
(3) revised to 9 months as a result of MRT's proposal
(4) according to the agreement Mr Rigg has with Halco this includes leave periods

CHAPTER 2

EQUIPMENT PROCUREMENT

2.1 Drilling Equipment

2.1.1 Tendering and Award of Contracts

Tender dossiers for the supply of five lots of drilling equipment, ancillary plant and vehicles (International Tender Nr.1971) were issued by the Consultant in June 1983; the tenders were opened at the FMWR on 17 August 1983. The contract to supply Lot 1 (drilling rig, hand tools, casing jacks, clamps, slips, mud pump, compressor, drill pipe, drill collars, drilling bits, down-the-hole hammers and bits, adaptors, fishing tools, bailers and drilling chemicals) and the services of an experienced driller mechanic (master driller) for a period of up to 24 months was awarded to the Halifax Tool Company Limited (Halco) on 9 December 1983.

The contract to supply Lots 2,3,4 and 5 (flat-bed truck with a cargo crane, water tanker, water trailer, fuel trailer, estate car, two 4-wheel drive vehicles, generator set, two test pump sets with trailer, cutting and welding gear, workshop tools, well casing and screen, and camping equipment) was awarded to Hydreq Ltd. on 7 December 1983.

A full list of the equipment supplied is given in Appendix A. The value of the two supply contracts was Pounds Sterling 596,373.02 (Pounds Sterling 544,373.02 for the equipment and Pounds Sterling 52,000 for the services of the master driller).

2.1.2 Delivery

The suppliers, under the conditions of the contracts, were required to deliver the equipment to the NWRI in Kaduna within four months. The Government Coastal Agency (GCA), acting on behalf of the FDWR, was responsible for the clearance of the equipment through Lagos seaport, and the suppliers were responsible for onward transport to Kaduna.

Details on arrival dates are given in Appendix A and summarised on Table 2.1. The bulk of the equipment arrived in Kaduna during June and July 1984, up to three months after docking at Lagos seaport. However, two crates (cases 50 and 51) and the test pump trailer from Hydreq's third consignment were held up in Lagos following a change in the clearance procedures and were not delivered to Kaduna until over a year later.

A major problem encountered during the clearance process was that it was very difficult to convey to the officials of the Customs, the GCA and the various ministries involved, that the equipment was exempt from any customs duties or import taxes under Protocol 6, Article 4 of the 1979 Lome I Convention.

Table 2.1
Delivery Dates of Drilling Equipment

Supplier	Vessel	Equipment Description	Arrival Date Lagos Seaport	Arrival Date(s) NWRI Kaduna
Halco	SS Balder Sund	Lot 1 complete (drilling rig and ancillary equipment)	5 May 84	18 Jun 84 (rig, mud pump, compressor) 25 Jun 84 (hand tools, casing jacks etc, drill collars, bits, down-the-hole hammers, adaptors, fishing tools, drilling chemicals) 23 Jul 84 (drill pipes)
Hydreq	SS Bore Queen	Main consignment (Lot 2 complete; Lot 3 generator, cutting and welding gear and workshop tools only; Lot 4 steel casing and screen only; Lot 5 complete)	15 Mar 84	18-19 Jun 84 (All except Peugeot 504 family estate)
"	SS St. Romain	Lot 4 PVC casing and screen, centralisers and plastic reducers only.	21 Mar 84	22 Jun 84
"	SS Stena Ionia	Case 50 (welding spares, hand tools, Land Rover spares, vehicle manuals, bulbs for lighting sets, steel casing adaptors and reducers), Case 51 (test pump sets) and trailer	14 May 84	22 Apr 85 (Case 51 and trailer) 29 Jun 85 (Case 50)

Most of the officials were not aware of the conditions and terms of the Convention, and resorted to the normal procedures for clearing commercial imports prevailing at the time. However, as these kept changing in line with the introduction of new government measures to control or limit imports, the task faced by the FDWR was often very difficult. The cost to Nigeria in terms of delay and storage/demurrage charges was high.

For any future EEC-assisted projects involving the importation of capital equipment the Customs, GCA and relevant Ministries should be thoroughly briefed beforehand on the conditions and terms of the Lome Conventions, and step by step clearance formalities should be worked out.

The consignments were transported by road to Kaduna by Nigerian Overseas Products Ltd. (NOP) of Apapa. On the first convoy some damage was incurred at a security check at the exit of the docks (Tin Can Island Ro-Ro Terminal); many of the wooden crates were smashed in by security staff with sledge hammers and, in order to let the drilling rig (mounted on a low loader) to clear an arch over the gateway, it was necessary to deflate the truck tyres of the rig. The tyres were not subsequently reflat, and the inner tubes on two tyres were trapped and split by being bounced and jolted on by the tyre rims. Fortunately the walls of the tyres were not damaged.

Some damage to the equipment occurred during the off-loading at the NWRI since NOP did not have the necessary manpower, fork lift trucks or cranes.

However, despite its long journey most of the equipment arrived in fair condition, having only suffered some dents, corrosion of unprotected metal, and perishing of rubber parts (see Table 3.2 of August 1984 Interim Report). Damage due to storage at the docks was most evident in the equipment from Hydreq's third consignment which was detained for over a year; one of the two test pumps was siezed up on arrival, and much of the other equipment had been damaged by water entering the crates.

2.1.3 Provisional Acceptance and Replacement of Items

Under Clause 9.2 of the EDF general conditions for supply contracts, provisional acceptance should take place not later than two weeks of the presentation of the supplies at the place of destination.

Representatives from the FDWR, EEC and the Consultant were required for the provisional acceptance. However, since the equipment was being cleared and transported to Kaduna (the place of destination) at different times it was not practical to hold a separate provisional acceptance meeting for each consignment; it was decided, therefore, that a composite meeting be held after the arrival of the final consignment.

Unfortunately, the delivery of this final consignment (from the SS

Stena Ionia) was held up by a change to the customs clearance procedures. However, once it became apparent that the consignment wasn't going to be released for some time the parties concerned agreed not to delay the provisional acceptance any further and to hold a partial acceptance for the equipment that had already arrived.

This was convened on 26 September 1984. The committee agreed that the equipment was in generally good condition, but there were a number of significant deficiencies which the suppliers were requested to make good.

Halco complied with this request, and replacement items were brought back by Mr Rigg on his return from home leave on 11 January 1985. These included brake air line, and cable and connector for the mud pump trailer; rear light assembly for the compressor; air swivel extracting tools; and assorted washers and O-rings. Two inner tubes for the rig truck, to replace those damaged during the journey from Lagos to Kaduna, were purchased locally.

Hydreq, however, contested the validity of the provisional acceptance (since it was held more than two weeks after the delivery of the equipment under inspection) and refused to replace the damaged or missing items. Hydreq also refused to comply with the findings of a second provisional acceptance meeting held on 12 and 15 July 1985 to inspect the SS Stena Ionia consignment after it had eventually been delivered to Kaduna.

As a result, the EEC called for Hydreq's guarantee bond (10% of the contract sum) on the grounds of non-performance. However, fortunately at the time (September 1985) Hydreq had just been taken over (by Dando Drilling Systems Ltd) and the new management pledged that all outstanding obligations would be honoured.

In the event, the replacement of the items found deficient during the September 1984 provisional acceptance was waived in lieu of a refund of their value (estimated at Pounds Sterling 2,192 CIF) by Hydreq to the EEC. The reason was that the absence of these items (two 12v truck batteries, tool kit and clock for the Peugeot 504 family estate, two Land Rover door lock cylinders and keys, 150m of lighting tower cable, 7 x 6m lengths of 8" steel casing and one 6m length of 10" steel casing) would not adversely affect the progress of the project, and the time involved in administering their clearance and internal transportation would be saved. The refund was effected on 5 February 1986.

The items found deficient during the July 1985 provisional acceptance were delivered to Kaduna between 5 November 1985 and 24 February 1986 (see Appendix A for details). They consisted of: two Peugeot 504 diesel engine manuals, Land Rover workshop manual and parts manual, 12 halogen tubes for the lighting sets, a Monolift BH 250 B pump assembly, 2 1/2" and 4" discharge regulating valves, and two Ott KL50 water level sounding tapes.

A provisional acceptance of these replacement items was held on 5 March 1986. Although the main item - the Monolift BH 250 B pump assembly - appeared to be in working order (the rotor could be turned by hand) it was recommended that final acceptance should not be given until the pump has been installed in a borehole and properly tested. However, since all the other items were satisfactory, and the previous issues resolved, it was thought reasonable that a recommendation could be made to the EEC to release the retention payment to Hydreq held under the guarantee bond (except for the pump) rather than waiting for a one year maintenance period to elapse - the retention on the pump (valued at Pounds Sterling 9,675) would not be paid until the pump had been satisfactorily proven in a borehole.

Following the provisional acceptance in September 1984 several deficiencies came to light when the equipment was used for the first time.

On the drilling rig the gear box air seal had suffered severe corrosion while the rig was in transit and storage; this allowed high pressure air to enter the gearbox and blow out the oil. Replacement bearing collars and seals were supplied by Halco, and brought to Nigeria on 11 January 1985 by Mr Rigg on his return from home leave.

On the water tanker the suction hose and tanker pipework couplings were found to be of different diameters (3 and 4 inch respectively), and on the generator engine there was extensive damage to one of the pistons, cylinder head and valve seats. Replacement parts were supplied by Hydreq, and brought to Nigeria on 3 May 1985 by Mr Jackson on his return from home leave.

The trailer which was supplied with the test pumps could not be towed by any of the project vehicles because the tow bar was at a different height to the vehicle hitches. However, modifications were made to the bar so that the trailer could be towed by the project Land Rovers.

2.2 Geophysical Equipment

Geophysical equipment, consisting of a MC Seis-1500 seismic data acquisition system (for seismic refraction), a SIE Geosource portable borehole logger, an ABEM SAS 300 Terrameter resistivity unit and a BGS-256 offset sounding system (for the Offset Wenner array), was airfreighted to Kano airport arriving there between 29 January and 15 April 1984.

The GCA was responsible for the clearance of the equipment, and the FDWR for transportation to Kaduna. However, the confusion over clearance procedures experienced in Lagos was exacerbated in Kano, and the equipment was not delivered to the NWRI in Kaduna until 13 August 1984, some four to seven months after its arrival in Kano.

The equipment was inspected during the provisional acceptance held on 26 September 1984 and found to be satisfactory. However, the Terrameter later malfunctioned and the error code indicated that the fault lay in the input amplifier stage. A replacement circuit board was requested from the manufacturer - it was received on 28 December 1984 after which the instrument functioned correctly.

Full details of the geophysical equipment are given in Appendix A.

2.3 Locally Procured Equipment

2.3.1 General

Under Schedule 4 of the Agreement for Engineering Services the FDWR was expected to provide the local costs needed to maintain and successfully run the project, including the procurement of locally available equipment to complement the imported items. However, since the project was based at Kaduna, this responsibility was passed to the NWRI.

A local currency budget was drawn up and approved at the beginning of the project which had provisions for the purchase of capital equipment - this included two vehicles (budget allocation N 26,000); office furniture, plain paper copier, air-conditioners, electric typewriter, refrigerator etc. (N 42,000); and technical and camping equipment to support the field operations (N 33,907). Full details are given in the August 1984 Interim Report, Chapter 5.

Unfortunately, for much of the project the necessary funds were not available to enable this equipment to be procured, and it was not until towards the end of project when the Institute's financial situation improved that some items could be purchased. In order to overcome this difficulty some technical items (particularly hydrogeological equipment) were loaned from FDWR Zonal Offices or procured by the Consultant using savings in the foreign currency contingency budget.

2.3.2 Vehicles

During the establishment phase of the project the Institute enquired about the purchase of a Peugeot 504 saloon and estate from PAN (Peugeot Automobile Nigeria), but funds did not materialise for their purchase. However, to make up for this, the Institute allocated a Toyota Land Cruiser station wagon (originally supplied by UNDP/UNESCO) to the project in late June 1985; this brought the number of light vehicles on the project to four.

2.3.3 Office Equipment

A plain paper copier (Minolta EP 300 RE) and an electric typewriter (TEC TW-3000) were ordered by the Institute in late 1984 and delivered on 20 March 1985 - only to be taken back by the supplier on 26 June because no payment had been made. The items were subsequently reordered towards the end of 1985 but their delivery has been held up by difficulties encountered by the supplier in obtaining an import licence.

2.3.4 Hydrogeological Equipment

The only hydrogeological equipment included in the EDF supply contracts consisted of three Ott KL50 electric contact gauges for water level measurement. Consequently, it was necessary to borrow as much as possible from nearby FDWR Zonal Offices since most items were not stocked by local survey equipment suppliers, and in any case funds did not materialise for their purchase. The following items were loaned:

- (a) 2 nrs Brunton type compass/clinometers;
- (b) 3 nrs 50m carbon fibre reinforced tape measures;
- (c) 20 nrs 200ml capacity sample bottles;
- (d) 5 nrs 1 lb. geological hammers, fibre glass shaft;
- (e) 1 nr Beckman Chem-mate pH/mV meter with two electrodes;
- (f) 2 nrs Hach DR/EL-4 portable laboratories.

A set of sieves, a sieve shaker and balance from the Institute's soil mechanics laboratory was used for particle size distribution analysis.

A request was made by the Consultant to the EEC in February 1985 for some items and supplies which could not be obtained locally to be procured from the project's foreign currency contingency fund. However, approval from the EEC was not given until the following December and, given the short length of time to the end of the project, the Consultant was only prepared to procure a few of the more essential items - these included a type MCI electrolytic conductivity (EC) meter (Kent model 5003), received on 5 March 1986, chemicals for the Hach kits, graph paper for plotting pumping test and chemical data, and a spare tape for an Ott KL50 electric contact gauge.

A weir tank, with a 90 degree V-notch was constructed in May 1985 for the measurement of discharge during airlift pumping tests; a 30 degree notch was subsequently fitted since the 90 degree notch was too large to measure the extremely low yields characteristic of Basement Complex boreholes with any level of accuracy.

2.3.5 Field Support Equipment

The lack of radio communication sets was one of the main logistical problems faced by the project.

Although several quotations were received from suppliers during the early part of the project through personal contacts, government regulations required that such items could only be purchased through open tender. Accordingly, once the Institute was in a financial position to proceed with the procurement (in November 1985), notices calling for quotations were posted in the Institute and elsewhere. The specifications called for three sets: one to be based in the Kaduna office, one in the drilling camp and one in a vehicle for the geophysical party.

Quotations were received from seven suppliers by the closing date of 6 December 1985. An analysis of the quotations was submitted by the Consultant on 15 January 1986, and the Institute awarded the contract to the recommended supplier in March 1986. Installation began on 17 March.

A lockable caravan was loaned from the FDWR Kaduna office in February 1985 for use as a mobile workshop and store on site. A work bench was installed and wiring for lights and power points for connection to the generator.

2.4. Equipment Provided by Consultant

The Consultant's geophysicist brought out a BBC microcomputer (with a word-processing facility), disc drive and a small Tandy TRS-80 printer for the analysis, interpretation and plotting of geophysical data, and for the preparation of training notes. An Epson LX80 printer was later provided (in November 1985) for report production.

For much of the time the project was very short of electric contact gauges for water level measurement due to the late supply of these items by Hydreq; the only gauge that was initially available was an Ott KL50 supplied free of charge by Halco. Because of frequent use it began to give a lot of trouble after May 1985 - the bottom weight unscrewed itself and fell down in a borehole during a pumping test, and parts of the wire became exposed and short circuited.

In order to prevent a situation whereby the project was without a gauge in working order - accurate water level measurement is crucial to the successful execution of pumping tests, and for borehole monitoring - the Consultant provided a reconditioned Wuidart gauge in November 1985.

CHAPTER 3

ESTABLISHMENT WITHIN THE INSTITUTE

3.1 Offices, Workshop and Stores

On arrival at the Institute in 1984 the consultants were given the use of two adjoining offices (rooms 11 and 12) in Block B in what is now the Research Centre (Figure 3.1). After the principal hydrogeologist of the Institute (Mr E.A. Moge kwu) was appointed project co-ordinator in early 1985 he moved to the consultants office in order to facilitate liaison on administrative and staffing matters.

Counterpart staff were accommodated in two classrooms in Block C which were made into one large open plan office by the removal of the intervening wall. This work was mostly carried out by the staff themselves, partly to keep costs to a minimum and partly to provide practical experience in carpentry and masonry. Unfortunately, the use which could be made of the office was limited by the lack of furniture - a few desks and chairs were supplied by the Institute, but financial problems prevented the purchase of the bulk of the furniture that was required.

Shelving was installed in April 1985 to store the geophysical and hydrogeological equipment.

For the maintenance and storage of equipment the project was allocated one half of one of the new workshops built for teaching and research purposes (Figure 3.1). A partition was erected between the two halves so that students taking practical classes would not be disturbed by the activities of the project.

A lockable store for spare parts was built along one side of the workshop; this work was also carried out by project staff, with the help and guidance of the Institute's own craftsmen, and provided useful practical experience in design and measurement of quantities.

3.2 Local Currency Budget

As mentioned in Section 2.3.1 the NWRI was responsible for meeting the local costs for the project. Accordingly, a budget was drawn up in May 1984 and approval for it was granted on 2 July 1984 by the FMAWRRD (Table 3.1) - full details are given in the August 1984 Interim Report, Chapter 5.

Although payments were made for staff costs, operational expenditures, the rent and services for the consultants' accommodation and the first year's rent for the senior counterparts' accommodation under this budget, virtually no funds were made available for capital expenditures (the purchase of locally available vehicles, equipment and furniture).

Figure 3-1 Plan of National Water Resources Institute

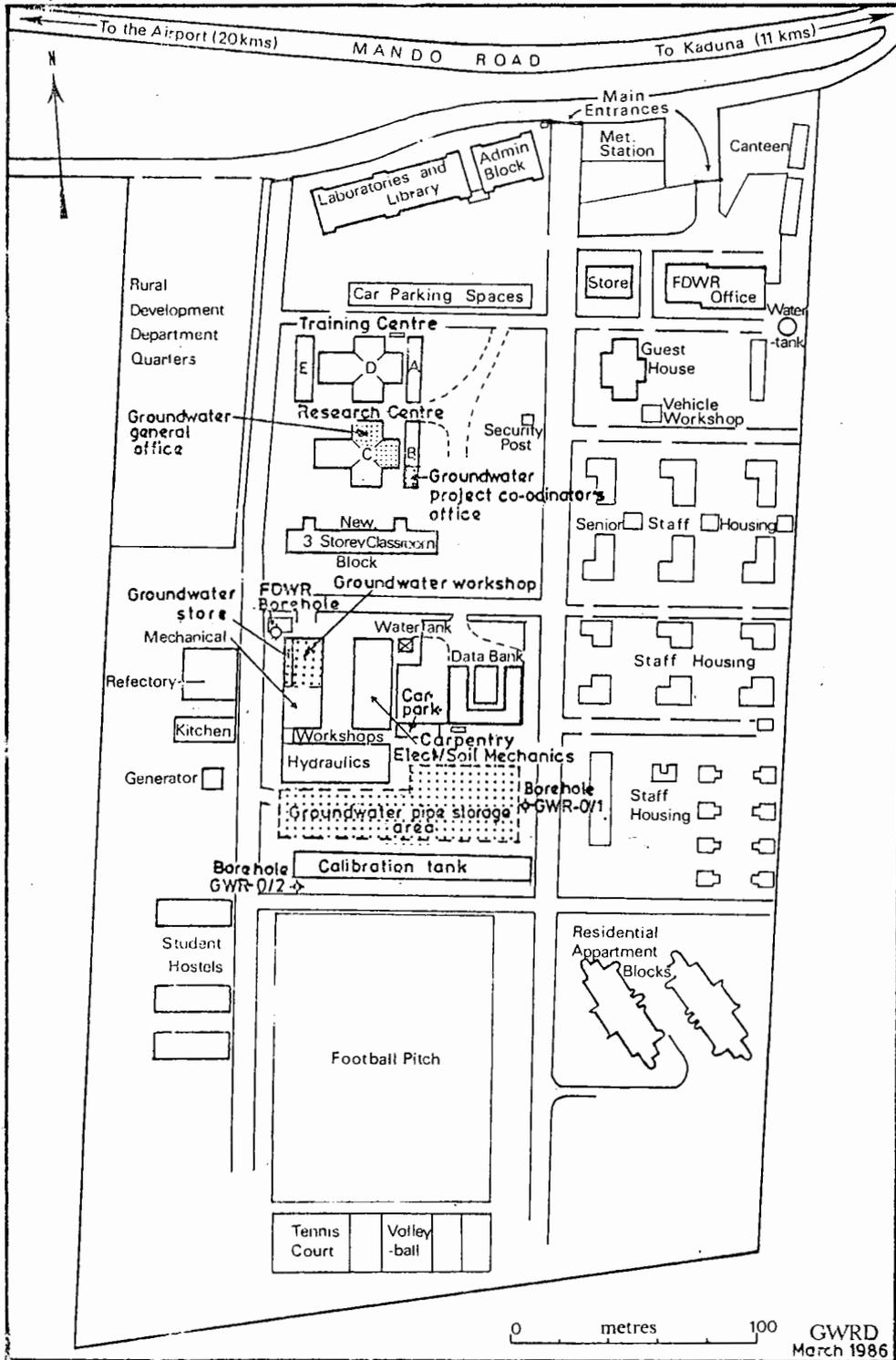


Table 3.1
Local Currency Budget Estimate

Item	Budget Heading	Capital Costs (#)	Operations			Total (#)
			1984	1985	1986	
1	Staff salaries, provident fund, overtime and allowances	-	79,500	238,500	238,500	556,500
2	Transport (b)	26,000	5,500	13,300	13,300	58,100
3	Offices, workshop and stores	6,000	2,400	2,400	2,400	13,200
4	Office furniture, equipment and supplies	42,000	1,000	1,000	1,000	45,000
5	Technical/field support equipment and supplies	33,907	5,430	14,910	24,910	79,157
6	Consultants' accommodation (c)	108,000	32,300	54,400	10,200	204,900
7	Senior Counterparts' accommodation	90,000	-	-	40,000	130,000
8	Training aids and technical literature	-	1,000	1,000	1,000	3,000
9	Travel (air fares, hotels, etc)	-	5,000	10,000	10,000	25,000
10	Report production	-	1,000	2,500	1,500	5,000
	Total	305,907	133,130	338,010	342,810	1,119,857

- Notes: (a) assumed to be incurred in 1984
 (b) capital item is for purchase of 2 vehicles
 (c) capital item is for furnishings, appliances and generators for 3 houses and operational items for rent and services

The problem of capital expenditure was also partly due to the fact that the Institute, being a government agency, had to adhere to the numerous rules and regulations designed to prevent abuses in the purchasing procedure; these involved a lengthy system of checks and balances. The inherent delays in this were compounded in the Institute's case by the fact that for the first year or so of the project (until the Institute was formally established by a Federal Government Decree) financial control was exercised from the Hadeija Jama'are River Basin Authority in Kano. This meant that applications for purchase approval and documents relating to the follow-up procedures (invitations to tender, tender analysis reports, minutes of tender committee meetings, preparation of local purchase orders, payment cheques, etc), had to be physically taken to and from Kano - in many instances, processing was held up by the absence of the relevant officials in Kano when the trips were made. During this time the Institute held an imprest account of only N 20,000 from Hadeija Jama'are.

In order to prevent delays in the setting up of the project and the execution of field operations, it was necessary for the Consultant to prefinance the day to day running expenses, and to invoice the Institute for reimbursement. Eventually, however, the Institute was able to give purchase advances to the Consultant (ranging up to N 10,000) which were replenished on the submission of full expenditure accounts.

On the consultants' accommodation the Institute was saved considerable expenditure; although three rented houses were budgeted for, in the event only one house was needed (Mr Jackson shared with Mr Cunningham who left before the arrival of Mr Jackson's family), and Mr Rigg elected to stay in the messes of companies with which he had personal contacts.

3.3 Staff Recruitment

Recruitment of the right calibre of counterpart staff was given high priority. It was considered important that the technical staff should have qualities that would enable them - after training and working alongside the consultants - to lead and direct their own work. The general qualities looked for during the recruitment process were intelligence, willingness to learn, professional integrity, an enquiring mind and initiative; academic qualifications were considered to be of lesser importance.

The Agreement for Engineering Services stated (Clause 1.3.2) that the Administration (FDWR) would provide the following technical staff for training by the consultants:

- 2 to 3 hydrogeologists;
- 2 drillers;
- 2 mechanics;
- 1 drawing technician and
- 1 geophysicist.

At the end of May 1984 an advertisement for hydrogeologists, geophysicists, drillers and groundwater technicians was circulated to all the FDWR zonal offices - this was to ensure that FDWR staff got priority in applying for the posts, although it was understood that applications from outside the FDWR would also be considered. The full text of the advertisement is given in the August 1984 Interim Report, Appendix A.

Applications were requested to be submitted by 29 June at either the FDWR office in Lagos or the NWRI in Kaduna. Responses were received from 72 applicants, and a shortlist of 37 was drawn up for examinations and interviews.

The selection process involved a 2 1/2 hour written examination, which was held on 19 July, and interviews which commenced directly after the examination and proceeded until the end of the following day. The examination paper is given in the August 1984 Interim Report, Appendix B. The interviews were held in front of a panel composed of the consultants and senior members of the NWRI and FDWR. As a result of the examination and interviews three hydrogeologists/geophysicists and four drillers/technicians were recruited.

Interviews and practical examinations for junior field staff were conducted in September 1984; 5 field assistants, 3 drivers, 9 labourers and 1 welder were recruited as a result.

Interviews were conducted in late October and November 1984 for the posts of cartographer/draughtsman and confidential secretary/report typist.

Watchmen at the consultants' house when Mr Ball and his family moved in during May 1984 were taken on by the Institute in November 1984.

The names and appointment dates of the 31 staff so recruited are summarised on Figure 3.2; the consultants' inputs are also shown.

Mr E.A. Mogeckwu, the Institute's Principal Hydrogeologist, assumed the role of project co-ordinator in February 1985 to liaise between the consultants and the Institute in matters concerning project administration and staff. He also in effect filled one of the six posts for counterpart hydrogeologists originally planned for the new department.

Following a review of staffing levels in early 1985 a need was recognised for more drivers and mechanics (only 3 drivers were originally recruited, but 6 vehicles were imported as part of the project equipment). Unfortunately, although interviews were held (on 21 February and 14 May 1985 for drivers and 12 March 1985 for mechanics) no further staff could be appointed (except a replacement for a driver who had resigned) because of the financial constraints the Institute was faced with. However, in order to assist the new department with the maintenance of vehicles and plant the Institute

Figure 3-2 Groundwater Research Department - Staff

Nr.	Post	Name	1984												1985												1986					
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun			
1	Chief Hydrogeologist (Project Coordinator)	D.M. Ball	18																													
2	Geophysicist	R.S. Jackson																														
3	Master Driller (Driller Mechanic)	L.J.F. Cunningham J. Rigg (Haico)	11				2	16	21	25	9	20	7	3			9	1														
4	Project Coordinator	A.E. Mogaekwu																														
5	Hydrogeologist/Geophysicist	B.O. Odusanya																														
6	"	S. Okedi																														
7	"	M.O. Edavie																														
8	Driller (Technician)	A.A. Oyintola																														
9	"	D.E. Aiyi																														
10	Technician	O.T. Olusola																														
11	"	S.O. Owolabi																														
12	"	I.O. Opuama																														
13	Senior Maintenance Officer	V. Ojag																														
14	Field Assistant	C.E. Dimpka																														
15	"	U.V. Oche																														
16	"	H. Elisha																														
17	"	A. Ndozhaga																														
18	"	D. Haruna																														
19	Driver	E. B. Njoku																														
20	"	B. Ibibu																														
21	Driver/Halter Mechanic	Mh. M. Idrachim																														
22	Labourer	J. Goloba																														
23	"	I. I. Amaji																														
24	"	D. Musa																														
25	"	D. Iwuogwu																														
26	"	E.O. Igwe																														
27	"	S. Abdu																														
28	"	S. Umaru																														
29	"	N. Sule																														
30	"	M. Ibrahim																														
31	Welder	H. Umaru																														
32	Cartographer	S. U. Jeremiah																														
33	Confidential Secretary	S. Jairo																														
34	Watchman	L. U. O. Njemanze (Mrs)																														
35	"	I. Garba																														
36	"	B. Anyawu																														
37	"	N. Musa																														
		L. Adamu																														

Key: 3 — 9 Input periods of expatriate staff, including travelling time UK/Nigeria/UK
 12 — Data assumed duty (counterpart staff)
 --- NWRJ permanent staff (not specifically recruited for GWRD)
 → Transfer to another department in NWRJ

provided the services of its Senior Maintenance Officer, Mr Vincent Ojong, on a full time basis.

Two of the field assistants were dismissed at the end of January 1985 since they were found to be completely unsuitable for project work, and a bad influence on the rest of the staff.

Following a review of staff qualifications and manpower requirements in September/October 1985 some members of staff were transferred to other departments in the Institute: Mr S. Okedi to the Biology Laboratory (since he graduated in biochemistry); Mr H. Elisha to the Hydraulics Laboratory; three labourers to Estate; and one watchman to Security. Thus, of the 31 staff originally recruited, 23 remained within the GWRD at the end of the project.

An FDWR driller, Mr D.E. Aiya, was attached to the project in September 1984 to receive training and gain practical experience. Unfortunately, he was retrenched from the FDWR in July 1985 as part of an overall adjustment to staffing levels in the Federal Ministries. However, since he showed himself to be a key member of the drilling team, the Consultant recommended that he be taken on by the Institute for the new department. He was eventually appointed on 21 November 1985.



CHAPTER 4

FIELD OPERATIONS

4.1 General Programme

The programme of field investigations undertaken by the project is summarised on Figure 4.1. The locations of drilling and geophysical work are shown on Figures 4.2 and 4.3 respectively.

At the start of the project five separate research investigations were envisaged to provide experience for the staff in the different hydrogeological, drilling and geophysical conditions of the country. However, in the event only two research investigations could be carried out (the Experimental Catchment Area and for the Niger State Water Board) - the rest of the programme was taken up with drilling individual boreholes for various institutions which had asked the FDWR/NWRI for assistance with their water supply problems.

The bulk of the work was carried out on the Basement Complex to the south and west of Kaduna in Kaduna, Plateau and Niger States - although part of the research investigations in Niger State involved sedimentary formations.

Apart from the drilling of a borehole at the Institute (GWR-0/1) to commission the rig and ancillary equipment, the programme started in the catchment of two small rivers about 30km west of Kaduna chosen to provide a convenient test bed for research into all aspects of water resources evaluation - it was hoped that the groundwater work would act as a stimulus to other research departments in the Institute. The catchment became known as the Experimental Catchment Area (ECA), and the results of the investigations are discussed in Chapter 6.

In June 1985 the programme moved away from the Kaduna base and work was carried out at Kwoi (near the southern boundary of Kaduna State) and on the Mar Farms near Nassarawa (Plateau State) at the request of the FMAWRRD.

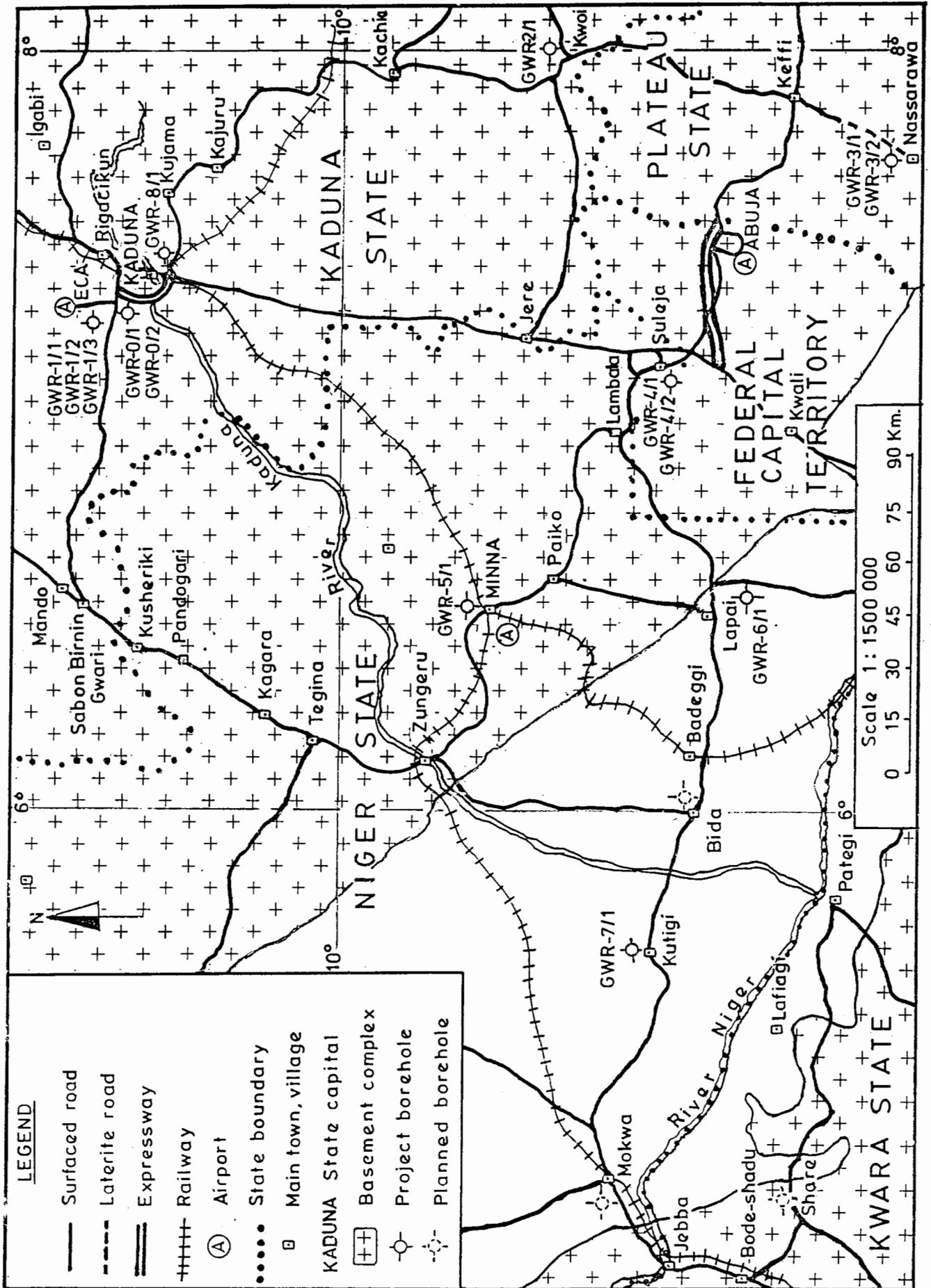
A research project was carried out at various locations in Niger State in response to a request from the Niger State Water Board (NSWB) in December 1984. Following discussions with Board officials on 27 and 28 March 1985 it was proposed that investigations be undertaken at representative locations on the Basement Complex and the Niger basin sedimentary formations - Suleja and Kutigi were chosen respectively for this purpose. In addition, aerial photograph interpretation (api) and reconnaissance surveys were proposed for three other locations on the Basement in the hope of being able to extrapolate the results obtained at Suleja.

Work started in July 1985 at Suleja, and two boreholes were drilled following a geophysical survey. Further geophysical work was carried out at the other locations on the Basement in November 1985, following earlier photogeological mapping. Drilling of the three

Figure 4.1 Groundwater Research Department - Programme of Fieldwork

Activity	1984			1985												1986						
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May		
	1. <u>KADUNA STATE</u>																					
Reconnaissance surveys																						
Geophysical work																						
Drilling and testing																						
Water level monitoring																						
2. <u>PLATEAU STATE</u>																						
Geophysical work																						
Drilling and testing																						
3. <u>NIGER STATE</u>																						
Aerial photo interp.																						
Geophysical work																						
Drilling and testing																						

FIGURE 4.2 GROUNDWATER RESEARCH DEPARTMENT-LOCATION OF DRILLING SITES



boreholes planned at Kutigi began in February 1986 but unfortunately was halted on the first borehole by serious leakages to the mud swivel on the rig. The remaining boreholes will have to be drilled once the swivel has been repaired or replaced. Results of the work for the NSWB are discussed in Chapter 7.

During March 1986, while the swivel was undergoing repairs (in Port Harcourt), the equipment was brought back to Kaduna to drill a borehole for a hospital in Kaduna South - on the Basement alternatives to mud drilling can be used, notably air and foam.

In November 1985 a borehole was drilled at Minna for the Upper Niger River Basin and Rural Development Authority, and in December 1985 on a farm near Lapai (Niger State) at the request of the FMAWRD.

During January 1986 the drilling team carried out a fishing operation in the FDWR borehole at the Institute (drilled in 1982 as part of the National Borehole Programme) to recover a pump which had previously parted company with the riser pipes and fallen to the bottom of the hole. The operation was successful and provided useful training for the counterpart staff.

4.2 Drilling

Fourteen boreholes were drilled during the project up to the end of March 1986; their locations are shown on Figure 4.2, and results summarised on Table 4.1. Full completion reports and composite logs are given in Volume II.

Drilling began in November 1984. Because the rig and support trucks were not licenced at the time, the first borehole (GWR-0/1) had to be drilled within the compound of the Institute (Figure 3.1). The purpose of the borehole was primarily to test the rig and the full range of ancillary equipment under working conditions. The drilling of the borehole was slow because, to avoid accidents or damage to the equipment (a major risk with an inexperienced crew), it was necessary for Mr Rigg to spend much time explaining what had to be done at each stage. Also, a number of problems arose as a result of deficiencies to the drilling equipment and these had to be dealt with as they arose.

The borehole was drilled to 92m and 8 inch steel casing was installed to 40.8m, just below the base of the weathered zone. Thus, the borehole effectively taps the fresh Basement rock which, because of the absence of significant fractures, is virtually impermeable. The borehole is only really suitable for monitoring purposes.

Following the licencing of the rig and support trucks in January 1985 the drilling equipment was mobilised to the catchment of the rivers Chidawaki and Chikaji (the ECA) near Buruku. Three boreholes were drilled on the fadama (alluvial plain) of the R. Chidawaki near the western end of the ECA.

TABLE 4.1

GROUNDWATER RESEARCH DEPARTMENT - SUMMARY OF BOREHOLE RESULTS

Borehole nr.	Location	Co-ordinates		Ground Elevation (m)	Total depth (m)	Depth to fresh BC Screen (m)	Completion		Test Discharge (m ³ /h)	Pumping Duration (m)	SWL (m)	Draw-Down (m)	EC (u.S.G.m)
		Longitude	Latitude				BC Screen (m)	Open hole (m)					
GWR-0/1	N.W.R.I.	07° 25' 18"	10° 34' 55"	625	92.0	38	None	40.8-92.0	2.9	7	7.5	>43	280
" -0/2	"	"	"	"	29.0	27.1	13.1-23.7	None	1.0	128	6.8	5.0	200
" -1/1	ECA	07° 16' 21"	10° 38' 27"	575.1	102.0	16.0	None	18.0-102.0	0.6e	60	1.9	>80	410
" -1/2	"	"	"	574.8	15.0	15.0	6.8-13.9	None	7.4	240	1.7	3.7	140
" -1/3	"	"	"	574.1	40.1	28.0	5.3-11.3 26.3-32.3	None	-	-	1.1	-	-
" -2/1	Kwoli	08° 00' 16"	09° 26' 46"	775	61.3	11.4	None	13.1-61.3	0.5	330	10.1	32	95
" -3/1	Nassarawa	07° 43'	08° 34'	?	43.5	14.9	6.0-30	30 - 43.5	1.2	196	3.3	24.4	400
" -3/2	"	"	"	?	61.4	12.8	5.3-14.3	14.3-61.4	1.6	1445	2.2	32.0	350
" -4/1	Suleja	07° 10' 21"	09° 10' 22"	410	40.0	5.2	None	9.0-40.0	0.4	1440	4.0	3.4	140
" -4/2	"	07° 10' 35"	09° 10' 49"	415	60.0	8.0	None	8.9-60.0	2.8	1440	6.6	21.3	150
" -5/2	Minna	06° 28'	09° 41'	?	70.0	4.7	None	5.4-70.0	1.4	45+	4.7	10.4	420
" -6/1	Lapai	06° 36' 13"	09° 00' 47"	145	61.3	22.8	13.0-24.4	24.6-61.3	2.5	420	13.8	19.6	250
" -7/1	Kutigi	05° 37'	09° 12'	140	114.9	114.9	17.1-20.1 40.2-45.9 54.6-57.6 100.5-103.9	None	3.1	660	8.7	<36	85
" -8/1	Kaduna S	07° 25' 15"	10° 28' 02"	615	73.3	24.0	12.9-24.3	24.5-73.3	7.2	1440	6.7	16.9	105
				Total	863.8								

The first borehole of the group, GWR-1/1, was drilled to the greatest depth (102m) in order to test the fresh Basement rock and to provide further training for the crews in the use of the down-the-hole hammer (some training had previously been given during the drilling of GWR-0/1). A sampling test was carried out by airlift.

The second borehole, GWR-1/2, was drilled just to the top of the fresh rock at 15m, and 6 inch (150mm) nominal diameter (nd) PVC screen was installed in the overlying alluvium and weathered zone. The crew was introduced to a different drilling method; only water was used as the circulating fluid and the hole was kept open by temporary casing following the bit. The casing was withdrawn as gravel pack material was emplaced around the screen string. After completion, a short pumping test was carried out by airlift.

The third borehole, GWR-1/3, was drilled on the opposite side of the fadama strip to determine the thickness of the alluvium and weathered zone near to the course of the R. Chidawaki. A biodegradable drilling chemical was used for the operation. Screen was installed opposite the alluvium and parts of the weathered zone. Unfortunately, however, the site had to be abandoned just when the borehole was ready for testing because of flooding following a period of heavy rain at the end of March.

GWR-0/2 was drilled for the hydraulics laboratory calibration tank at the Institute (Figure 3.1), while funds were awaited for the mobilisation away from Kaduna. The borehole was drilled to 29.0m and fresh Basement rock was encountered at 27.1m. Screen was installed opposite the lower part of the weathered zone, and the annular space was filled with a sand filter. Unfortunately a leak occurred in the bottom length of screen which allowed sand to enter the well in large quantities during airlift development. However, this problem was solved by backfilling the bottom 3m of the borehole with gravel and cement. A short airlift test was then carried out at a discharge of 1.0 m³/h - this is more than enough for the requirements of the calibration tank. The water quality is good, with an EC of 200 uS/cm.

GWR-2/1 was drilled as a goodwill gesture at the Government Girls Secondary School at Kwoi, following the checking of an FDWR borehole there. The yield of the FDWR borehole was reported to be unsatisfactory and it was thought by the FDWR that the screen may have clogged up in the two years between the completion of drilling (in November 1982) and the installation of the pump. However, it was found after two days of testing that the pump was able to produce a reasonable supply of water (1.8 m³/h), providing some back pressure was applied on the discharge line to prevent air surging.

The drilling of GWR-2/1 began on 13 June but was not completed until 3 July. Much time was spent in trying to install steel casing past a granite boulder in the weathered zone - the boulder was rather

loose and kept deflecting the string during reaming. It took, 10 days to produce a straight enough hole to enable 6 inch nd casing to be installed to the top of the fresh Basement. The water producing capacity of the borehole is too low for the efficient operation of a mechanically-driven pump. However, the water quality is excellent for drinking purposes, and it was recommended that a handpump be installed to serve the needs of the nearby houses and school buildings - (such a pump was subsequently fitted by the school authorities).

GWR-3/1 and GWR-3/2 were drilled on the Mar Farms near Nassarawa in Plateau State. Both boreholes were completed with open-ended 6 inch nd PVC screen opposite the weathered zone, and open hole in the fresh rock below. The bottoms of the screens were packed around with inner tubes and sacks to ensure a tight seal with the borehole wall to prevent the inflow of gravel pack material from above. Both boreholes have been equipped with electric submersible pumps by the farm owner.

GWR-4/1 and GWR-4/2 were drilled at Suleja as part of the research project for the Niger State Water Board. GWR-4/2 encountered significant fracture zones in the Basement rock at 11 to 15m and 21 to 22m - these render the borehole relatively productive; the terminal yield during pump testing was 2.8 m³/h.

At GWR-3/2, GWR-4/1 and GWR-4/2 pump testing was run for continuous periods of 24 hours.

GWR-5/1 was drilled at the Minna headquarters of the Upper Niger River Basin and Rural Development Authority near a site selected by a resistivity survey undertaken by Ahmadu Bello University in 1983. The borehole encountered Basement rock at about 5m and some fracture zones to 13m and around 46m. However, the borehole yield was relatively low (1.4 m³/h by bailing).

GWR-6/1 was drilled on the farm of Malle Farms (Nig.) Ltd. near Lapai. The only aquifer occurs in the lower 9m of the weathered Basement; the fresh rock below has no discernable fractures. However, a yield of 2.5 m³/h was obtained during a 7 hour pumping test, and the water quality is good for domestic purposes.

After the Christmas/New Year break the drilling rig was brought back to Kaduna for an attempt to fish out a Mono pump from the borehole originally drilled for the FDWR at the Institute - the pump assembly and about 15m of the riser pipes attached to it were missing when the pump string was pulled on 26 November 1985.

After several fishing attempts, and the fabrication of a special tool from a length of 4 inch GI pipe the pump was successfully recovered on 16 January 1986.

Caliper and SP logs were run on 20 January to check on the borehole depth and screen settings - the depth was found to be only 93m (as opposed to 102m in the FDWR completion certificate) and, although

the total screen length was the same (15m), the setting depths were 7 to 9m shallower than reported. During subsequent redevelopment (by airlift for 4 hours), the discharging water contained significant quantities of yellowish green micaceous sand, and the bottom of the borehole was found to consist of gravel pack material.

An SP2-18 solar-powered electric submersible pump (provided by Grundfos for a demonstration of the application of solar energy for borehole pumping) was installed to 54m with 3/4 inch riser pipes on 22 January. Unfortunately, however, the pump failed to work when connected to the solar panel arrays, and it was removed on 27 January for checking by Grundfos. The pump was indeed found to be defective, and Grundfos will arrange for the installation of a replacement.

The drilling rig and ancillary equipment were moved to Kutigi on 28 January to drill three boreholes in the sedimentary formations (Nupe Sandstones) of the Niger basin as part of the research project for the NSWB. It was the intention to drill the first borehole, GWR-7/1, as deep as the drill pipes would allow (about 270m) in order to obtain as complete a picture as possible of the lithological sequence and occurrence of aquifer layers - indeed, it was hoped that the underlying Basement would also be encountered.

Unfortunately, however, drilling had to be halted at 115m because of a serious leak of mud from the mud swivel. Despite an attempt to build up the shaft of the swivel to ensure a tighter fit for the seals, the leakage continued. In the circumstances, the borehole was completed as a piezometer with the installation of 4 inch PVC casing and screen.

A trip was made to Port Harcourt on 4-6 March to see if a replacement swivel could be obtained. Since no swivel of the type required could be found the existing swivel was left with a specialist workshop for reconditioning. At the same time steps were taken to try and import a replacement swivel and spare from abroad.

While the swivel was being reconditioned the rig was brought back to Kaduna to drill a borehole on the Basement (where alternatives to mud drilling can be used) at a hospital in desperate need for water in the south of the city.

4.3 Geophysics

Table 4.2 summarises the geophysical work undertaken by the project. Field data, interpretation plots and location maps are given in Volume III.

Surveys were generally carried out in the same areas as the drilling in order to select the most favourable sites and to calibrate the results with actual borehole logs. However, some work was also done at other locations on the Basement in Niger State, in connection with the photogeological mapping exercise of the research project for the Niger State Water Board.

Table 4.2 Summary of Geophysical Work

Location	Number of VES		Number of Resistivity Traverses	Number of Seismic Spreads
	Offset	Wenner Schlumberger		
ECA (Jan-May 85)	23	2	3	2
ECA (Aug 85)	2	1	-	-
ECA (Feb-Mar 86)	1	-	1	-
Kwoi	1	-	-	-
Nassarawa	7	-	4	-
Suleja	3	3	-	5
Kagara	5	3	8	6
Pandogari	4	-	4	1
Nasko	3	1	2	2
Rijau	2	1	7	4
Total	51	11	29	20

Both resistivity and seismic refraction methods were employed, although it was found that the latter was only of use in areas where the fresh Basement rock occurs at depths of less than 10m or so because of limitations to the equipment supplied. The resistivity method was much more useful in estimating the depth to rock and locating the most favourable zones for productive boreholes - vertical electrical soundings (VES) using both the Offset Wenner and Schlumberger arrays were carried out, as well as constant electrode separation traversing.

Field data were processed and analysed on the BBC microcomputer belonging to the Consultant, and the interpreted results printed out on specially prepared formats.

In the ECA, soundings and traverses were carried out mainly between the borehole group (GWR-1/1, GWR-1/2 and GWR-1/3) and Nagijmbe Hill near the western end of the area, a distance of about 1.4km. Some work was also done near proposed drilling sites on the watershed between the rivers Chidawaki and Chikaji along the road to the new airport, and near the confluence of the two rivers.

Field work was interrupted at the end of February 1985 when the resistivity recording instrument (Terrameter) stopped functioning, apparently with the same fault as had previously required the input amplifier circuit board to be replaced in 1984. Work did not resume until May, after the instrument had been sent to Europe for repair.

The survey at Mar Farms, Nassarawa was executed from 21 to 26 June. Six vertical electrical soundings (VES) and four 400m long constant separation traverses (25m electrode spacing) were done. The data were analysed in the field with the computer, and the interpreted results included in a report prepared by the counterpart hydrogeologist/geophysicist concerned. A plot of apparent resistivity contours was used to select the drilling site for the borehole to supply water to the farm houses (GWR-3/1) - the site for the second borehole (GWR-3/2) was chosen from access and utilisation considerations, before the survey was carried out.

Geophysical investigations were undertaken at Suleja on behalf of the Niger State Water Board with the aim of locating suitable sites for drilling productive boreholes in water-short areas of the town. Only two areas of sufficient size for conducting surveys could be found in the town itself; both were at schools. Six VES were carried out, using both Offset Wenner and Schlumberger arrays, and five seismic refraction spreads (there was not enough space for resistivity traversing). The survey started on 22 July and was completed two days later. A report was prepared by the counterpart hydrogeologist/geophysicist who directed the survey, which gives full details of the results obtained. It was concluded that Basement rock occurs at 5 to 8 metres (this was confirmed by the subsequent drilling of GWR-4/1 and GWR-4/2).

During August the sounding curves produced from a survey carried out

by Ahmadu Bello University for the Upper Niger River Basin and Rural Development Authority (UNRBRDA) at Minna in 1983, were analysed using the computer to check on the validity of the interpreted results. Unfortunately, no indication was given in the survey report on what arrays or electrode spacings were used. However, it was decided to use apparent resistivities taken from the curves and feed them into the computer using the Offset Wenner array program. In the event very similar curves were produced, and the interpreted results supported the previous conclusions on the location of the best drilling site (GWR-5/1 was subsequently drilled near to the recommended location).

The survey in Niger State was carried out from 31 October to 19 November 1985. The areas investigated included the villages of Kagara, Nasko and Rijau where photogeological maps had previously been prepared for the Niger State Water Board research project. A report on the work was prepared by the counterpart hydrogeologist/geophysicist concerned.

4.4 Aerial Photograph Interpretation

The proposed research project for the Niger State Water Board included the preparation of a photogeological map for Suleja incorporating the results of the geophysical survey and drilling; in addition, aerial photo interpretation was to be carried out for the villages of Kagara, Nasko and Rijau to extrapolate the techniques developed for Suleja.

Unfortunately, it was subsequently found that aerial photographs for Suleja were not available at the Geological Survey in Kaduna so no photogeological map could be prepared. However, photographs for Kagara, Nasko and Rijau were available, and the resulting photogeological maps were used as a basis for the subsequent geophysical surveys.

4.5 Water Level Monitoring

Regular monitoring of the boreholes at the Institute and the ECA began in April 1985 for the determination of seasonal water level fluctuations.

The elevations of the boreholes were determined by instrument survey from nearby national benchmarks and trigonometrical stations to enable water levels to be reduced to a common datum. A local benchmark was established near the borehole group in the ECA. The work was carried out by students of the Institute under the supervision of the land surveying lecturer in the Training Centre.

4.6 Operational Problems

4.6.1 Administrative and Logistical Problems

The projects's field programme has been encouraging - the staff recruited for the GWRD have worked well in the field and benefited from the training and experience, and much useful data have been obtained. However, although there were technical problems and breakdowns to the equipment at times, progress was mainly constrained by several administrative and logistical issues which need resolving if the GWRD is going to continue to be effective. The most serious issues were:

- (a) **Travelling allowances and overtime.** According to the staff regulations of the Institute, staff are entitled to a travelling allowance for each night spent away from their duty station (Kaduna), and for overtime up to 45 hours in one month. However, processing of the staff's claims was always exceedingly slow which caused hardship amongst the more junior staff since they generally had to leave most of their salary with their families; if the allowance payment was late they themselves had almost nothing to live on in the field. But what really upset the staff was the Accounts Department's practice of deleting the first travelling day from the claims; generally this was for the mobilisation to a new site which involved a long drive late into the night and sleeping rough because there was usually insufficient time to make arrangements for proper accommodation. For staff to be penalised in this way, especially when in many instances they were under pressure from the Institute's management to mobilise just before a weekend, is deplorable and staff morale suffered as a result.

The travelling allowance is an important incentive for staff to work in the field, especially for the labourers and drivers since it effectively doubles their income. If improvements are not made in this matter the Institute may find it difficult to retain the loyalty and goodwill of the field staff.

- (b) **Radio communication sets.** As mentioned previously funds for the local purchase of budgeted technical and field support equipment only became available towards the end of the project. This was most serious in the case of radio communication sets and meant that for most of the project the field teams had no direct contact with the Kaduna base. As a result much time (and money) was spent by senior staff driving to and from the field sites - some as far away as 400km from Kaduna - in order to monitor progress and give necessary directions; all this could have been minimised had radios been available. (However, this issue will shortly be resolved since the installation of radios began in late March 1986).
- (c) **Field Accommodation.** Another major logistical problem centered on field accommodation. Although tents were provided as part of the project equipment it was thought it would be better for the field teams to be accommodated by the beneficiaries of the drilling and geophysical programmes, especially since no charge was being made for the resulting boreholes. However, the standard of accommodation provided at most locations was very disappointing - indeed, at many places the accommodation was not even ready when the teams arrived. As a result privation and frequent illnesses were experienced by both expatriate and counterpart staff.

The difficulties with field accommodation eventually affected staff moral so much that it was decided in February 1986 that the teams should be entirely self-sufficient, and that extra camping equipment be procured to augment that provided under the EDF supply contracts. However, in the long term, caravans or customised modules are the only satisfactory answer to this problem and are included in the package recommended for any future procurement (Chapter 9).

4.6.2 Equipment Breakdowns

Drilling Equipment. Generally the equipment has performed satisfactorily. The only breakdowns occurred in March 1985 (to the variable displacement hydraulic pump on the rig, and to the clutch on the mud pump power take-off) and in February 1986 (to the mud swivel on the rig).

The hydraulic pump was easily put back into service by the replacement of a corroded part on the drive shaft. New clutch plates for the mud pump, however, had to be procured in Port Harcourt. (During the visit a 3 inch high pressure ball valve, also for the mud pump, was procured - the valve was required to control the pump pressure while using the mixing line for mud preparation).

As mentioned previously the mud swivel developed a serious leak during the drilling of GWR-7/1 in the Niger basin sedimentary formations at Kutigi. The swivel was reconditioned at a specialist workshop in Port Harcourt, but since the grease seals were burnt off during the process replacement seals will have to be obtained from abroad - (the seals available in Port Harcourt were of the wrong type and in any case ludicrously expensive).

Some problems were experienced with the Monolift P631 CE test pump. The pump initially would not work, and success was only achieved after a non-return valve (fashioned from a coach bolt, washer and spring) was installed in the inlet assembly below the pump. The manufacturer, Mono Pumps Limited, recommended immersing the pump in water for some time before operation to permit a good seal between the stainless steel rotor and rubber stator - this practice worked, and the non-return valve was later removed.

However, the pump is not really suitable for the very low yields associated with Basement Complex boreholes - its rated capacity is 9.5 m³/h at 80m total head (and 1000 rpm), whereas the yields of the boreholes so far drilled lie in the range 0.4 to 7.2 m³/h. In order to prevent the pump from running dry the regulating valve on the discharge line had to be almost closed - on a positive displacement pump such as the Monolift this can cause water slip at the rotor/stator interface which may eventually damage the pump.

In order to correct this situation, and as a gesture of goodwill, Mono supplied a C32 P301 BC pump on a free of charge basis to the project in February 1986 (this pump was originally designed for hand operation and is better suited to the very low flow rates associated with the Basement).

Geophysical Equipment. The Terrameter did not work when first tested by the Consultant's geophysicist in October 1984. The error code indicated a fault to the input amplifier stage. A replacement input amplifier circuit board was received from the manufacturer in December. However, after some two months of field work the instrument again stopped working and the error code indicated the same fault as before. It was decided to send the instrument back to

the manufacturer in Europe for repair. Since its return (on 3 May 1985) it has worked satisfactorily.

The borehole logging equipment (SIE Geosource T450) developed a fault in the SP-resistivity mode at the end of July 1985; in some boreholes, no response at all could be obtained from the E-log. Although the fault was largely rectified by reheading the cable, the resistivity log response is still not satisfactory.

Vehicles. The only major breakdown occurred on 19 November 1985 when the geophysical team were returning to Kaduna after a two week survey in Niger State. The engine of the Land Rover station wagon they were using seized up at a place over 400km from Kaduna, and the flat-bed truck had to be despatched to recover the vehicle. Repairs to the engine took some time because certain spare parts had to be procured from abroad, and the vehicle only became serviceable again in March 1986.

Very little geophysical work could be done while the vehicle was off the road because the other transport was needed for the drilling operations.

4.7 Use of Drilling Consumables, Casing and Screen

Since much of the drilling has been by compressed air (with the DHH), consumption of consumables such as bentonite and drilling chemicals has been moderate; Table 4.3 summarises the consumption to the end of March 1986.

No bit has yet been worn out and become unusable. However, some buttons were lost from the DHH bit used in GWR-4/1, and one of the 4 3/4 inch tricone bits has loose bearings.

Casing and screen usage during the project to the end of March 1986 is summarised in Table 4.4.

4.8 Operational Expenditure

A statement summarising the operational expenses incurred by the project from January 1985 (when the field programme began) to March 1986 is given in Table 4.5.

There was a marked increase in costs during 1986 following the government announcement on 1 January of the partial removal of subsidy on petroleum products - the price of diesel was increased three-fold from 11.0 to 29.5 kobo a litre, and petrol two-fold from 20.0 to 39.5 kobo a litre.

Fuel for the transport and drilling equipment accounted for about half of the operational costs. However, despite this, overall costs remained well within the budget estimates. The budget allocation for the operational costs for 1985 and for three months of 1986

Table 4.3 Use of Drilling Chemicals

Item	Chemical	Unit	Qty supplied (contract doc.)	Qty as at 31/3/86	% used
1	Foam	200 l barrel	20	16	20
2	Bentonite	50 kg sack	200	140	30
3	CMC Hi Vis	25 " "	15	10(a)	-
4	Q-Broxin	" " "	40	45	-
5	Drill Aid Custom Mud	10 kg tub	80	72	10

Note: (a) 5 damaged

Table 4.4 Use of Casing and Screen

Item	Material	Nom.diam (in)	Qty actually supplied (m)	Qty in stock at 31/3/86	% used
1	Steel casing	4	201.0	201.0	0.0
2	" "	6	814.5	751.5	7.7
3	" "	6 5/8	90.0	66.0	26.7
4	" "	8	360.0	312.0	13.3
5	" "	10	144.0	144.0	0.0
6	PVC casing	4	350.1	249.9	28.6
7	" "	6	299.1	212.4	30.0
8	PVC screen	4	402.6	381.9	5.1
9	" "	6	367.8	279.0	24.1
10	" "	8	200.7	199.2	0.7
11	" "	10	117.0	117.0	0.0
12	Stainless steel screen	4	40.6	40.6	0.0
13	Stainless screen	6	60.9	60.9	0.0

Table 4.5
OPERATIONAL/RUNNING COSTS

Budget Heading Code	Transport (fuel, etc) 4.4	Office Accomod. 4.5	Office Supplies 4.6	Technical Equipment 4.7	Technical Supplies 4.8	Consultant Accomod. 4.9	Training Aids/Literat. 4.11	Travel 4.12	Report Product. 4.13	Total
Month										
Jan 85	211.10	240.00	202.25	699.70	463.30	4.00	-	273.00	-	2,093.35
Feb "	225.70	-	8.00	254.40	965.00	-	-	-	126.00	1,579.10
Mar "	196.41	-	-	1,419.95	341.80	-	5.00	627.50	100.00	2,690.66
Apr "	314.30	12.00	170.55	262.35	117.70	635.69	25.00	128.00	-	1,665.59
May "	205.35	-	190.50	155.50	358.90	43.50	-	323.63	-	1,277.38
Jun "	312.70	-	118.50	47.70	891.80	77.60	-	11.21	-	1,459.51
Jul "	282.03	-	222.15	130.00	339.26	143.00	-	-	185.50	1,301.94
Aug "	167.67	-	-	-	12.00	26.00	-	-	257.00	462.67
Sep "	497.44	-	5.20	-	251.00	484.72	-	-	-	1,238.36
Oct "	1,262.95	-	3.00	-	49.95	101.70	-	17.00	199.00	1,633.60
Nov "	937.66	15.00	142.50	68.70	107.00	11.00	4.00	14.50	-	1,300.36
Dec "	535.39	-	18.00	-	506.10	65.70	-	19.00	115.00	1,259.19
Jan 86	393.01	-	3.00	37.50	1,040.80	133.54	-	-	112.00	1,719.85
Feb "	2,535.80	-	77.51	15.00	533.50	161.90	-	19.50	183.00	3,526.21
Mar "	872.18	-	20.00	1,055.50	848.59	81.50	5.20	539.60	204.00	3,626.57
Total	8,949.69	267.00	1,181.16	4,146.30	6,826.70	1,969.85	39.20	1,972.94	1,481.50	26,834.34
%	33.4	1.0	4.4	15.5	25.4	7.3	0.1	7.4	5.5	100.00

(except staff salaries and rent for the consultants' accommodation) amounted to N 58,637 (Table 3.1). Thus, the actual expenditure of N 26,834.34 was only 45.8% of the budget allowance.

CHAPTER 5

TRAINING

5.1 General Approach

One of the primary roles of the MRT and Halco consultants was the training of counterpart staff in order to achieve the main objective of the project: the creation of a Groundwater Research Department within the Institute composed of staff able to undertake studies on a wide range of hydrogeological problems.

Although some introductory lectures were given, the main emphasis was on practical, 'on-the-job' training during the execution of the field programme. Staff were exposed to a wide variety of problems and were guided to a solution rather than being presented with a ready-made answer - this was to encourage initiative and resourcefulness. The consultants were mindful of delegating work at as early a stage as possible in order to develop co-operation amongst the staff and to encourage a command structure.

The on-the-job training was complemented by the preparation of a manual on groundwater investigation procedures, and the provision of reference text books for the GWRD general office and senior counterpart staff.

5.2 Introductory Training

Before the field programme got underway some lectures were given to introduce staff to the basics of hydrogeology, the application of geophysics to groundwater exploration, and to elementary vehicle maintenance. Also, the staff were encouraged to assist in the preparation of the offices, workshop and stores to gain some practical experience in building design, carpentry, masonry, decorating, etc.

5.3 On-the-Job Training

The commissioning of the equipment at the Institute, and the ECA study provided the first opportunity for on-the-job training. Staff were introduced to mud and down-the-hole hammer (DHH) drilling (including the use of foam and 'custom mud'), formation sample collection, penetration rate measurement, casing installation and gravel pack preparation. Training was also given in formation sample description, particle size analysis, geophysical well logging, chemical analysis, and pumping test operation and data plotting.

Training in geophysics was given on the various field techniques, and on data processing and interpretation on the Consultant's microcomputer.

Standard forms were prepared for all these activities to encourage a uniform approach to data collection and presentation; these forms are given in Appendix B. The counterpart hydrogeologist/geophysicists were encouraged to prepare the composite logs for the boreholes they supervised (which involved the interpretation of geophysical logs, drilling records and sample descriptions), and the reports on the geophysical surveys undertaken.

A rota system was initiated amongst the hydrogeologists/geophysicists and some of the technicians to ensure that staff were introduced to both geophysical and hydrogeological fieldwork and data analysis. However, those staff with some previous practical drilling experience were allocated to form the senior members of the drilling crew from the start to ensure that the training in the operation of the rig - which is an expensive and potentially dangerous piece of equipment - was concentrated on the most suitable personnel.

Once the field programme moved away from Kaduna the drilling crew gained experience in installing casing past a loosely-set boulder (GWR-2/1), and seating open-ended screen securely in boreholes in the Basement rock so that gravel material emplaced round the screen did not enter the hole below during subsequent development and pump testing (GWR-3/1, GWR-3/2, GWR-6/1 and GWR-8/1). The work at Kutigi (GWR-7/1) provided an introduction to deep mud drilling in sedimentary formations - unfortunately it was cut short by the leakage to the mud swivel.

The recovery of the pump installed in the FDWR borehole at the Institute provided a good opportunity for the drilling team to be trained in fishing techniques. Because of the nature of the 'fish' the fishing tools supplied with the drilling equipment were not effective and a special tool had to be fabricated - this was very useful experience for the team.

Even some of the mishaps that occurred during the project provided valuable experience for the staff - these included: coping with equipment breakdowns; recovering bogged-down plant and vehicles from a flooded site (ECA); emplacing a gravel/cement backfill to prevent the flow of sand through broken screen (GWR-0/2); and recovering a broken-down vehicle over 400km from Kaduna.

After the end of the 1984/1985 academic year (in July) two students were attached to the project as part of their industrial training programmes; one was from the Institute itself, the other from the Anambra State University of Technology. Students of the Institute also received some training when they carried out a levelling survey to determine the elevations of the boreholes drilled in the ECA.

5.4 Training Manual and Reference Books

In order to complement the training received in the field a manual on groundwater investigation procedures, based on the experience of the project and of work undertaken by the Consultant elsewhere, was begun in October 1985. A list of all the groundwater reports in the Institute's library was prepared for inclusion in the manual.

Sets of reference text books and papers on groundwater exploration and data analysis were ordered for the senior counterparts and the GWRD general office, using savings in the project's foreign currency budget. Delivery of these books (listed in Table 5.1) is expected in April 1986.

A copy of the British Drilling Association's "Code of Safe Drilling Practice Part I" was provided by the Consultant in October 1985.

Table 5.1 Groundwater Reference Books and Papers

Item	Author	Title	Date	Qty
1	J.D. Hem	Study and Interpretation of the Chemical Characteristics of Natural Water (photocopy)	1970	4
2	G.P. Kruseman and N.A. De Ridder	Analysis and Evaluation of Pumping Test Data	1983	4
3	M.D. Campbell and J.H. Lehr	Water Well Technology	1973	3
4	W.H. Telford, L.P. Geldart, R.E. Sheriff and D.A. Keys	Applied Geophysics	1976	2
5	L.G. Hutton	Field Testing of Water in Developing Countries	1983	4
6	British Standards Institute	British Standard Code of Practice for Test Pumping Water Wells	1983	4

CHAPTER 6

EXPERIMENTAL CATCHMENT AREA STUDY

6.1 Introduction

During the initial stages of the project in 1984 it was decided that a small Experimental Catchment Area (ECA) be selected near Kaduna in order to get a field programme for the GWRD underway, and to provide a convenient test bed for research in all aspects of the hydrologic cycle by the Institute as a whole.

The catchment of the rivers Chidawaki and Chikaji was chosen as being suitable for this purpose (Figure 6.1). These small rivers drain westwards into the R. Tubo which drains southwards to the R. Kaduna, one of the main tributaries to the Niger. The catchment area covers 186.4 km² and starts about 10km west of the Institute along the Mando Road. The road to the new airport traverses the catchment and further access is gained by the Rigachikun-Afaka road.

Besides being within easy reach of the Institute the Chidawaki catchment is attractive for research purposes because it is unlikely to come under any pressure from industrial or domestic developments. This is because most of the land falls under the nominal control of the Afaka and Rigachikun forestry reserves and the Nigerian Defence Academy (NDA).

The collection of existing information began in October 1984 with visits to the Kaduna State Water Board, the FDWR Kaduna office and the new airport. Field surveys were then carried out to inspect geological features and existing wells, and to choose the first drilling site.

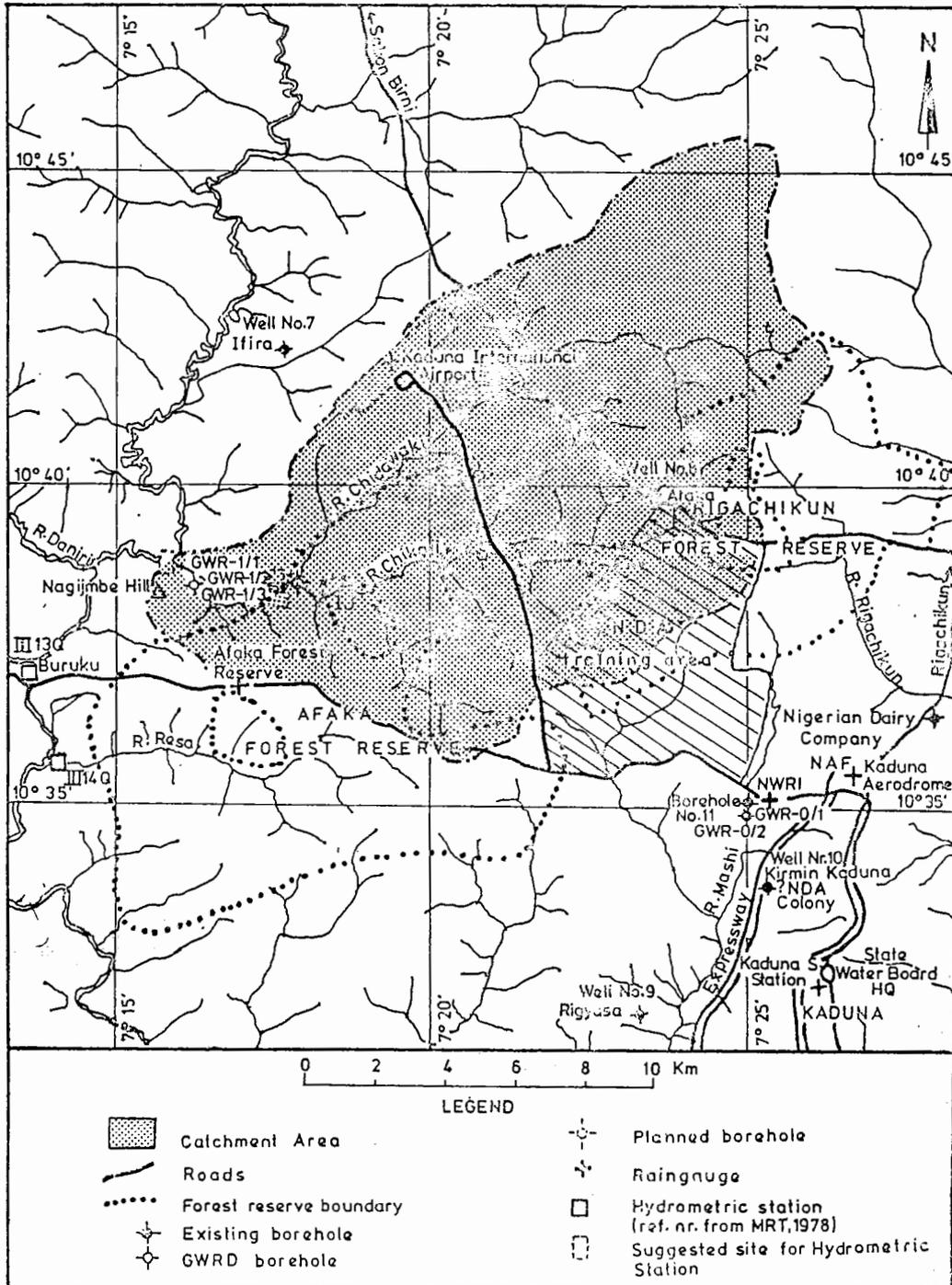
Members of the Institute's Research Committee visited the area on 16 January 1985; the proposed drilling site was inspected and a survey was made around the lower part of the catchment and along the R. Tubo.

The original aim was to drill five boreholes (Interim Report, November 1984): three in a line across the valley at the western end of the catchment, one on the crest of the rise between the two rivers along the road to the new airport, and one nearby on the flank of one of the valleys (Figure 6.1).

Drilling began in early February 1985 at the western end of the catchment, but was abruptly curtailed after the third borehole because of flooding of the site following two nights of heavy rainfall at the end of March. The drilling equipment was withdrawn from the site and taken to the base workshop for checking and servicing. Further drilling will probably be carried out in April 1986.

Resistivity field work began in January 1985 in the western part of the catchment near to the first drilling site, but unfortunately was

Figure 6.1 Experimental Catchment Area



halted towards the end of February by a breakdown to the recording instrument (Terrameter). The instrument was sent back to Europe for repair, and field work did not resume again until early May.

6.2 Existing Data

6.2.1 Maps and Aerial Photographs

The Catchment area lies almost wholly on sheet 123 SE (Kaduna SE) of the second edition of the 1:50,000 map. The sheet was published in 1966, and is largely based on 1:40,000 scale air photography taken in January 1962; the relevant photographs for the catchment area are 5906 - 5911 (Run 7), 5975 - 5977 (Run 5) and 6328 - 6332 (Run 6).

The Geological Survey of Nigeria interpreted the aerial photography and produced a photogeological map at 1:100,000 scale; sheet 123 covers the catchment area.

Aerial photography at 1:25,000 scale, taken in March 1972, also covers the catchment area. The number of the photograph covering Nagijmbe Hill and the confluence of the R. Chidawaki with the R. Tubo is 72903 - 57.

6.2.2 Geophysical Surveys and Boreholes

No specific groundwater surveys were carried out in the Kaduna area until the National Borehole Programme in the 1970s; this involved regional investigations on the Basement Complex to assess the potential for the development of rural water supplies. The Basement was divided into 12 areas by the Federal Ministry of Water Resources, and consulting firms were assigned to carry out the 'pre-drilling hydrogeological investigations'. The ECA lies in Area III which was investigated by German Consult/GWE/Isumma, whose report was published in May 1978. On their map of groundwater potential the ECA is included in the zone of "preferential interest", where the Basement Complex is interpreted as being very weathered.

MRT Consulting Engineers (Nigeria) Ltd appraised the groundwater potential of Kaduna State during the Waterboard Master Plan Study (MRT, 1978). They concluded that the best prospects for groundwater in the Basement Complex lay in areas of subdued topography, where weathering is likely to be most developed. The ECA is included in their zone of favourable groundwater potential.

Data on existing boreholes are given in Table 6.1. Borehole locations are shown on Figure 6.1.

Electrical sounding surveys were carried out by Eptasa/CEC in October-November 1981 to site a borehole at the FDWR/NWRI compound in Kaduna, and at Buruku. The borehole at the FDWR/NWRI compound (Well Nr.8/11) was drilled during April-May 1982 and produced the

Table 6.1 Experimental Catchment Area - Existing Borehole Data

Borehole number	Location	Coordinates E N	Date completed	Total depth (m)	Depth to fresh BC (m)	Screen setting (m)	Max. tested yield (m ³ /h)	SUL drawdown (m)	Draw-down (m)	Pumping duration (h)	Spac. capacity (m ³ /h/m)	TL (m ² /day)	KL (m/day)
S 62	Sidon Gidan Afaka Ibad, Zaria	07° 24' 10° 40'	27/4/76	25.3	22.9	20.4-25.3	3.5	9.8	-	6	-	-	-
S 63	Sidon Gidan Afaka Ibad, Zaria	" "	28/4/76	19.2	16.8	14.3-19.2	1.8	9.8	-	6	-	-	-
GSN 1423	Rural Water Supply Dept., Kaduna	07° 25' 10° 30'	7/2/55	22.6	>22.6	-	1.7	4.6	-	-	-	-	-
GSN 2175	Rural Water Supply Dept., Kaduna	07° 25' 10° 29'	17/10/69	19.9	>19.8	5.8-19.1	-	2.1	-	-	-	-	-
GSN 3153	Kaduna Textiles 1, Kaduna.	07° 25' 10° 29'	25/8/54	31.4	30.2	11.0-30.2	3.8	1.6	23.2	5.0	0.16	4.8	0.25
Ru 6	Kaduna Water Board Dept	07° 25' 10° 27'	15/2/72	29.0	26.6	6.7-10.4) 19.2-20.7)	11.7	2.4	5.2	11	2.3	66	13
Well No.1	Ribuckhon A	07° 28' 10° 38	19/5/82	27.5	24.0	10.0-22.0	2.0	9.1	15.6	24	0.22	3.9	0.32
Well No.2	" B	" "	11/5/82	31.5	30.0	19.2-25.2	3.2	7.6	17.1	24	0.19	5.5	0.55
Well No.3	" C	" "	13/5/82	32.2	27.0	17.8-26.4	2.5	6.7	25.9	24	0.10	2.6	0.33
Well No.6	Sidon Sirmi Daji	07° 18' 10° 49'	15/5/82	35.5	33.0	11.8-29.5	2.9	9.3	21.4	24	0.14	4.0	0.22
Well No.7	Zaria	07° 18' 10° 42'	27/5/82	30.2	27.0	16.9-24.4	2.0	8.6	16.2	24	0.12	3.6	0.48
Well No.9	Nigita	07° 23' 10° 32'	5/6/82	38.2	>36.2	24.6-32.6	3.6	8.5	25.3	24	0.14	4.2	0.51
Well No.10	Kurmin Kaduna	07° 25' 10° 34'?	2/6/82	50.2	?	26.3-32.0) 42.5-45.6)	2.5	5.7	37.1	24	0.07	2.0	0.23
Well No.8	Afaka	07° 23' 10° 40'	16/5/82	34.2	32.2	17.3-29.3	1.3	6.4	24.3	24	0.05	1.6	0.13
S/N. No.11	Ibad, Kaduna	07° 25' 10° 35'	17/5/82	102	42	24 - 27) 36 - 42) 69 - 72) 82 - 85)	3.2	5.3	39.6	72	0.08	2.4	0.16
"	Nigerian Dairy Co. Ribuckhon CR.2	07° 28' 10° 36'	1980 ?	100 ?	?	-	2.0712.2	(27/5/85)	-	-	-	-	-
"	Livestock Production Dept Kaduna.	07° 26' 10° 35'	1981 ?	-	-	-	-	-	-	-	-	-	-
"	Waters International Ribuckhon	07° 20' 10° 41'	Aug - May 80	-	-	-	10	-	-	-	-	-	-

required yield of 3 m³/h. It was subsequently fitted with a Monolift pump driven by solar energy - (however, the pump has now been withdrawn - see Section 4.2). No borehole has yet been drilled at Buruku, where a continuous supply of 20 m³/h was required - a yield of this magnitude is unlikely from the Basement Complex unless extensive fissure zones are encountered.

Electro-magnetic and electrical sounding surveys were carried out by Geoexploration (Nig) Associates in March and June 1980 to select borehole sites for the new Kaduna airport (Kaduna International Airport). The borehole drilled on the site selected by the first survey reportedly produced a yield of 10 m³/h.

Several boreholes and dug wells were monitored for water quality from June 1983 to June 1984 as part of a study on groundwater pollution in Kaduna conducted by Loladson Consultants.

6.3 Physical Background

6.3.1 Geology and Topography

The ECA is underlain by the Basement Complex. In Kaduna State three divisions of the Basement are recognised:

- (a) the migmatites and gneisses;
- (b) the metasediments; and
- (c) the Older Granites (MRT, 1978)

Migmatites (mixed rocks generally consisting of a metamorphic host invaded by granitic material) and gneisses make up the ECA, with the Older Granites forming inselbergs along the western margin.

Quartz, potassium feldspars (such as orthoclase and microcline) and plagioclase (sodium and calcium feldspar series) each generally account for between 20 and 50% of the total minerals present in the Basement (Jones, 1985). Micas, amphiboles and pyroxenes can comprise up to 25%.

The topography of the ECA is that of a gently undulating plain, sloping from an elevation of about 670m along the eastern watershed to about 580m at the drainage point into the R. Tubo. The dominant slope in the Tubo plains is 2% (Bennett et al., 1977). The only prominent topographic feature is the 660m high Nagijmbe Hill near the western end of the catchment.

The main structural trend detected by aerial photograph interpretation is northwest - southeast (Figure 6.2), although the relative straightness of some of the rivers, notably the R. Tubo, may also indicate the presence of north-south trending structures, possibly faults. At a more local level north-south and northeast-southwest trending joints and fracture zones were detected by Geoexploration (Nig.) Associates during surveys to select borehole sites for the new airport; banded gneiss outcropping in the

area had a strike in the range of 330 to 10 degrees and a southwesterly dip.

Over most of the area underlain by the Basement Complex in northern Nigeria there is a thin, discontinuous mantle of weathered rock, most pronounced where the topography is subdued - as in the ECA. The average thickness of the mantle is probably of the order of 15m, but in some areas it may extend to depths of up to 60m (du Preez and Barber, 1965). In the Kaduna area existing borehole data indicate that the weathered mantle is on average about 28m thick (Table 6.1).

The junction between weathered and unweathered rock is usually sharp. Weathering tends to be particularly well developed along fissure systems, which allow deep percolation of weathering agents - principally oxygenated water (Mandel and Shifan, 1981, in Clark, 1985). River systems can sometimes be a guide to fault lines and associated fissure systems because they represent lines of weakness for erosion and weathering.

Over large areas the upper part of the weathered mantle is laterised to form a hard, resistant crust; this process probably took place during the Pliocene period (Burke and Durotoye, 1970, referred to in Bennett et al., 1977).

Areas of rugged topography, subjected to a high rate of erosion, have a thin weathered zone.

River courses on the Basement Complex tend to be characterised by a narrow strip of alluvium known as fadama in northern Nigeria. The extent of fadama in the ECA is shown on Figure 6.2, and has been measured to be 23.6km² (12.7% of the catchment area).

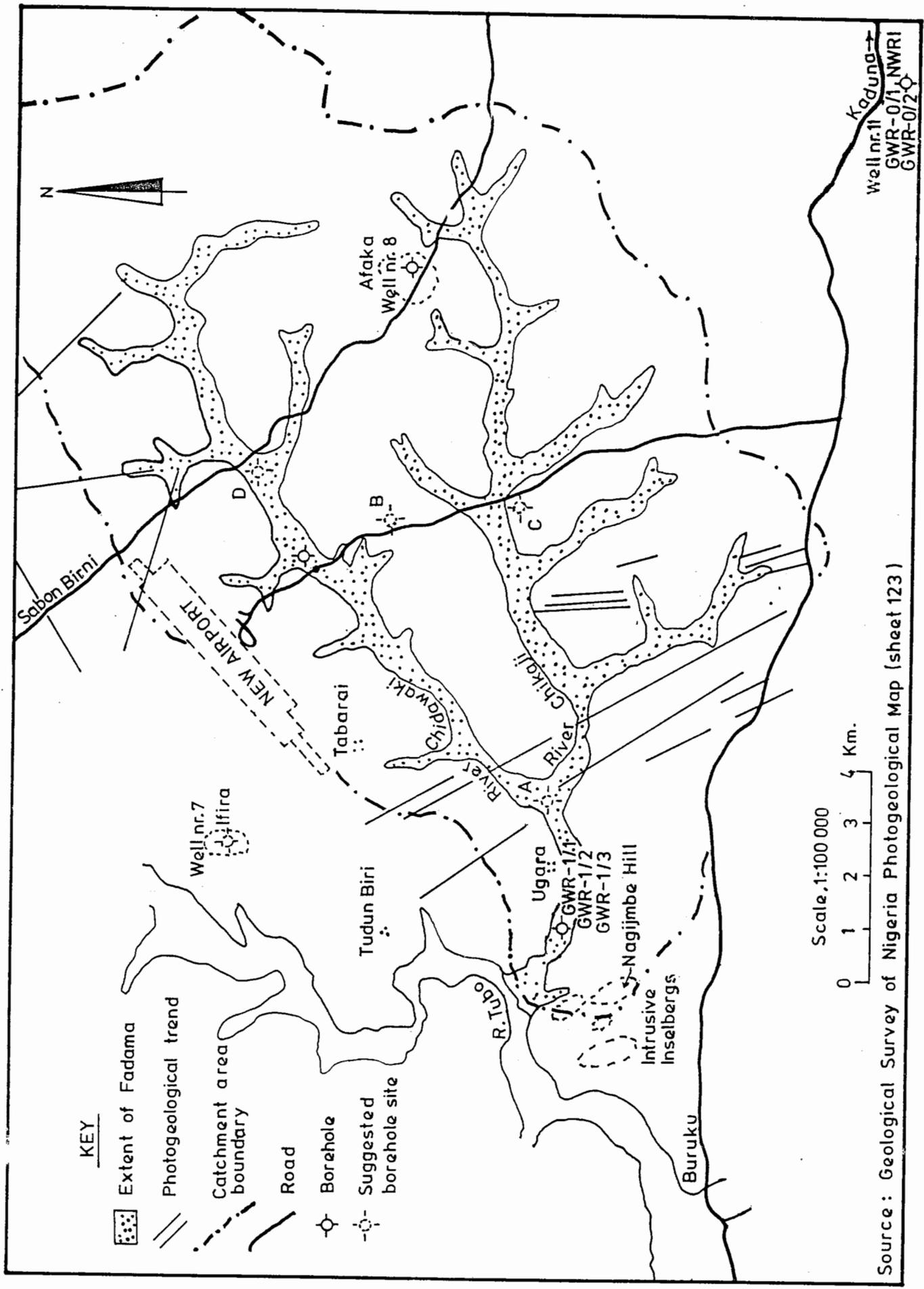
6.3.2 Groundwater Occurrence

Groundwater in the fresh Basement Complex is restricted to fissure systems which, because they occupy only a fraction of the rock volume, offer very limited storage potential. Available drilling data indicate that fissure systems rarely extend beyond 50m in Nigeria (Clark, 1985).

The main occurrence of groundwater is in the weathered mantle, and overlying fadama alluvium where present. However, the saturated zone is usually thin - a thickness range of 8 to about 20m is typical (Omorinbola, 1983) - and its permeability is generally low because of the high clay or mica content of the weathered rock. Nevertheless, the aquifer is areally extensive and its storage potential is significant.

Highly weathered migmatites and gneisses are degraded to a material containing a very large proportion of kaolinite (MRT, 1978). This stage of weathering is often found in the uppermost part of the zone and is associated with low permeability. At greater depth beneath the kaolinised layer, the degradation product has similar

Figure 24 Experimental Catchment Area - Extent of Fadama



lithological characteristics to a clayey grit; any joints or fractures tend to be open. This part of the weathered zone passes downwards into the hard, essentially unaltered rock. The best prospect for groundwater production occurs in that part of the weathered zone below the kaolinised layer. Jones (1985) has also indentified that the aquifer is most productive towards the base of the weathering zone (the active weathering front) where the rock has been broken down into sand-size and larger fragments, and not yet subjected to the weathering processes.

The water in the weathered zone aquifer is unconfined and water tables are shallow, rarely exceeding 20m below ground surface. Annual fluctuations in water level are usually large and may exceed 3m (MRT, 1978).

Water quality is generally good though local deterioration in quality due to sewage pollution and to evaporation from shallow water tables does occur. Most of the waters contain less than 200 mg/l of dissolved solids and the waters are of the calcium bicarbonate type.

The ECA lies in the Basement Complex zone exhibiting more favourable groundwater potential (MRT, 1978 and German Consult/GWE/Isumma, 1978), where the subdued topography indicates that the weathered mantle is likely to be well developed. Geoexploration (Nig.) Associates interpreted a water-bearing sandy clayey layer 8 to 68m thick from the geophysical surveys carried out to select borehole sites for the new Kaduna airport. A borehole drilled after the first survey yielded 10 m³/h.

Most boreholes in the Kaduna area have a yield in the range 1.3 to 3.8 m³/h (Table 6.1); the two boreholes with yields of 10 to 12 m³/h - RW8 at the Kaduna Water Board Depot, and the borehole near the new airport - probably encountered well developed fractures. Mean screened section permeabilities (estimated by the Logan approximation of the Theim formula) mostly range from 0.1 to 0.6 m/day.

6.3.3 Climate

Weather and rainfall regimes are the result of the general atmospheric circulation of air masses over the earth modified by surface topography and elevation (Kowal and Knabe, 1972). The principal air masses affecting the weather of northern Nigeria are:

- (a) the monsoon - a moist, cool air mass originating from the South Atlantic Ocean in the southwest, and;
- (b) the harmattan - a dry, hot mass originating from the Sahara Desert and reaching the area as a dust-laden, north-easterly wind.

The monsoon and the harmattan air masses flow towards each other

from opposite directions into a belt known as the Inter-Tropical Discontinuity (ITD), an unstable region of ascending air.

The ITD oscillates slowly and irregularly during the year. The annual motion over Nigeria is northwards between February and August and southwards from September to January. South of the ITD are air streams charged with moisture together with the mechanism that can convert it to rain. A rainy season follows in the wake of the northerly movement of the ITD.

Rainfall in Kaduna State has so far most thoroughly been analysed by MRT (1978). The mean annual rainfall was mapped for a standard period (1941 - 1970), using sophisticated techniques to infill gaps in the data base from stations with long-term, reliable records. The ECA lies just south of the 1200mm isohyet, and a figure of 1215mm is probably representative of the mean annual rainfall. Data from rainfall stations in the Kaduna area are summarised in Table 6.2; locations are shown on Figure 6.1.

The rainy season in the ECA starts on average in mid-April and ends in mid-October, a period of 6 months (Maps 12 to 14 in Kowal and Knobe, 1972). Rainfall generally reaches a peak in August. Because the energy content of rainfall systems in Nigeria is large, the amounts of water they hold and the rates at which they are shed are also large - as a result flooding, sheet erosion and gullying are common occurrences.

6.3.4 Vegetation and Land Use

The ECA lies in the Northern Guinea Zone of the Savannah region of Northern Nigeria (du Preez and Barber, 1965). In this zone the climax vegetation consists of broad-leaved savannah woodland. When well developed the trees may attain heights of 10 to 15m and may be dense enough to suppress grasses. More usually, however, the vegetation is relatively open, as is the case over the catchment area, because of the influence of grazing, cultivation and burning. The larger flood plains carry a distinctive vegetation of tall grass and palms, while relatively dense gallery forest occurs along some of the streams.

Much of the land in the ECA is used for non-agricultural purposes: the Afaka and Rigachikun forest reserves in the south and east, the NDA training ground in the southeast, and the new airport complex along the northwestern watershed. The rest of the land is mainly used for cattle grazing, with cultivation of vegetables, rice and other food crops along the lower parts of the fadama. Generally, less than 10% of the land is cultivated in the area northwest of Kaduna (Wall, 1978).

6.4 Field Investigations

A group of three boreholes (GWR-1/1, GWR-1/2 and GWR-1/3) was

Table 6.2

EXPERIMENTAL CATCHMENT AREA - SUMMARY OF RAINFALL DATA

Meteorological Service nr.	Station name	Longitude (E)	Latitude (N)	Records (years complete)	Mean annual rainfall (mm) from records	Data source
1020720	Kaduna Junction	07° 25'	10° 29'	1916-75 (52)	1305	MRT, 1978
1020721	Federal Prisons, Kakuri	07° 24'	10° 28'	1960-75 (5)	1609	" "
1030710	Afaka Forest Reserve	07° 17'	10° 37'	1960-74 (6)	1181	" "
1030720	Kaduna Aerodrome (now NAF base)	07° 27'	10° 36'	1939-75 (36)	1283	" "
		"	"	1976-84 (9)	1213	Dept. of Meteorological Services
1030721	Kaduna Hydrometric Station	07° 26'	10° 30'	1959-75 (9)	1386	MRT, 1978
"	"	"	"	1976-84 (9)	1191	Kaduna State Water Board. (1) (hand-written records)
1040730	Birnin-Yero Railway Station	07° 31'	10° 48'	1953-73 (8)	1145	MRT, 1978
1050710	Sabon-Birni Jun. Pry. Sch.	07° 18'	10° 50'	1957-64 (3)	1018	" "
?	Kaduna Internat. Airport	07° 19'	10° 42'	1965 (1)	1223	Fed. Min. of Transport and Aviation.
?	National Water Resources Inst.	07° 25'	10° 35'	1983-84 (1)	1017	NWRI.
?	Kaduna North	07° 26'	10° 32'	1981-84 (3)	1044	Kaduna State Water Board.

(1) annual totals in these records for 1976 - 78 do not agree with totals published in Kaduna State Water Board's Hydro-Meteorological Year Book 1977 - 78.

drilled on the fadama of the R. Chidawaki near the western end of the ECA (Figure 6.1 and 6.2). Full completion reports are given in Volume II.

Regular monitoring of the borehole water levels began in April 1985. The elevations of the bore heads were determined by levelling from nearby national benchmarks.

Geophysical investigations consisted of 4 VES using the Offset Wenner array in the vicinity of the boreholes, 12 Offset Wenner VES along a traverse line from GWR-1/1 to Nagijmbe Hill, constant electrode separation traversing along the line, 7 Offset Wenner VES west of the crushing plant at Nagijmbe Hill, and 4 VES and a constant separation traverse at future possible drilling sites. Some Schlumberger VES and seismic refraction spreads were also carried out. VES data sheets are given in Volume III.

6.5 Preliminary Conclusions

6.5.1 Hydrogeology

The only aquifer of any significance in the ECA occurs within the alluvium of the fadama and the underlying weathered zone of the Basement Complex. The fresh Basement is virtually impermeable, the only water occurring in minor cracks and fissures; however, prospects may be better along the lineaments shown on the photogeological map (Figure 6.2) and it would be worth drilling in this area during a future phase of the research programme.

The aquifer consists of alluvial sand and gravel, containing significant quantities of vegetation and wood remains in the area investigated, underlain by clayey silt of the weathered zone grading down into sand-sized particles and fragments of decomposed Basement rock. The Basement itself consists mainly of dark coloured, banded gneiss with some quartzite veins.

Grading curves of the alluvial sand and gravel are shown on Figures 6.3.

The aquifer is phreatic, the water table lying about 2m below ground surface. Its thickness varies from about 14m at GWR-1/1 to 26m at GWR-1/3, and it is probable that the aquifer is thickest along the river courses, where weathering of the Basement is likely to be most pronounced. A cross-section of the area investigated is shown on Figure 6.4.

Only one borehole, GWR1/2, was pump tested (by airlift). The drawdown and recovery (residual drawdown) data are shown on Figure 6.5. There is fairly close agreement between transmissivity (T) calculated by the Jacob and Theis Recovery methods; if T is assumed to be 30 m²/day, a permeability of about 4 m/day is indicated (screen length 7.1m). However, not much credence can be given to the results of one, short test and more substantial tests are

Figure 6.3 Experimental Catchment Area- Grading Curves

GWR/HG-04

PARTICLE SIZE ANALYSIS

GROUNDWATER RESEARCH DEPARTMENT
NATIONAL WATER RESOURCES INSTITUTE KADUNA

Sieve size(mm)	Cum-wt-retain(g)	Cum-% retained	Sieve size(mm)	Cum-wt-retain(g)	Cum-% retained
13.2			0.425		
6.7			0.300		
4.75			0.212		
3.35			0.150		
2.36			0.075		
1.18			Bottom pan		
0.600			Orig. wt.		

BOREHOLE NR :
SAMPLE DEPTH(M) :
ANALYSIS DATE :
SIGNATURE :

D10 =
D50 =
D60 =

$$\frac{D_{60}}{D_{10}} =$$

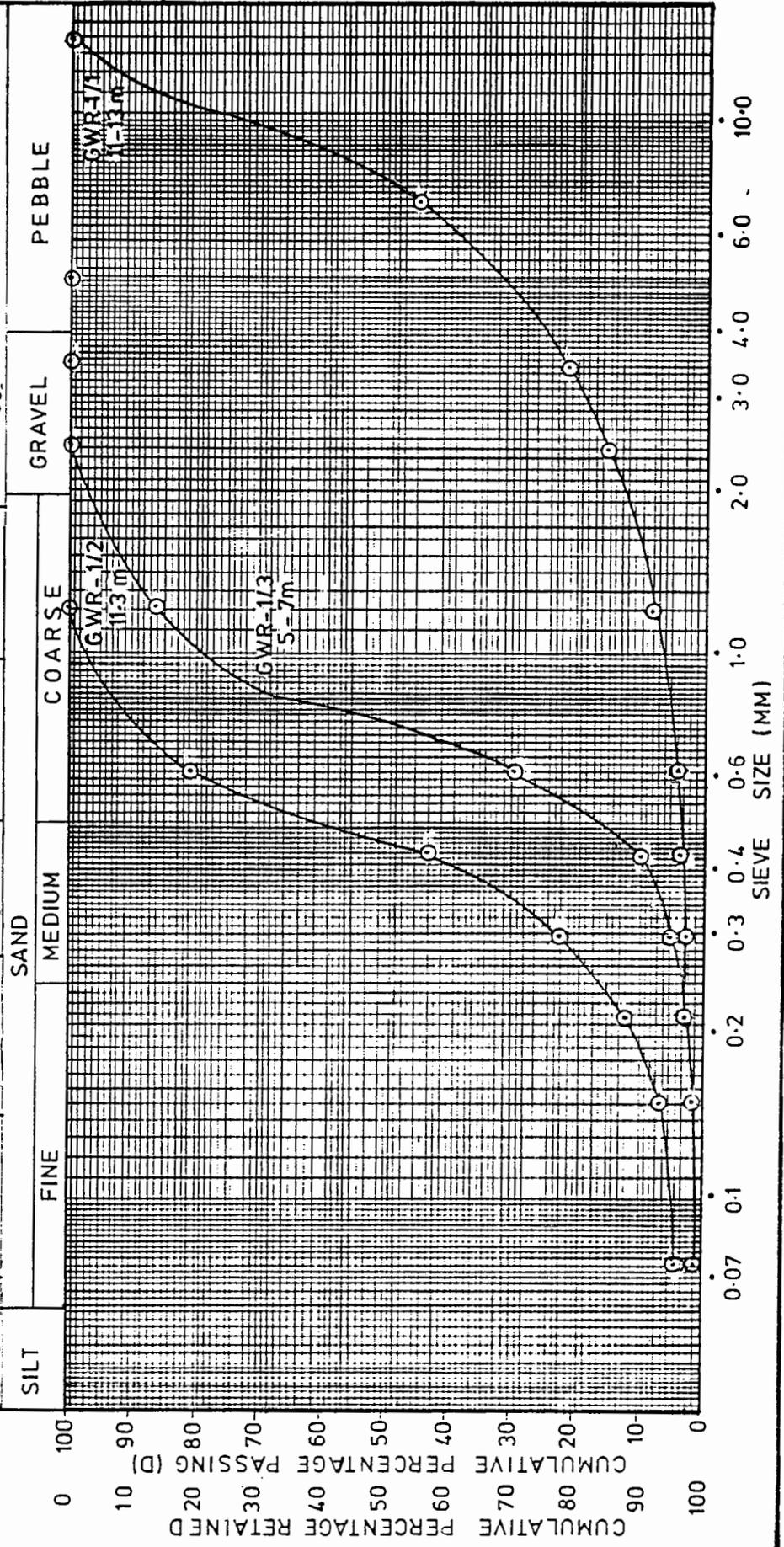


Figure 6.4 Hydrogeological Cross-Section

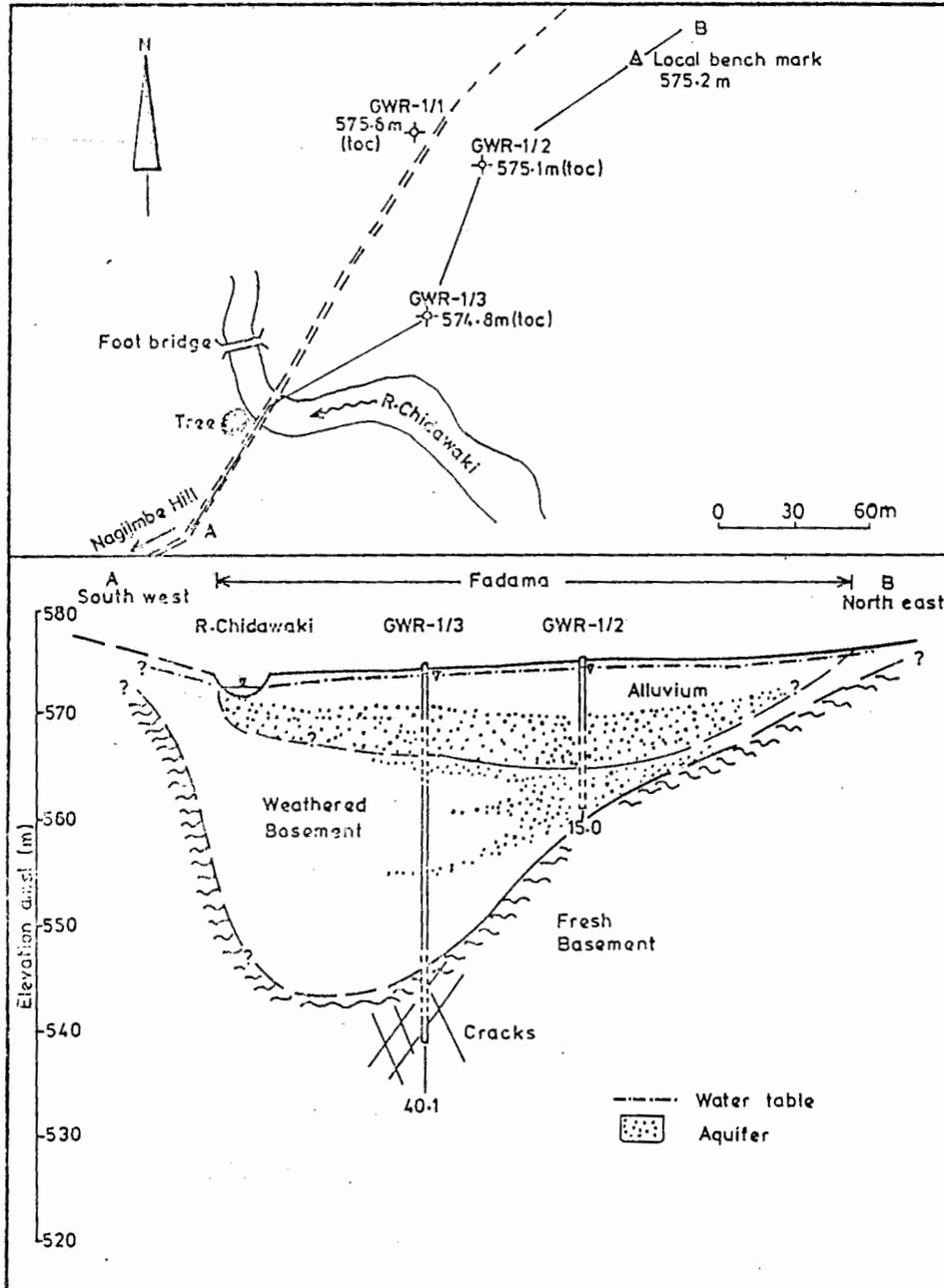
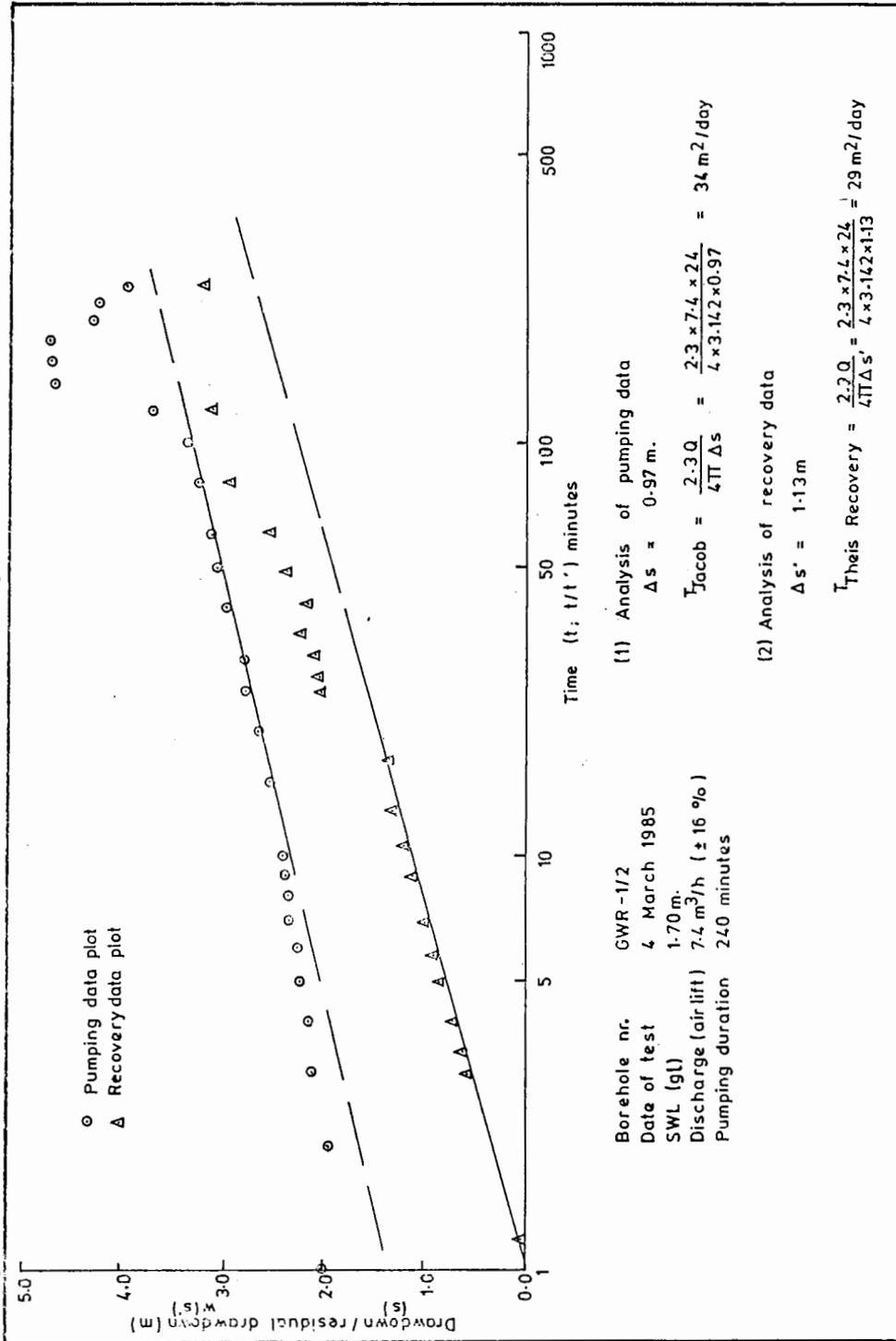


Figure 6.5 Experimental Catchment Area - Pumping Test Data



required, with observations not only on the pumped borehole but also on piezometers spaced some distance away, before more reliable estimates can be made.

The areal extent of the fadama in the ECA has been determined to be 23.6 km². The aquifer is likely to be thinnest in the head reaches and thickest, where the drilling was carried out, towards the outlet of the drainage system. Taking an average aquifer thickness of, say, 10m for the fadama as a whole, an aquifer volume of 236 million m³ is indicated. Assuming a specific yield of 10% (a value typically applied to clayey sands and sandstones) the amount of water in storage can be estimated to be of the order of 23.6 million m³.

The aquifer storage is increased when recharge occurs. As demonstrated by the events at the end of March 1985 the main recharge mechanism appears to be the infiltration of floodwater following periods of heavy rainfall. A water level rise of about 0.8m occurred in GWR-1/1 following the flooding of the fadama after the heavy rainfall of 29/30 March (61mm at the new airport and 70mm at the NWRI). The R. Chidawaki rose and flooded the site about 24 hours after the rainfall; the water was about 0.7m deep when the site was visited a few hours later.

Borehole hydrographs, illustrating the seasonal change in groundwater storage from March 1985 to March 1986, are shown on Figure 6.6. It can be seen that there is a close correlation between rainfall and water level fluctuation. During the wettest months (August and September) the fadama was fully saturated; the composite water level rise during the rainy season was 1.5 to 2.0m.

Results of chemical analyses, carried out using a Hach DR-EL/4 portable laboratory, are summarised on Table 6.3. Unfortunately, many of the ion concentrations could not be determined because of shortages of the relevant reagents. Also, determinations of sodium, potassium and total dissolved solids (which cannot be done with the field equipment), were not possible because the Institute's Water Quality Laboratory did not have all the necessary equipment.

Despite these shortcomings, the analyses confirm that the water from the Basement Complex and related aquifer is of good quality (EC 200 to 410 uS/cm). Salinity is lower in the fadama aquifer than in the underlying rock, since the flushing action of fresh recharge water is more pronounced where the permeability is highest. However, the fadama aquifer water appears to have a significant iron content; this will cause staining of pipes and fittings and impart a slightly unpleasant taste to drinking supplies if untreated.

Figure 6.6 ECA - Borehole Hydrographs

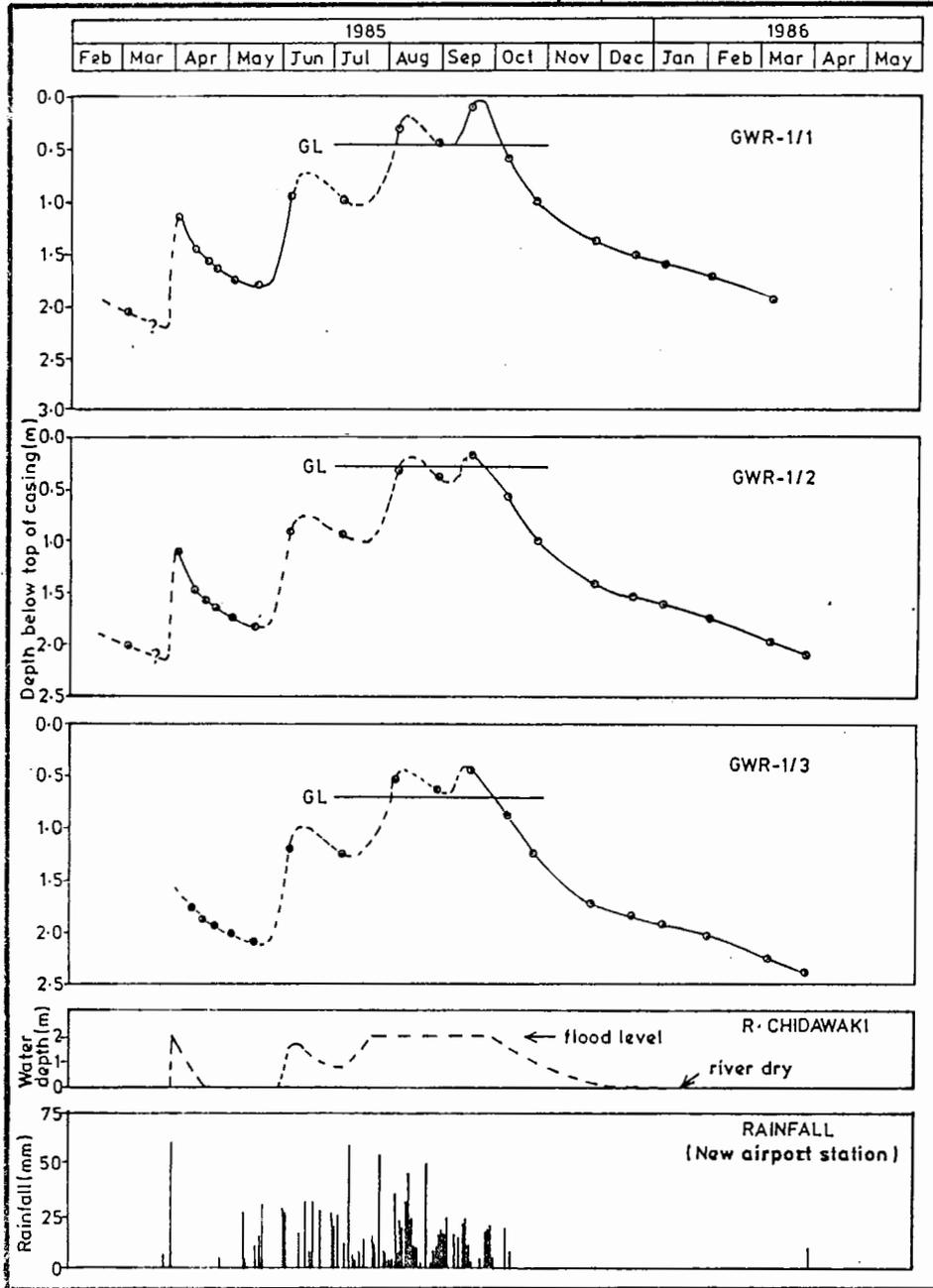


Table 6.3 Experimental Catchment Area - Chemical Analyses

Borehole number	GWR-0/1	GWR-0/2	GWR-1/1	GWR1/2
Test section (m)	40.8-92	13.1-23.7	18-102	6.8-13.9
and rock type	fresh BC	weath. BC	fresh BC	alluvium + weath. BC
Sampling date	21/6/85	3/6/85	19/2/85	1/3/85
Calcium (meq/l)	1.2	0.64		1.22
Magnesium (meq/l)	0.66	0.18		0.18
Sulphate (meq/l)		0.19	0.1	
Chloride (meq/l)	0.82	0.80		2.59
EC (uS/cm)	280	200	410	140
pH	7.21	9.46		
Total iron (mg/l)		0.05	0.16	0.55

Source: Groundwater Research Department

6.5.2 Geophysics

The soundings and constant separation traverses are shown on Figures 6.7, 6.8, and 6.9.

The Offset Wenner array was found to be much more convenient to use than the Schlumberger. The main drawback of the latter is that it is necessary for the operator to tell his assistants when to move electrodes, and without radios this becomes time consuming at the larger electrode spacings, with a serious risk of mistakes which could cause delays or even an erroneous sounding curve. For this reason it was decided to use the Offset Wenner array as the normal array for soundings.

In a number of cases crossed soundings (i.e. two soundings with the same centre point but orientated at approximately right angles to each other) were carried out. In most instances the two sounding curves were similar to each other and thus their interpretations were similar, the differences being less than the ambiguities caused by suppression and equivalence.

Considerable lateral variations were found between some adjacent soundings towards Nagijmbe Hill from the borehole group (Figure 6.10). It is believed these variations, which were most notable in the shallower depths, are due to differences in vegetation and tree cover, and the related extraction of moisture by the root zone. Resistivity was found to be higher in the upper layers where tree roots were present.

During the early part of the rainy season (in May 1985) two soundings were carried out at the same positions, and with the same orientations, as two earlier soundings which had been carried out during the dry season (in January-February 1985). As shown on Figure 6.11 the apparent resistivities for small electrode spacings were found to have decreased, but at larger spacings there were no significant changes in the sounding curves. Also, there was no marked difference in the reliability of the two sets of results. However, field work was slightly easier during the rainy season as the electrodes could be pushed into the ground, instead of having usually to be hammered in; also, it was not necessary to use water to reduce contact resistances and so allow enough current to be used for accurate readings.

Comparison of soundings with borehole logs is only possible for 1V1 and 1V2 (borehole GWR-1/1) and 1V14 (GWR-1/3). These are shown in Figure 6.12. The interpretations were revised after the boreholes had been drilled to ensure that the depths were consistent with the drilling results.

In the case of 1V1, the 850 ohm-metre layer is the dry surface layer while the 270 ohm-metre layer could be the capillary fringe. Variations in resistivity in the alluvium below the water table will be caused by variations in grain size and clay content. The main surprise is the relatively low resistivity (300 ohm-m) of the upper

Figure 6.7 ECA - Location of Resistivity Soundings

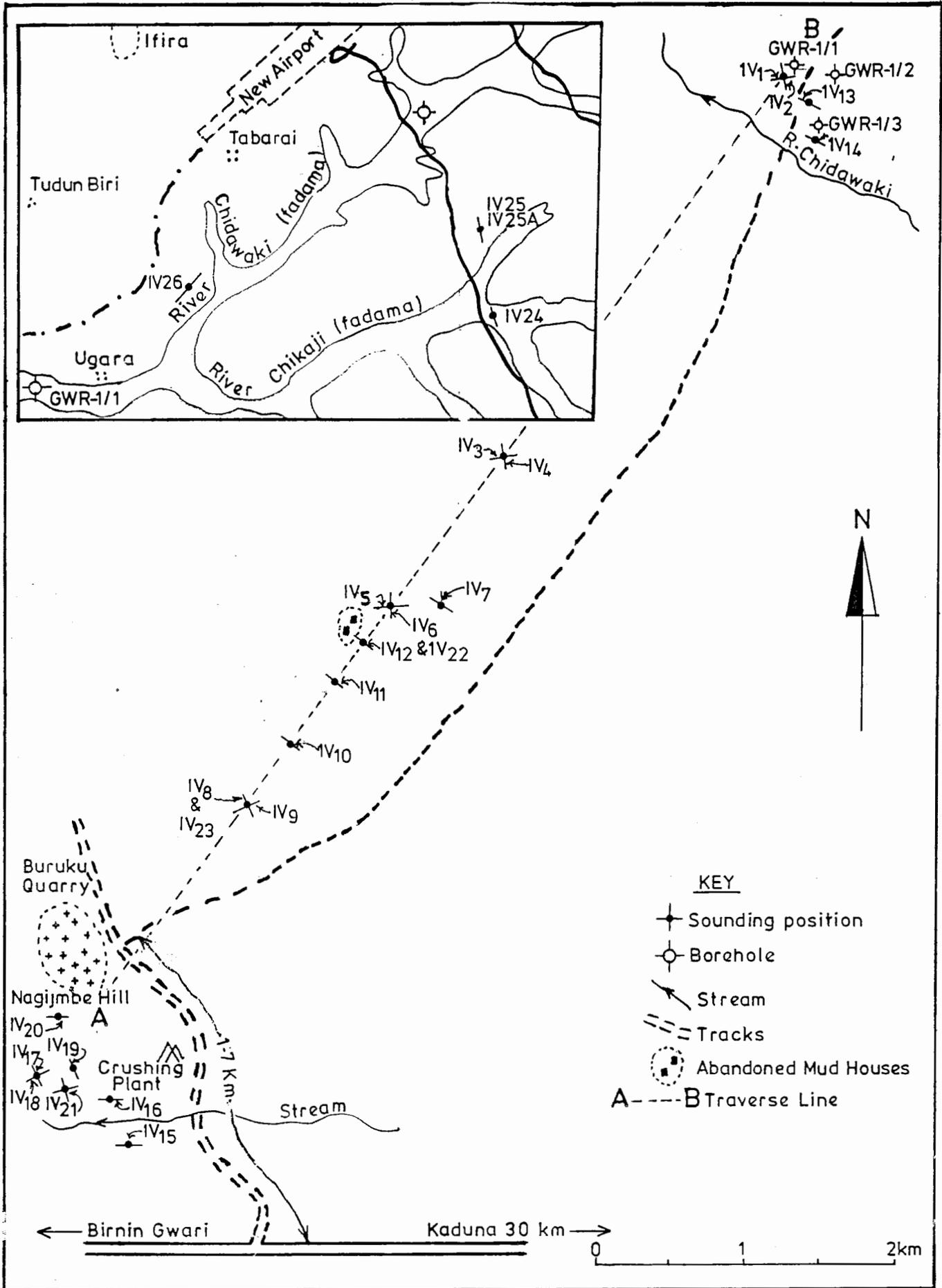


Figure 6-8 Experimental Catchment Area – Resistivity Profile

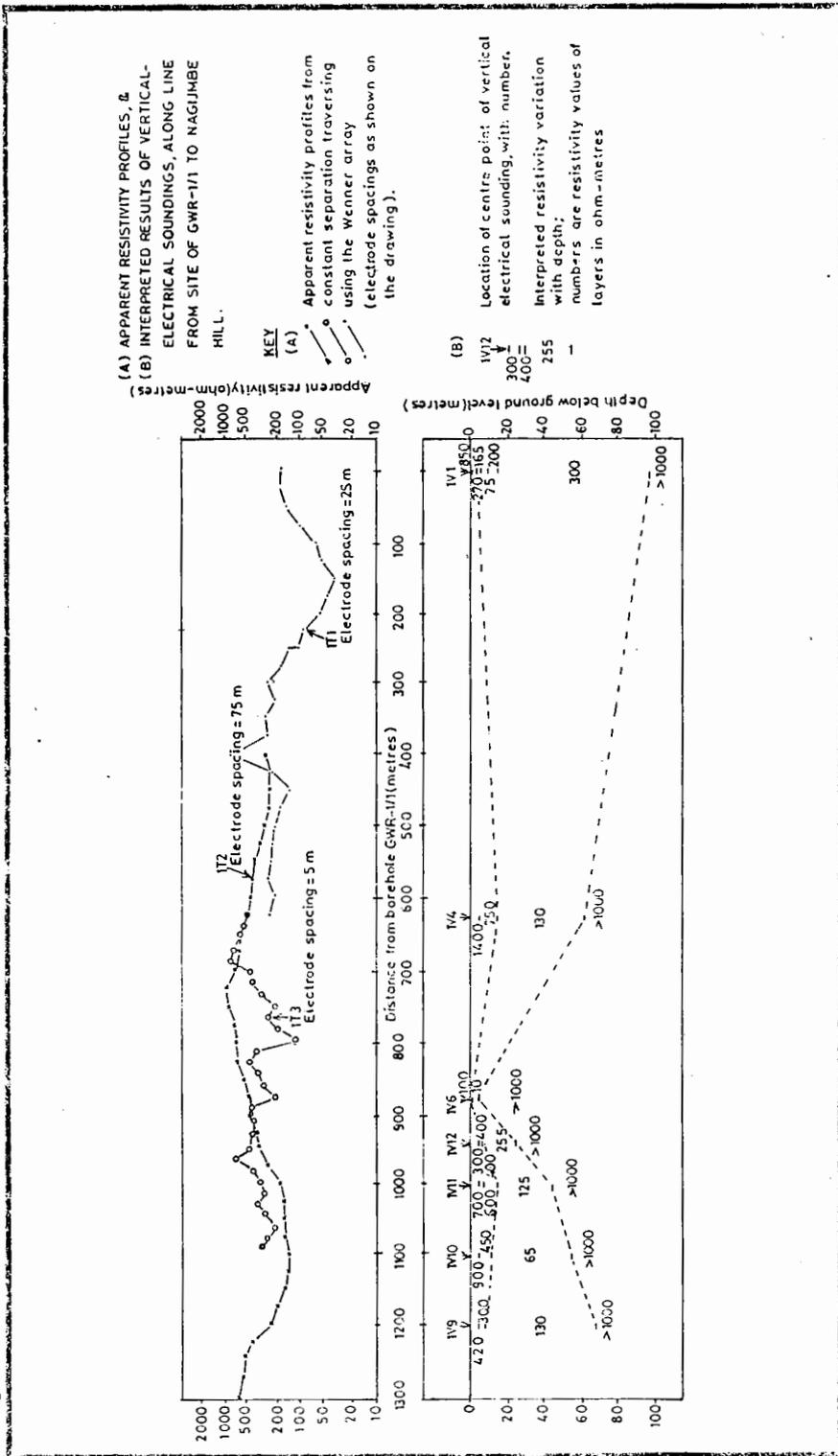


Figure 6.9 ECA - Resistivity Profile at IV26

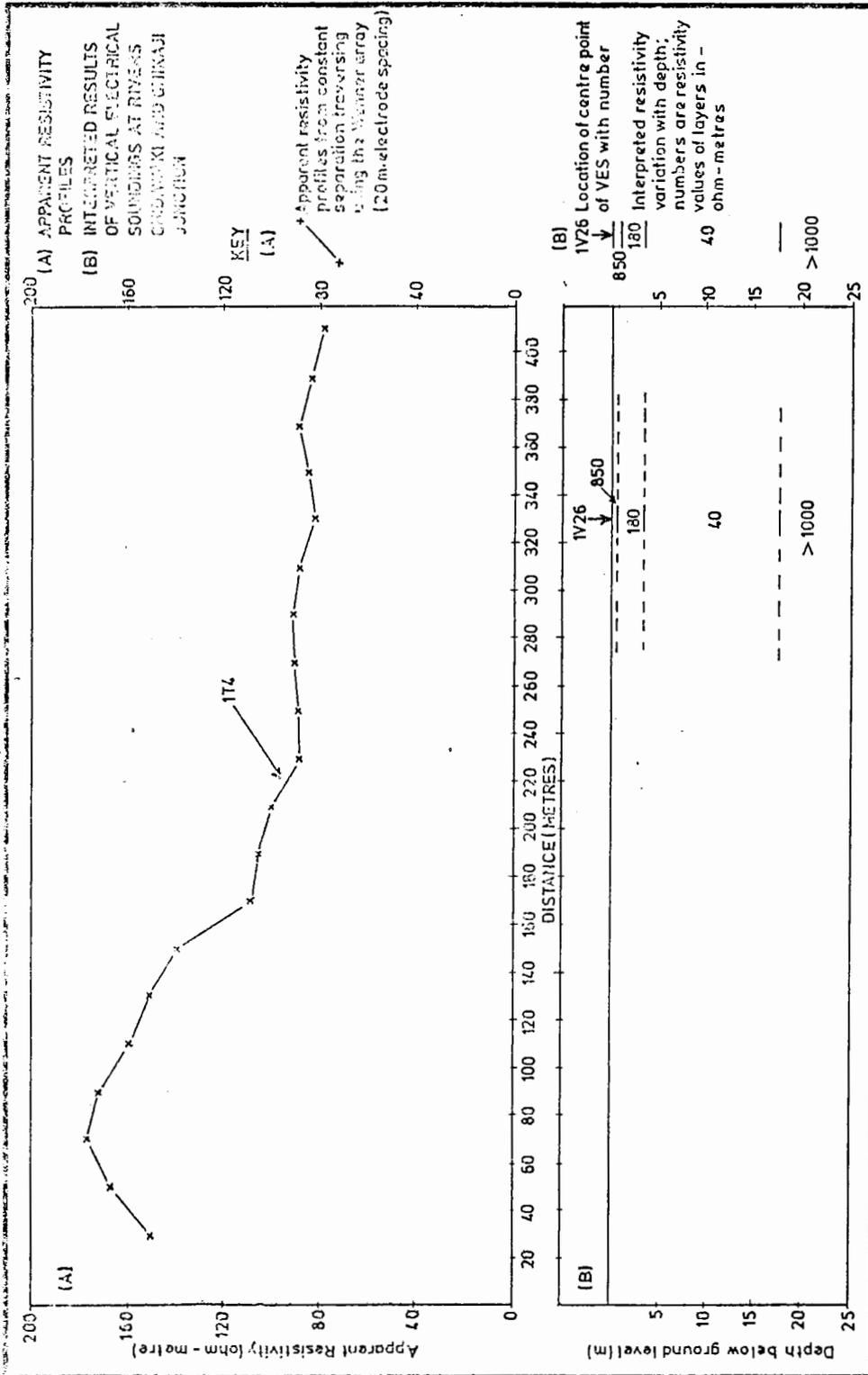


Figure 6.10 Resistivity-Lateral Variations

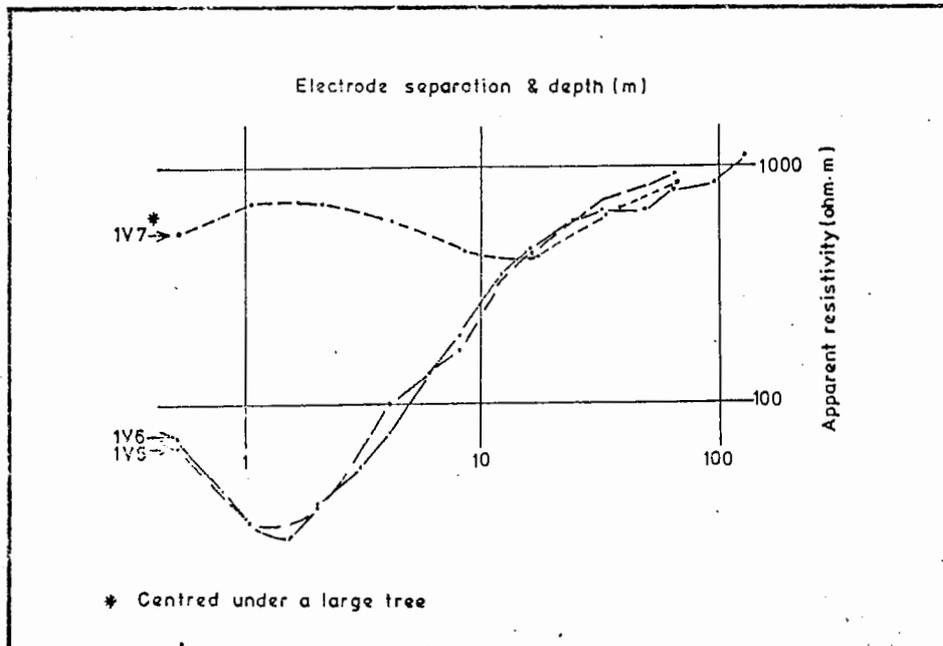


Figure 6.11 Resistivity-Effect of Seasonal Variations

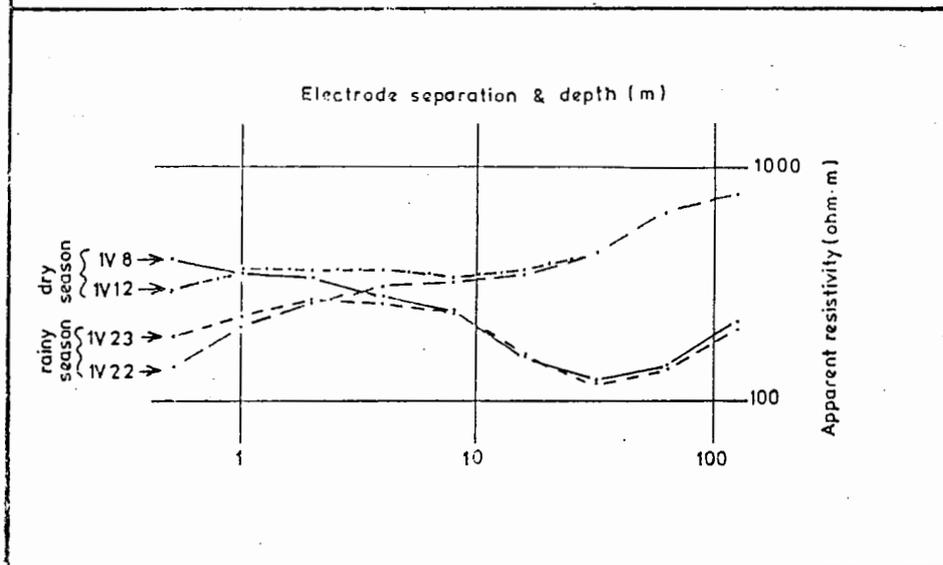
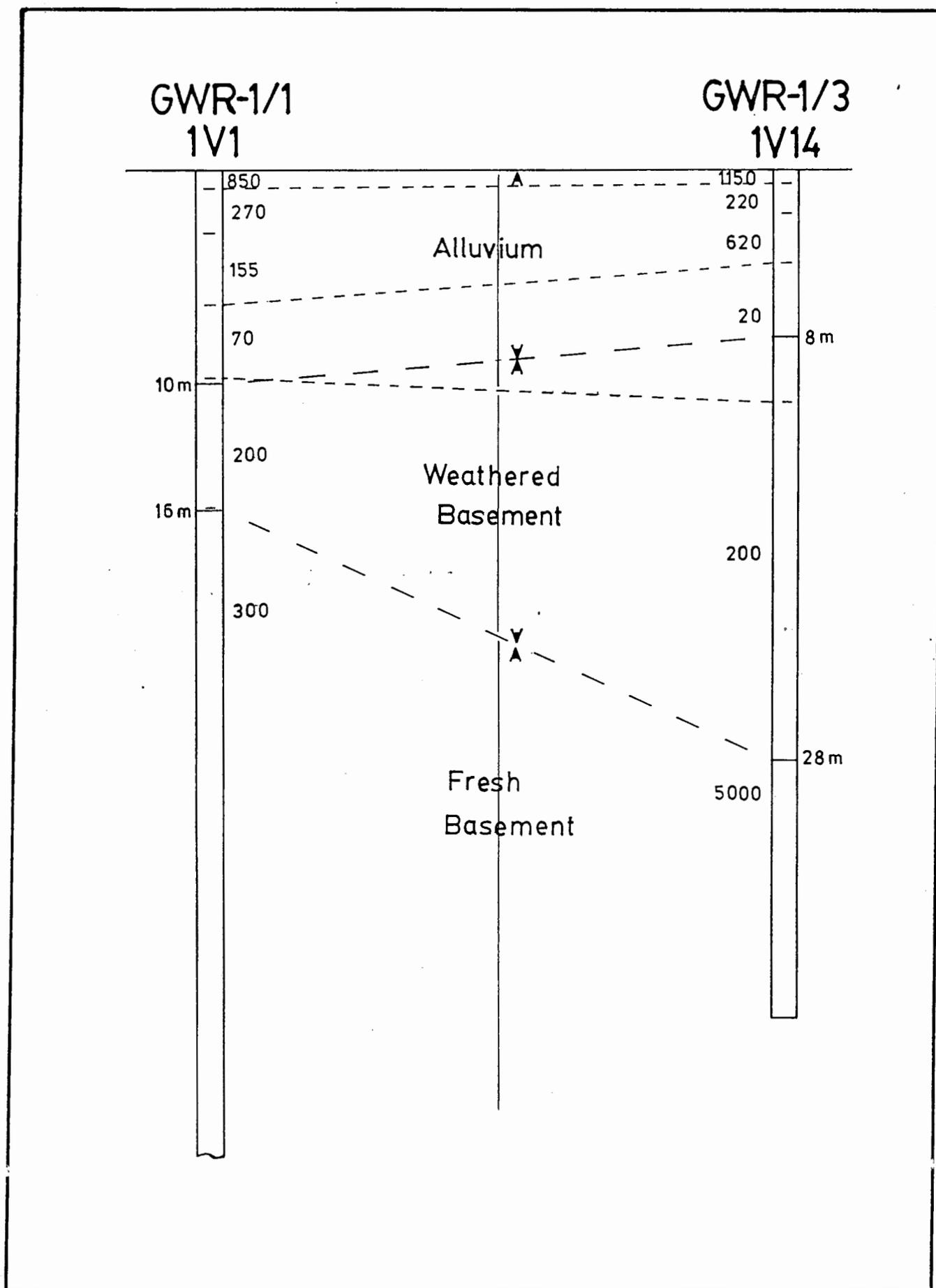


Figure 6-12 Comparison of Resistivity and Drilling Results



part of the fresh Basement rock, which could extend to about 100m below surface (the sounding curve does not define this depth with any accuracy). This is confirmed by 1V2. A possible explanation of this is extensive fracturing of the rock, but this is not apparent from the drilling results.

In the case of 1V14, the sounding can again be interpreted in a way that is consistent with the drilling results, although it is not possible to identify the interface between the alluvium and the weathered rock.

6.6 Recommendations for Further Work

6.6.1 Drilling and Testing

The flooding of the drilling site at the end of March 1985 prevented further field work from being carried out, and the achievement of the original objectives of the research programme. Therefore, it will be necessary to return to the ECA to complete the outstanding work - (some work is scheduled for April 1986).

Recommendations for further work are:-

- (a) drilling of two piezometers in the fadama aquifer between GWR-1/2 and GWR-1/3, at distances of 15m and 30m from GWR-1/2;
- (b) pump testing of GWR-1/2 and GWR-1/3 with observations in the piezometers - step test followed by a 24 hour constant discharge test and recovery periods;
- (c) drilling and testing of a borehole into the fresh Basement at location A (Figure 6.2), and related pump testing;
- (d) drilling and testing boreholes at locations B and C (Figure 6.2);
- (e) drilling of a test well and two piezometers in the fadama aquifer at location D (Figure 6.2), and related pump testing, to determine the aquifer properties in the upper part of the catchment area;
- (f) continuation of water level monitoring in the boreholes;
- (g) tying the elevations of the boreholes to be drilled to the national datum.

6.6.2 Geophysics

Geophysical work is required at site D (Figure 6.2). Where the exact position of the borehole group is not determined by other factors, detailed constant resistivity traversing combined with soundings should be used to select the drilling location.

6.6.3 Hydrology and Mapping

The ECA was selected to provide an opportunity for the different disciplines in the Institute to carry out practical research, involving the students, into the various components of the hydrological cycle, with a view to calculating the overall water balance. Thus, a hydrometric network needs to be set up (for rainfall, evapotranspiration, infiltration and runoff measurement) to complement the results so far obtained from the groundwater investigations.

Sites for hydrometric stations have been suggested at the point where the catchment drainage system flows into the R. Tubo, and along the R. Chikaji (Figure 6.1).

A detailed topographic and land use map (perhaps at 1:10,000 scale and with 1m contour intervals) needs to be prepared to study the effect of slope and vegetation on erosion and runoff and for general reference.

Research could also be carried out to investigate whether any pollution is related to agricultural practices.

CHAPTER 7

INVESTIGATIONS FOR NIGER STATE WATER BOARD

7.1 Background

The Niger State Water Board (NSWB) wrote to the Institute on 7 December 1984 requesting for studies into some of the groundwater problems of Niger State. The request was considered favourably since Niger State, consisting as it does of both Basement Complex and sedimentary formations, was thought to be an ideal location for research, particularly in the early stages of the project as it borders Kaduna State and distances are not too great. Accordingly, a visit was made to Minna on 27 and 28 March 1985 to hold discussions with officials of the Water Board.

Niger State consists of Basement Complex in the north and east, and Nupe Sandstones (Cretaceous age) in the R. Niger basin in the west and south (Figure 7.1). The main groundwater problems identified by the Water Board were: how to site successful boreholes on the Basement, and how to prevent sand pumping and corrosion of well components in the Nupe Sandstones. Most existing boreholes had been randomly sited by trial and error and the success rate was disappointing.

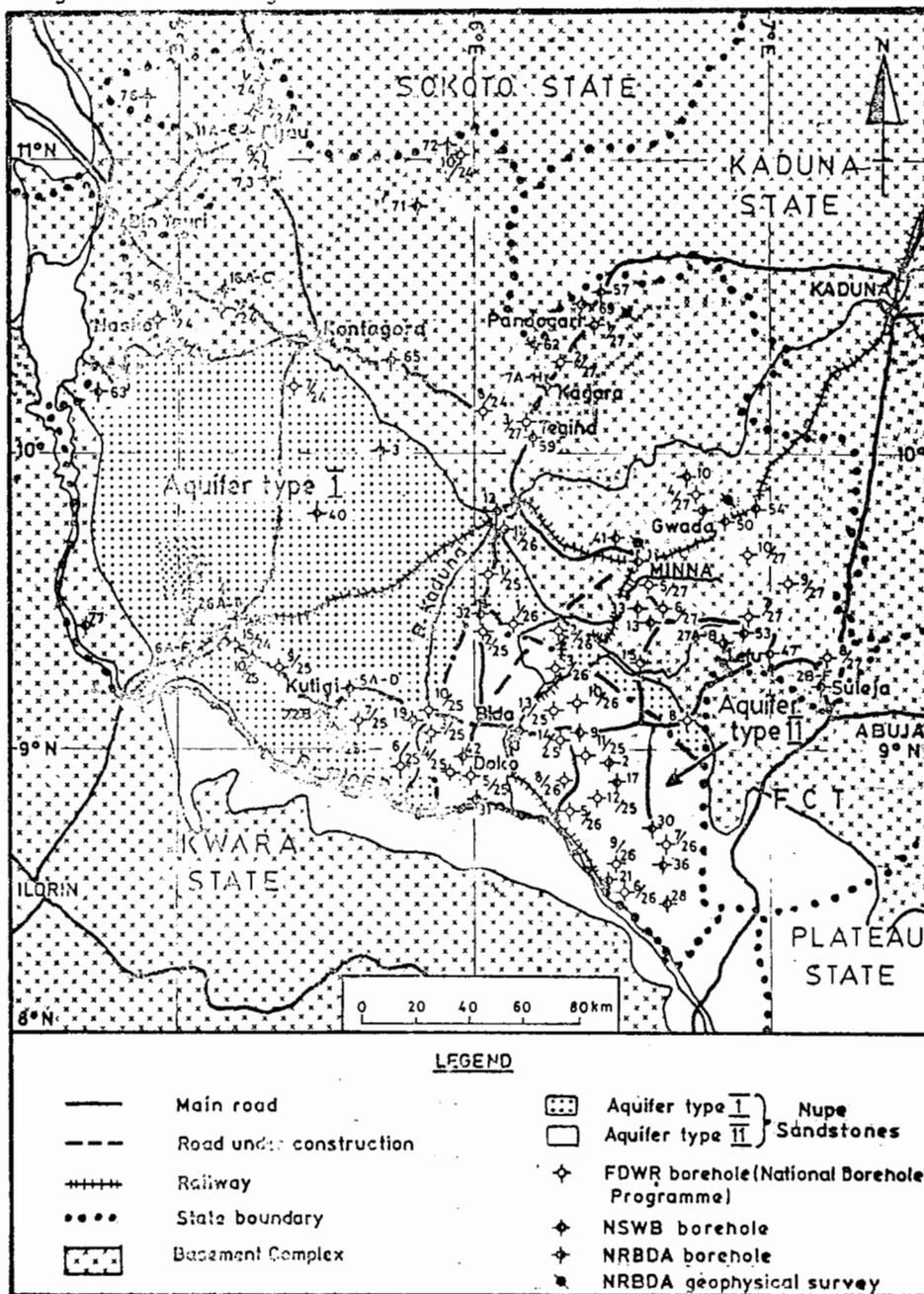
Two study areas were selected to represent each of the geological environments: Suleja for the Basement, and Kutigi for the Nupe Sandstones. In addition, photogeological mapping was proposed for the villages of Rijau and Kagara on the Basement to extrapolate the techniques developed at Suleja (the village of Nasko was later added for this work).

The intention at Suleja was to identify fracture and weathered zones (which offer the best prospects for successful boreholes) by aerial photograph interpretation and geophysical surveys, and to drill two or three boreholes on the most promising sites. However, no aerial photographs for Suleja could be found at the Geological Survey, Kaduna, and only limited geophysical surveys could be carried out because the chosen drilling sites were heavily built up. Two boreholes were drilled (GWR-4/1 and GWR-4/2).

Aerial photographs for Rijau, Kagara and Nasko were available and photogeological maps were prepared. It was decided to carry out geophysical surveys in the most promising areas to recommend possible borehole sites (the village of Pandogari was also included for this work at the request of the Water Board).

The intention at Kutigi was to identify the main aquifer layers in the Nupe Sandstones, and to recommend a suitable well design so as to minimise sand pumping and corrosion. Three boreholes were planned (a test well and two piezometers), the first borehole to be drilled as deep as the drill pipes would allow (about 270m) in order to obtain the full lithological sequence. Unfortunately, drilling of the first borehole (GWR-7/1) was halted at 115m due to a leakage

Figure 7.1 Niger State - Location of Boreholes



from the mud swivel on the rig and blockages to the bit, and no further boreholes could be drilled.

7.2 Existing Data

The locations of existing boreholes and related geophysical surveys (where applicable) are shown on Figure 7.1. Data for the boreholes drilled for the FDWR and Niger River Basin Development Authority (NRBDA) are summarised on Table 7.1; data for the 186 NSWB boreholes are not included since they are incomplete, and most yield values are considered to be implausible (up to 82 m³/h for Basement Complex boreholes for example).

Niger State formed parts of three areas of the pre-drilling hydrogeological investigations undertaken in the late 1970s for the National Borehole Programme administered by the FDWR: the Basement Complex in the northern part of the State around Kontagora was included in Area II; the Basement Complex in the eastern part around Minna was included in Area III; and the Nupe Sandstones of the Middle Niger Basin in the south and west was included in Area XVII.

The reports produced by the various consultants assigned to carry out the investigations were largely an overview of the data available at the time, and describe groundwater occurrence and potential in only the most general terms. Much of the data studied, particularly borehole records, were of poor quality which did not lend themselves to rigorous scientific analysis. Sites for test boreholes were suggested to improve the data base and to fill gaps in the data network.

Geophysical work was carried out at several locations on the Basement Complex for the NRBDA to select the most favourable drilling sites. As mentioned previously (Section 4.3), ABU undertook a resistivity survey at the NRBDA compound in Minna in 1983 (Stenzel, 1983) and the sounding curves were reinterpreted on the Consultant's computer prior to the drilling of GWR-5/1 near the recommended site. Biwater Shellabear carried out electro-magnetic (EM) and resistivity investigations at Lefu, Gwada and Pandogari between February and May 1984 (Figure 7.1) - boreholes were subsequently drilled at the first two locations (Table 7.1).

Causes of declining yield in boreholes tapping the Bida Sandstone Formation (another name for the Nupe Sandstones) were presented in a paper to the International Conference on Arid Zone Hydrology and Water Resources at Maiduguri in September 1985 (Shekwolo and Stenzel, 1985). The research for the paper involved an analysis of borehole sludge samples and strata logs collected from drilling sites, resistivity measurements, analysis of pumping test data, and analysis of screen slot sizes and gravel pack materials.

The Nupe Sandstones Formation consists essentially of an intercalated sequence of weakly cemented siltstones, clays and fine to coarse sandstones. Lenses of conglomerates and gravels occur at

TABLE 7.1 NIGER STATE - EXISTING BOREHOLE DATA

Bore ref.	Location	LGA	Completion date	Total depth(m)	Geology	Screen setting (m)	Yield (m ³ /h)	SWL (m)	DWL (m)	s (m)	Data source
FDWR Boreholes (National Borehole Programme)											
1/24	Tungo Magajia (Tungan Magajia)		No report								
2/24	Rijau		Report in Sokoto Office								
3/24	Ibeto		" "	" "							
4/24	Sakuru		No report								
5/24	Takuma		" "								
6/24	Shambo		" "								
7/24	Kaboji	Mariga	12/7/84	119?	NS	49-61) 111-119)	12.6	48.0	48.8	0.8	FDWR, Minna
8/24	Duruqu	"	2/3/83	70	BC	52-55) 61-70)	4.1	2.4	55.4	53.0	" "
9/24	Mamba		Abortive								
10/24	Konton-Koro		No report								
?	Nasko	Mariga	2/8/82	120	BC	5-75	0.4	5.4	72.0	66.6	FDWR, Minna
1/25	Lokogoma	"	21/1/82	167.5	NS	44-46) 55-60)	10.8	37.0	47.8	10.8	" "
2/25	Lemu	Gbako	29/1/82	195	"	65-68) 120-125)	6.5	45.8	65.0	19.2	" "
3/25	Lima	Lavun	8/3/82	200	"	169-174) 187-199)	0.4	13.3	90.0	76.7	" "
4/25	Boku (Doko)	"	4/3/82	95	"	15-20) 44-49)	18.0	6.4	11.3	4.9	" "

Bore ref.	Location	LGA	Completion date	Total depth(m)	Geo-logy	Screen setting(m)	Yield (m ³ /h)	SUL (m)	DWL (m)	S ² (m)	Date source
10/26	Tsaduku	Gbako	28/11/82	66	NS	45-60	10.0	7.8	15.4	7.6	FUNA, Minna
11/26	Wushishi	Mariga	30/10/82	135	BC ?	8-13) 22-32)	2.1	5.1	9.3	4.2	"
1/27	Pandogari	Rafi	10/9/82	40	BC	28-40	3.3	12.1	35.7	23.6	"
2/27	Maikujere	"		40	"	21-30	4.7	6.3	26.5	20.2	"
3/27	Tegina	"		60	"	27-36) 51-57)	4.7	12.1	27.3	25.2	"
4/27	Kuta	Chanchaga	25/11/82	100	"	36-48) 67-70)	1.8	2.1	67.8	55.7	"
5/27	Chanchaga	"	17/5/82	60	"	12-18) 30-36) 46-49)	7.5	2.2	37.0	34.8	"
6/27	Kato (Paiko)	"	5/9/82	100	"	51-54) 77-89)	0.3	16.0	58.0	42.0	"
7/27	Kwakuti	Suleja	22/8/82	100	"	27-30) 56-65) 95-98)	3.8	19.0	56.0	37.0	"
8/27	Dikko(Diko)	"	18/6/82	100	"		0.3				
9/27	Kafinkoro	Chanchaga	27/6/82	50	BC	23-32) 36-40)	2.4	6.2	30.2	24.0	"
10/27	Fuka	Suleja	26/5/82	36.5	"	51-55) 70-77)	Unproductive				"
<u>Niger River Basin Development Authority Boreholes</u>											
	Gwada	Kutu	16/3/84	75	BC	15-21	3.6	1.8	44.0	42.2	Biwater Shellabear
	Edoko Nuhu	Gbako	9/4/84	72	NS	54-60	1.1	10.6	43.4	32.8	"
	Lefu	Paiko	16/4/84	60	BC	21-27	7.6	5.1	44.8	39.7	"
	Mashegu	Gbako	16/5/84	75	NS	53-57) 63-66)	18.0	39.3	44.0	4.7	"

Note: BC Basement Complex; NS Nupe Sandstones

Bore ref.	Location	LGA	Completion date	Total depth(m)	Geology	Screen setting (m)	Yield (m ³ /h)	SUL (m)	DWL (m)	s (m)	Data source
5/25	Mambe	Lavun	7/3/82	61	N5	14-19) 33-38)	9.0	4.6	29.1	24.5	FDWR, Minna
6/25	Gazhe (Gazie)	"	10/4/82	141	"	115-120) 130-133)	4.3	11.4	44.0	32.6	" "
7/25	Sakpe	"	28/3/82	81	"	17-20) 24-39)	18.0	7.5	16.7	9.2	" "
8/25	Enagi	"	19/3/82	72	"	35-45) 55-58)	0.8	16.9	38.2	21.3	FDWR, Minna
9/25	Kudu	"	25/3/82	141	"	82-84) 94-105)	18.0	50.9	52.5	1.6	" "
10/25	Shabakolo (Sebkolo)	Gbako	6/6/82	197	"	118-127) 134-137)	4.3	119.0	121.9	12.9	" "
11/25	Markun-Damaru (Makun-Damaru)	Agai	15/5/82	203	"	137-145) 157-162)	4.7	19.9	79.7	59.8	" "
12/25	Bini	"	"	"	"	29-42	1.1	19.1	41.3	22.2	" "
13/25	Zimabekpegi (Zhimagi)	Agie	8/5/82	43	"	"	"	"	"	"	"
14/25	Agai	"	12/5/82	186	"	57-59) 100-103)	0.9	54.4	80.0	25.6	" "
1/26	Gbangban	Gbako	8/9/82	60	"	30-50	9.0	8.1	19.5	11.4	" "
2/26	Tsadu Kashi	"	21/10/82	150	"	18-36	7.9	10.2	21.5	11.3	" "
3/26	Ebba	Lapai	17/10/83	195	"	149-164	7.6	4.5	17.8	13.3	" "
4/26	Birin Masa	"	12/9/83	55	"	16-25	4.8	7.1	7.9	0.8	" "
5/26	Logona	Gbako	7/7/83	192	"	137-152	0.1	25.3	95.0	69.7	" "
6/26	Etsu Tasha	Gbako	12/9/84	160	"	72-75) 96-102)	7.2	14.0	49.2	35.2	" "
7/26	Gbedako	Lapai	24/8/84	200	"	57-60) 160-166)	12.6	29.2	30.1	0.9	" "
8/26	Mauogi	Agai	2/12/82	123	"	50-65	12.3	6.1	13.3	7.2	" "
9/26	Zago	Gbako	6/6/83	143	"	93-108	0.5	18.8	70.6	51.8	" "

varying depths, especially near the contact with the underlying Basement. In addition, thin beds of carbonaceous shales occur locally, especially in the northwestern sector of the Middle Niger Basin. The thickness of the formation may range up to 1000m along the central axis of the basin. Alluvial deposits occur along the channels of the major rivers (Niger, Kaduna and Gbako).

Two main aquifer types were identified: type I and type II. The type I aquifer is the more prolific of the two, consisting largely of medium to coarse sands, and occurs in the area west of the R. Kaduna and along the northern fringe of the basin (Figure 7.1) The type II aquifer, consisting of finer sands and often intercalated with silts and clays, occurs east of the R. Kaduna. Generally, aquifer layers occur at depths between 20 and 60m and range in thickness up to 4m.

Borehole failures, particularly in the type II aquifer area, were attributed to random siting (no geophysical survey carried out) and the use of perforated pipe with low open areas or screen with a slot size not suited to the grading of the formations being tapped - also, gravel packs were not designed on the basis of the screen slot size. Generally, the drilling contractors used whatever materials were available at the time without regard to the local hydrogeological situation.

Another factor not mentioned in the paper was probably the random positioning of screens in the boreholes (in the absence of down-hole geophysical logs crucial sand layers would be missed).

7.3 Results of Investigations

7.3.1 Suleja

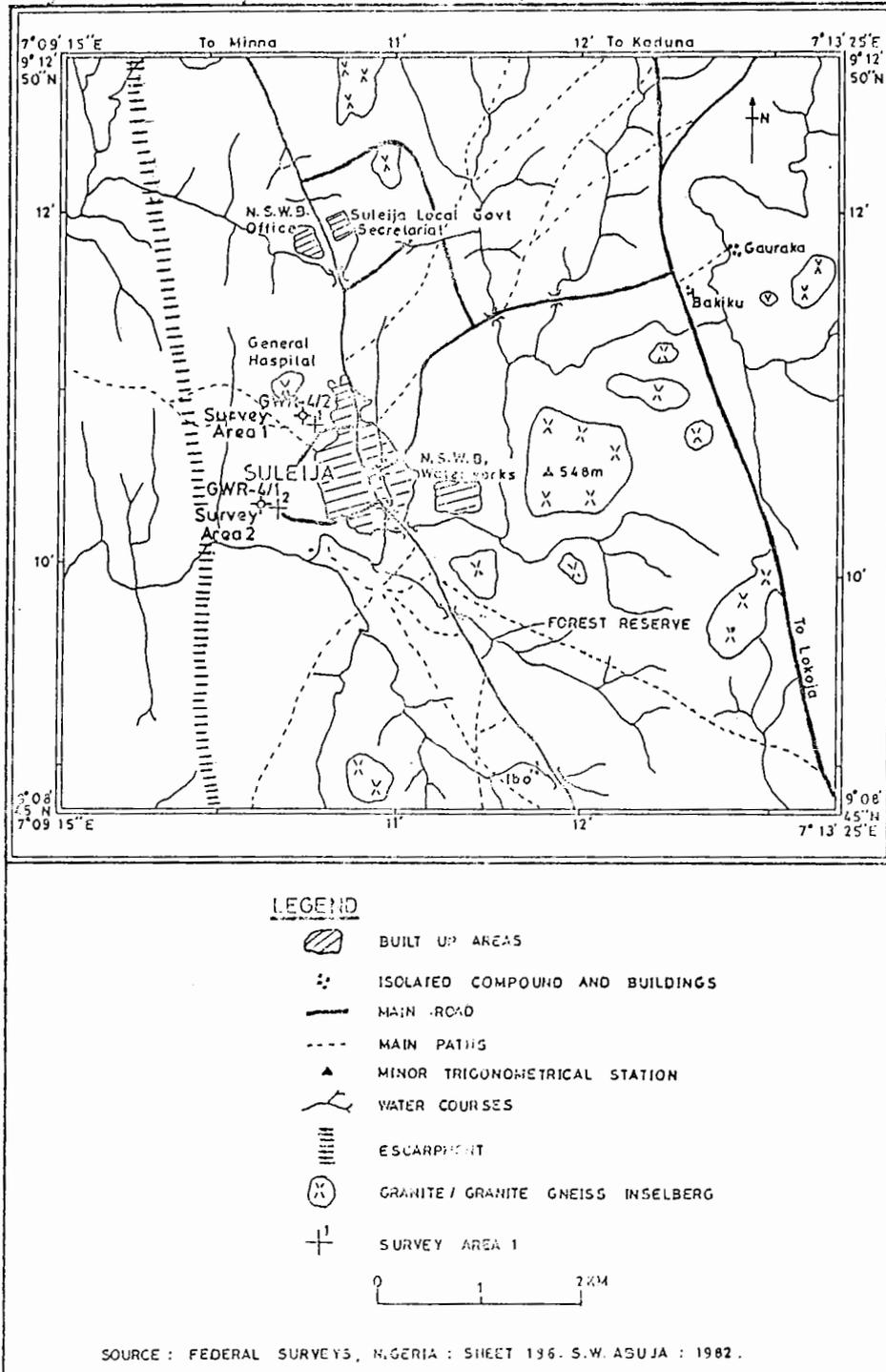
Suleja is situated on a high plain of between 395 and 425m elevation above mean sea level. The plain descends gradually to the west of the town to form a NNW-SSE running escarpment, and is interrupted by numerous inselbergs (Figure 7.2). A trellis drainage pattern predominates, and the principal river is dammed at the NSWB treatment works to provide potable water for the town.

Aerial photographs for Suleja could not be located at the Geological Survey in Kaduna, so no photogeological map could be prepared.

A geophysical survey, consisting of 3 Offset Wenner VES, 3 Schlumberger VES and 5 seismic refractions spreads, was carried out at two selected areas of the town from 22 to 24 July 1985 (Figure 7.2). A report was prepared by the counterpart hydrogeologist/geophysicist concerned (Odusanya, 1985).

A borehole was drilled in each of the areas investigated: GRW-4/1 at seismic spread point 4S5, and GWR-4/2 at 4S2. The geophysics predicted Basement rock at 7.5m for GWR-4/1 (actual depth was 5.2m) and 6.1m for GWR-4/2 (8.0m). Although both boreholes were drilled

Figure 7.2 Suleja-Location of Survey Areas and Boreholes



well into fresh Basement rock, fractures of any significance were only encountered in GWR-4/2 - at 11 to 15m and 21 to 22m. These rendered the borehole relatively productive - the terminal yield after 24 hours pumping was 2.8 m³/h (as opposed to 0.4 m³/h for GWR-4/1).

7.3.2 Kagara

The photogeological map produced by the counterpart hydrogeologists/geophysicists is shown on Figure 7.3.

A geophysical survey consisting of 5 Offset Wenner VES, 3 Schlumberger VES, 8 constant electrode separation traverses and 6 seismic refraction spreads was carried out in November 1985. The locations of the VES and seismic spreads are shown on Figure 7.3, and the traverse lines and interpreted profiles on Figures 7.4 to 7.9. Details of the investigation were included in a report prepared by the counterpart hydrogeologist/geophysicist concerned (Eduvie, 1986).

The dominant structural trends in the Basement are north-south and NE-SE - these are reflected in the drainage pattern. The R. Kwakia is dammed at Kagara and serves as a source of water for part of the town.

Four sites were selected for the geophysical survey: Kagara maternity clinic (Figure 7.4 and 7.5), Rafi Local Government Secretariat (Figure 7.6), Ahmadu Attahiru Secondary School (Figure 7.7) and the government low cost housing area (Figures 7.8 and 7.9).

The geophysics indicated that the Basement rock is fairly shallow (3 to 10m), and that significant fractures are only likely around the school and the low cost housing area. The most promising site for a borehole is thought to be at NG-KV5 (Figure 7.8).

7.3.3 Rijau

The photogeological map is shown on Figure 7.10, which also shows the locations of the 3 Offset Wenner VES, 1 Schlumberger VES and 4 seismic refraction spreads undertaken in November 1985.

Three sites were investigated: Old Rijau, Sabon Gari and the Government Vocational Training Centre. The results of constant electrode separation traversing measurements are shown on Figures 7.11, 7.12 and 7.13 respectively. Resistivity profiles of these traverses are shown on Figure 7.14.

Rijau is characterised by numerous outcrops of the Basement, particularly in Old Rijau where the lack of available water is a major problem. At the time of the geophysical survey most of the streams were dry. Water levels in dug wells were around 12m.

The rocky nature of Old Rijau was demonstrated by the traversing -

resistivity was considerably higher there than in the two other areas investigated (Figure 7.14).

It is considered that the most promising site for a borehole is at Sabon Gari (Figure 7.12) where a low resistivity layer is indicated at 30 to 40m depth.

7.3.4 Nasko

The photogeological map is shown on Figure 7.16, together with the locations of the 3 Offset Wenner VES, 1 Schlumberger VES and 2 seismic refraction spreads carried out in November 1985. Only one constant electrode separation traverse was undertaken; measurements are given on Figure 7.16, and a resistivity profile on Figure 7.17.

The Basement consists of granite gneiss and is fairly well jointed. Water is drawn mainly from the stream running alongside the village and from a hand dug well (water level 15m).

Resistivity lows occurred at two points along the traverse line. The VES and seismic survey indicated a depth to bedrock of 8-10m, and the likelihood of fractures at 25-35m. The most promising site for a borehole is at NG-NV1.

7.3.5 Pandogari

The geophysical survey was carried out in two areas (Figure 7.18): Area I near the Chief's palace (Figure 7.19), and Area II at the Government Vocational Training Centre (Figure 7.20). It consisted of 4 resistivity traverses, 4 Offset Wenner array VES and 1 seismic refraction spread and follows an earlier investigation undertaken by Biwater Shellabear in May 1984.

Faults and fractures in the Basement are aligned along two main trends; E-W to WNW-ESE, which controls the orientation of the elongated granite intrusions and the drainage pattern; and NNE-SSW to N-S, related to narrow localised fracture zones.

There are many shallow hand-dug wells with total depths of 5 to 8m; the water level measured in six wells around the chief's palace was 2.4m.

The most promising site for a borehole occurs along traverse NG-PT4 where low resistivity values may indicate deep weathering and fracturing at depth. Two VES were conducted along the traverse, one at the site recommended by Biwater Shellabear (NG-PV2), and the other at what is considered to be a more favourable site (NG-PV3). Depth to bedrock is estimated to be 10 to 12m.

Figure 7.3 Kagara - Photogeological Map and Location of Geophysical Stations

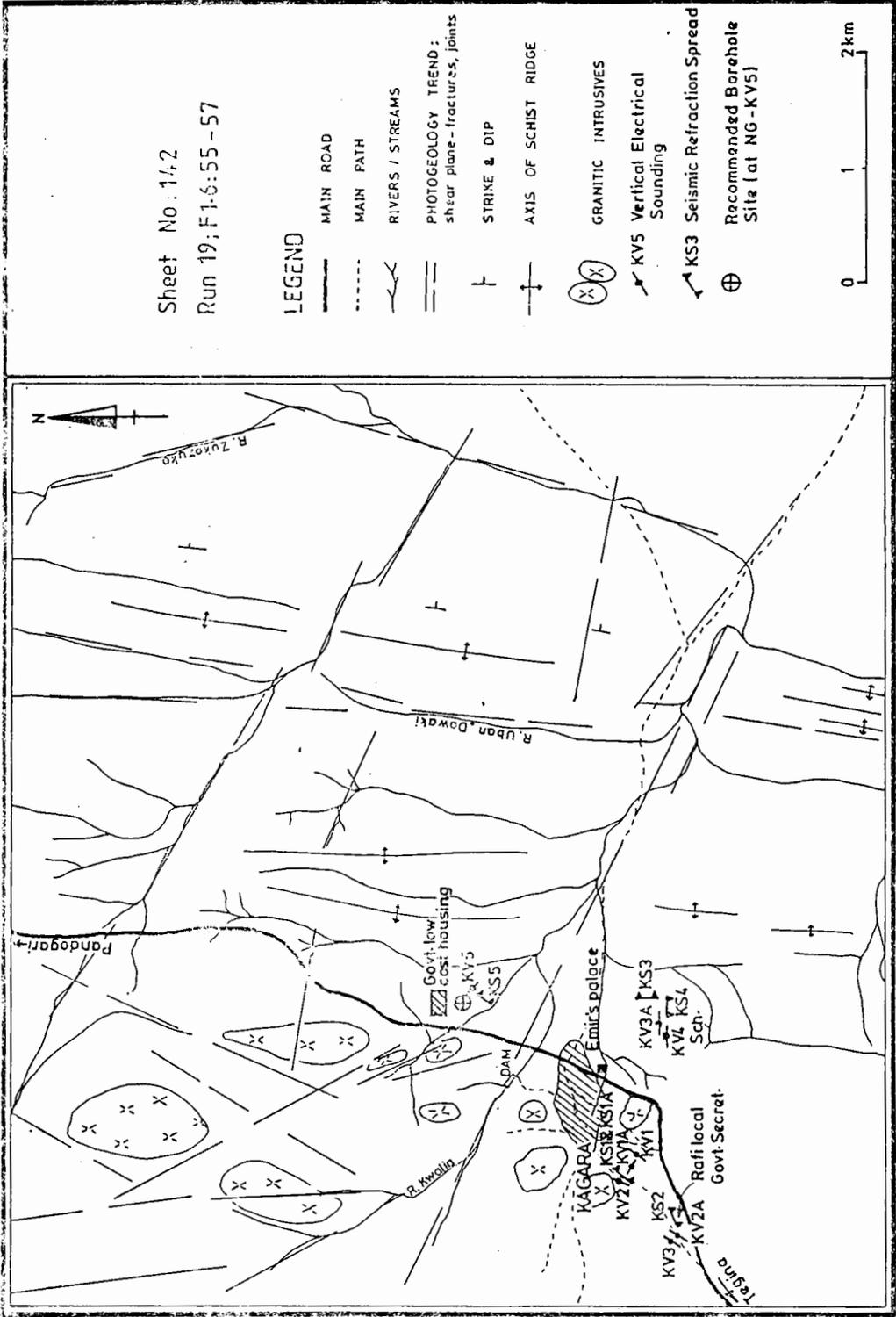


Figure 7.4 Kagara - Contoured Resistivity Map (Traverses NG-KT1 to NG-KT3)

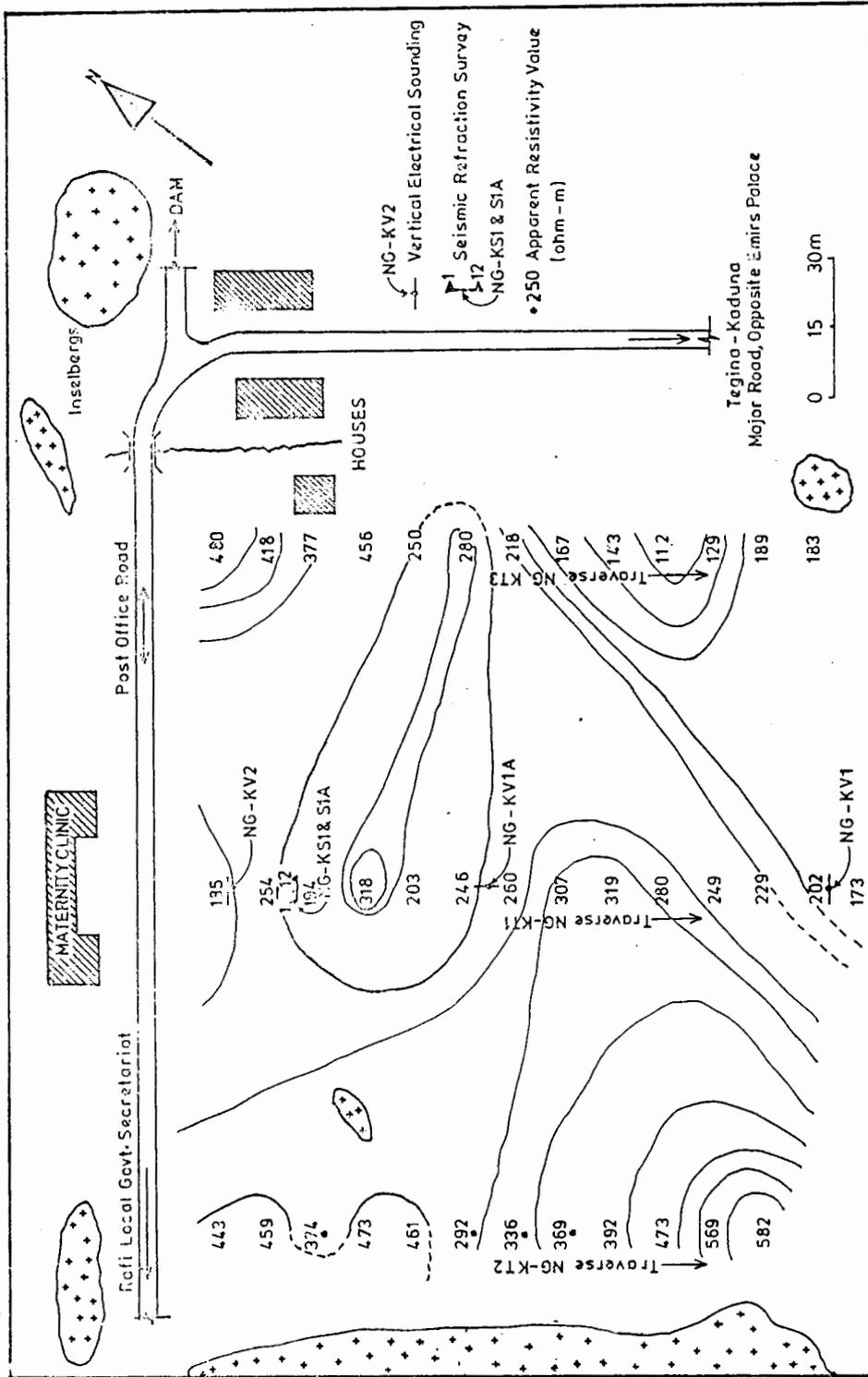


Figure 7.5 Kagara - Resistivity Profile (Traverses NG-KT1 to NG-KT3)

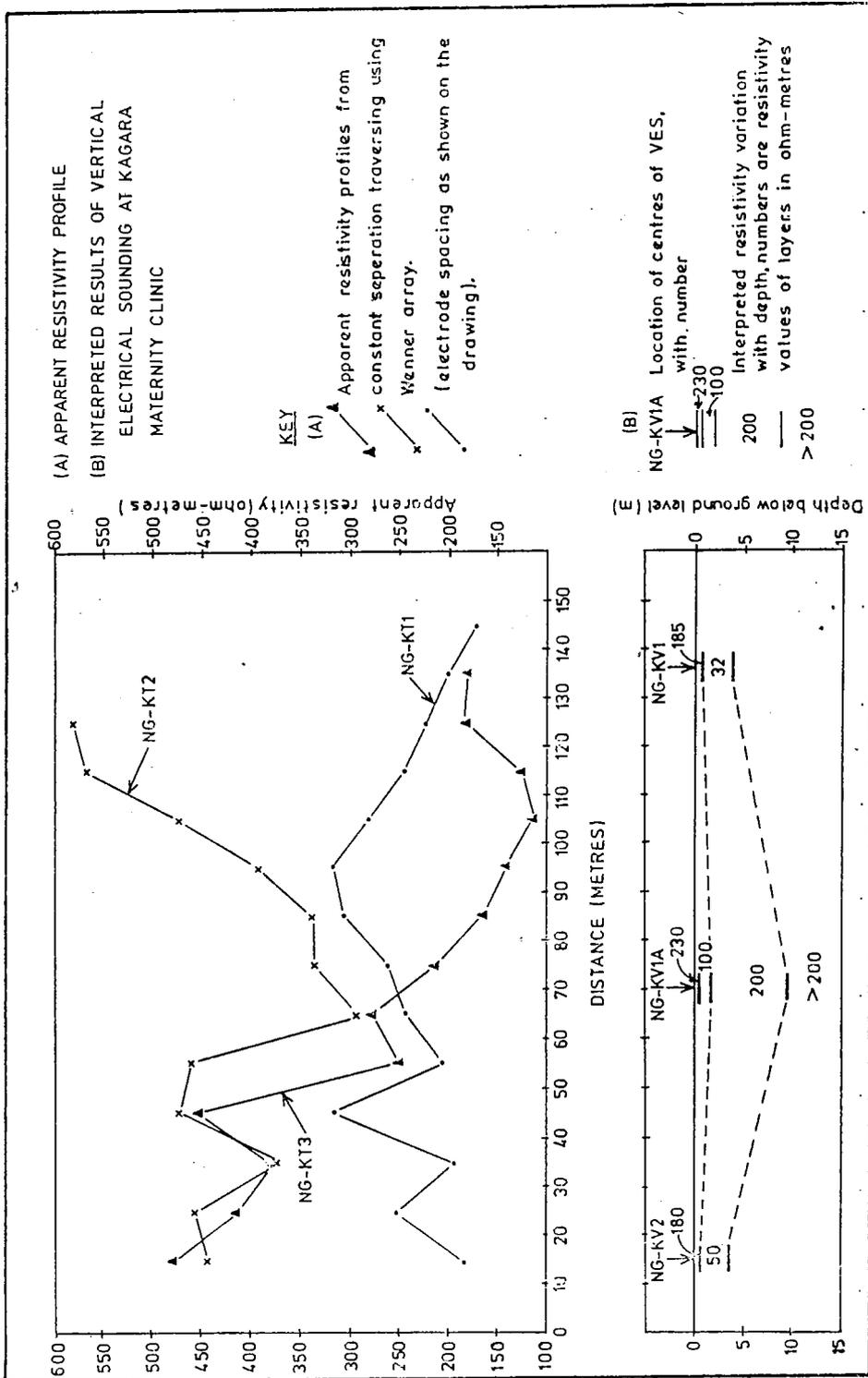


Figure 7-6 Kagara-Location of Stations at Rafi Secretariat

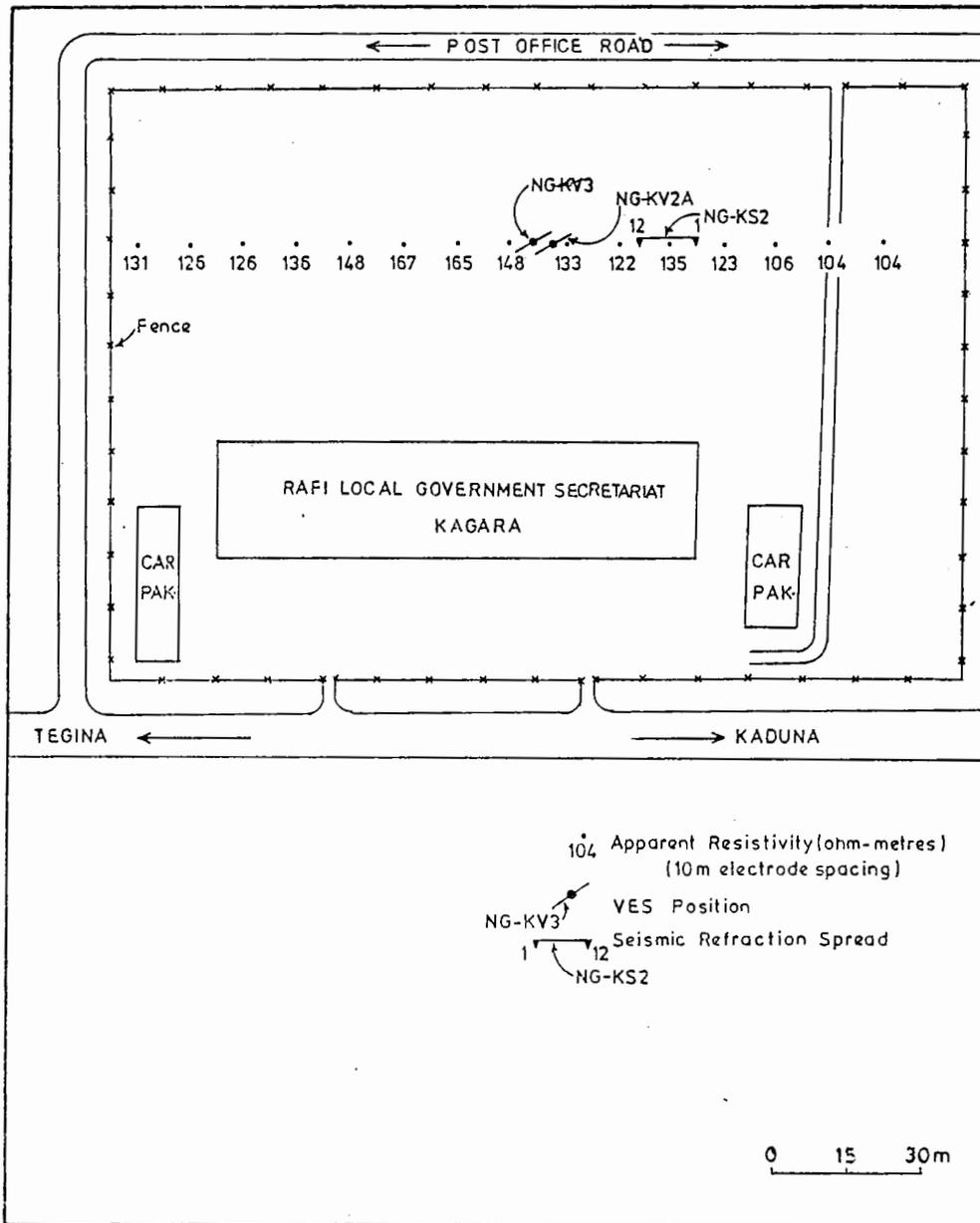


Figure 7-7 Kagera - Traverses NG-KT5 and NG-KT7

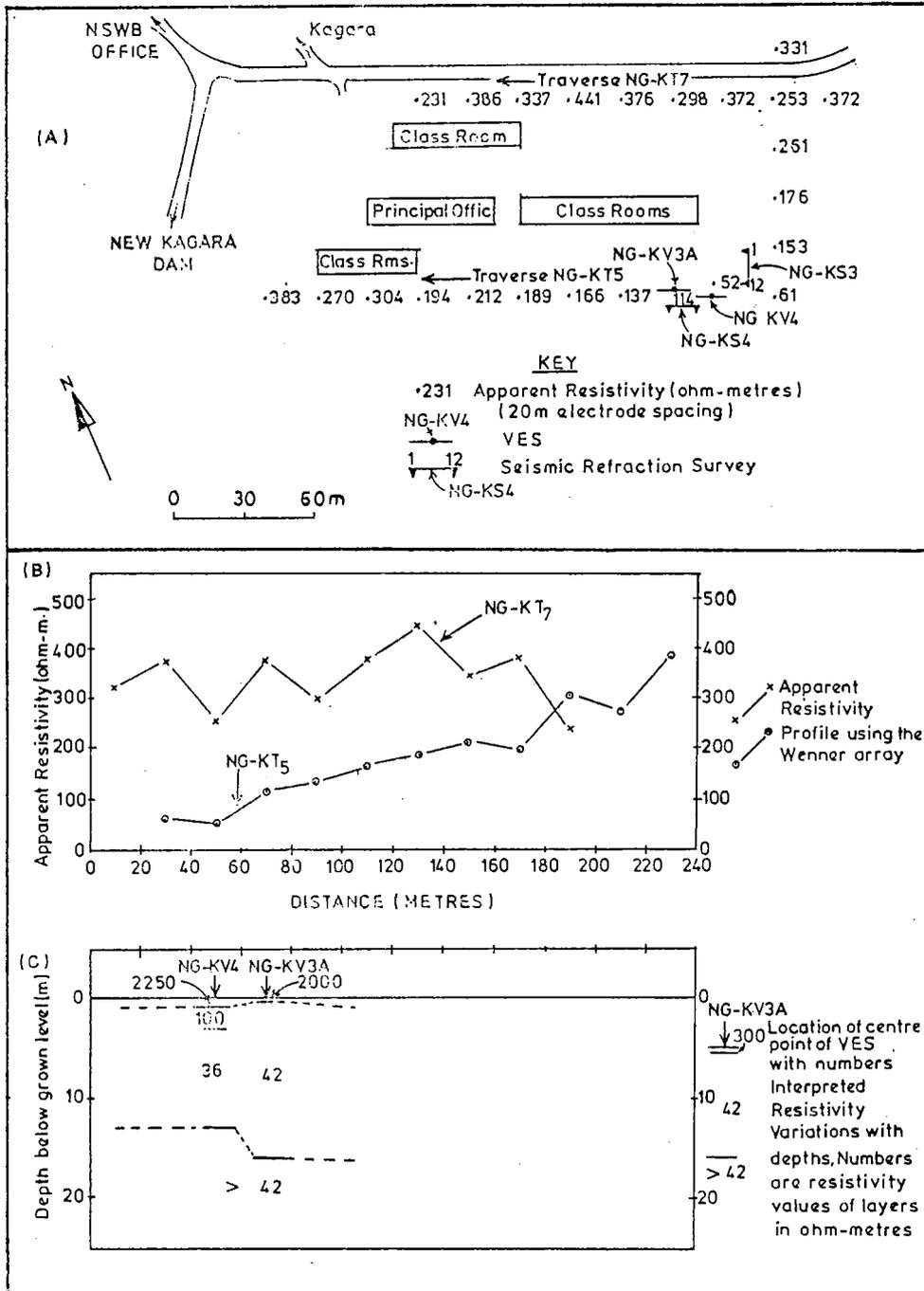


Figure 7.8 Kagara - Location of Traverse NG-KT8

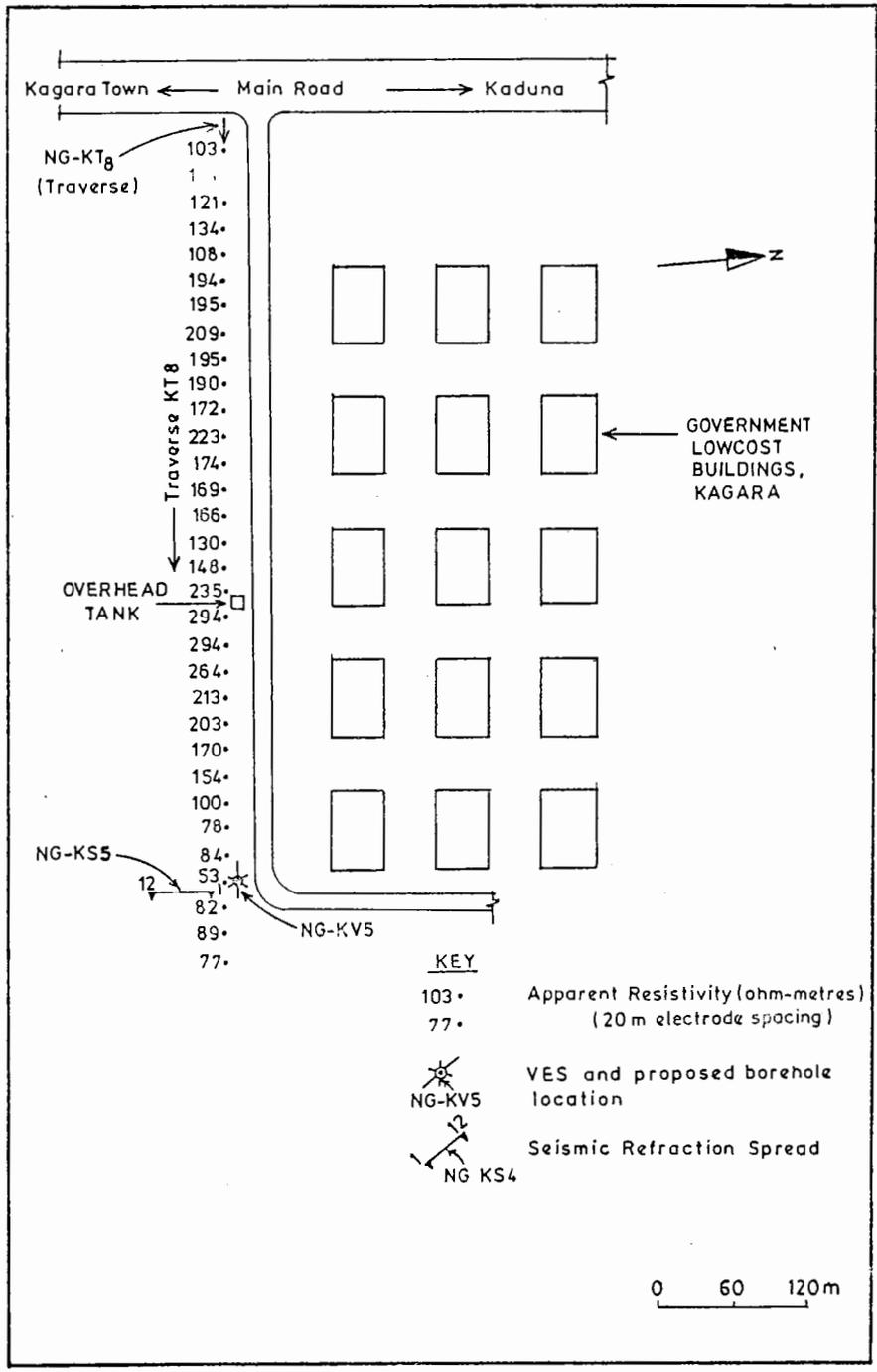


Figure 7-9 Kagara-Resistivity Profile (Traverse NG-KT8)

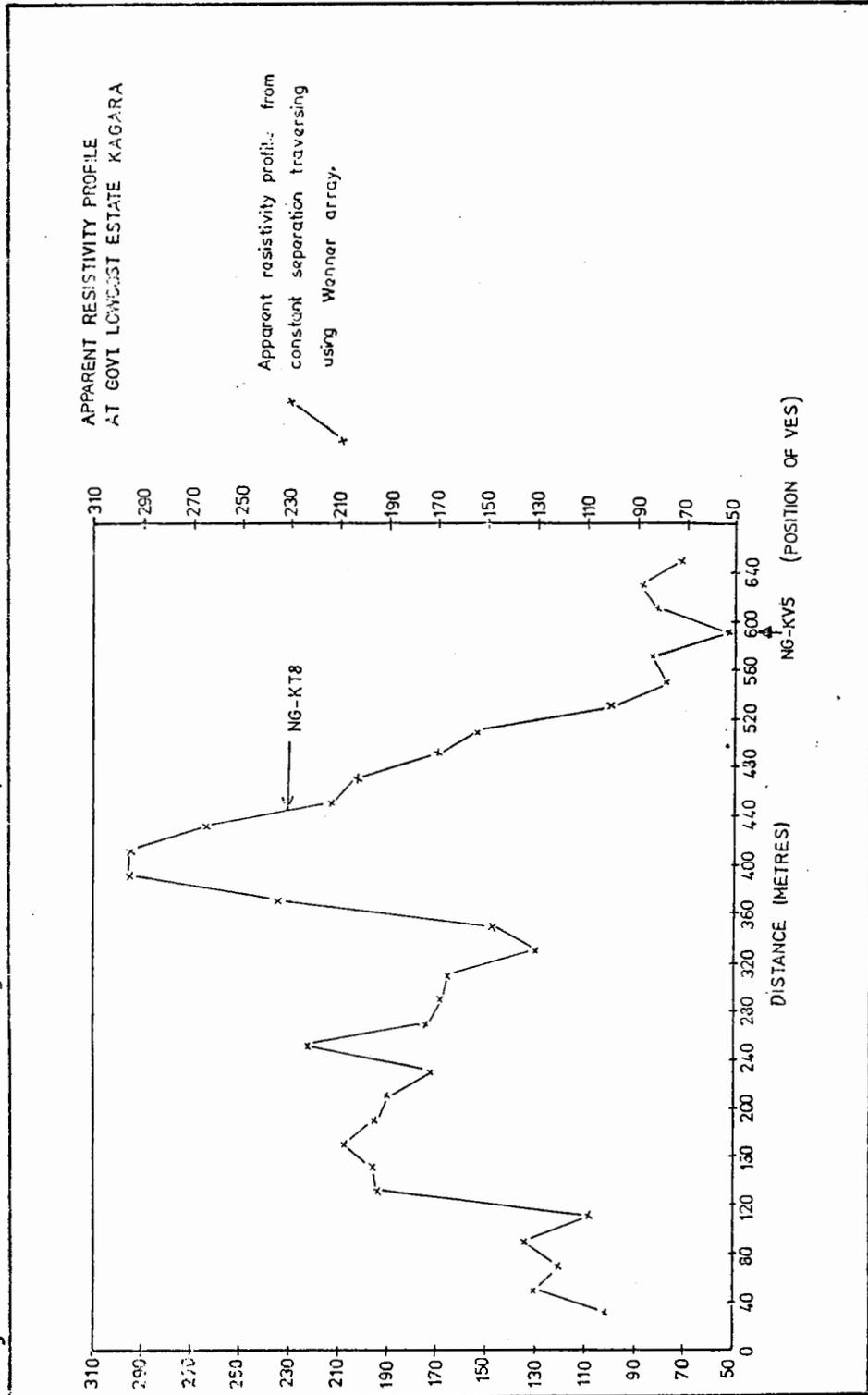


Figure 7.10 Rijau - Photogeological Map and Location of Geophysical Stations

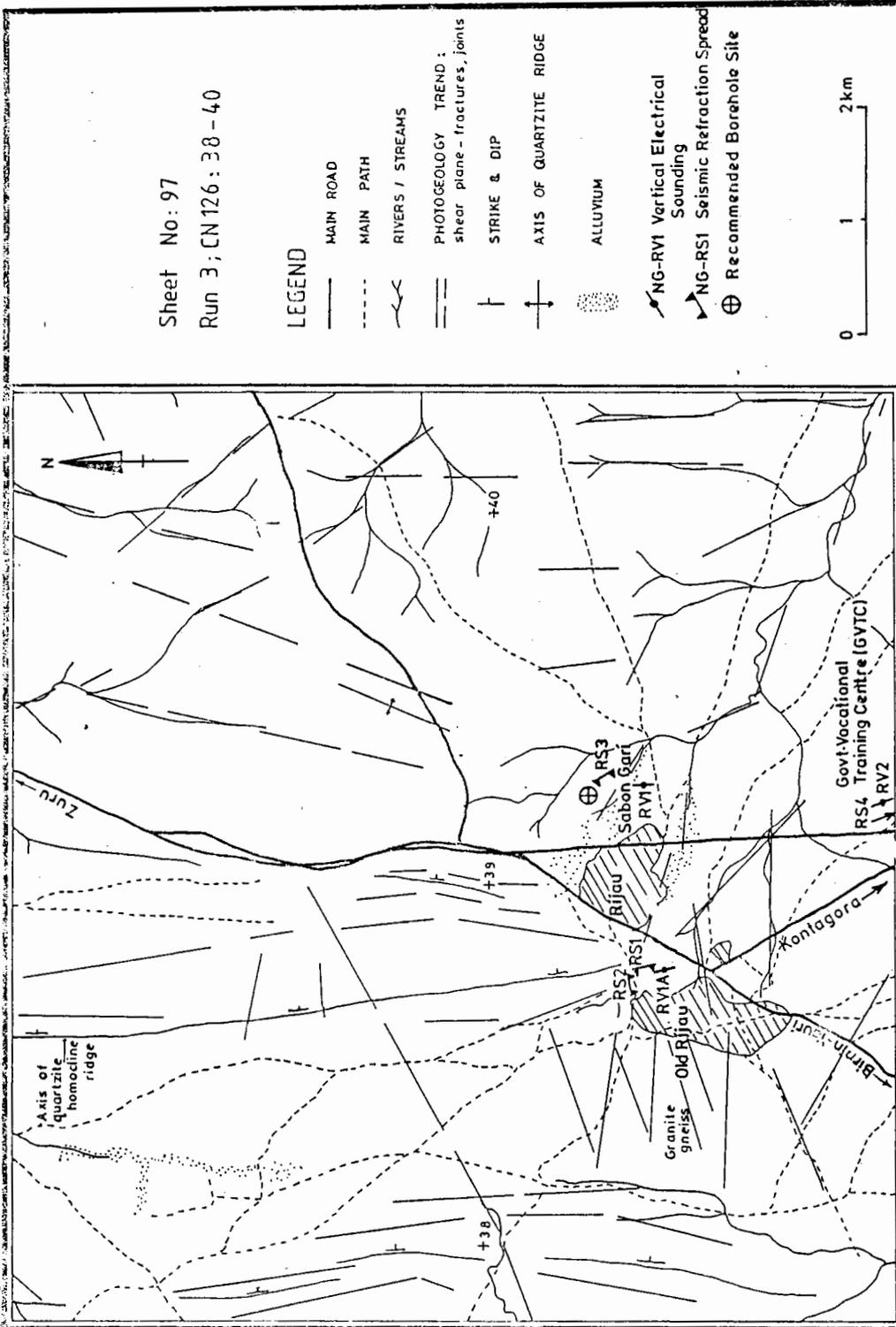


Figure 7.12

Rijau - Sabon Gari Survey Area

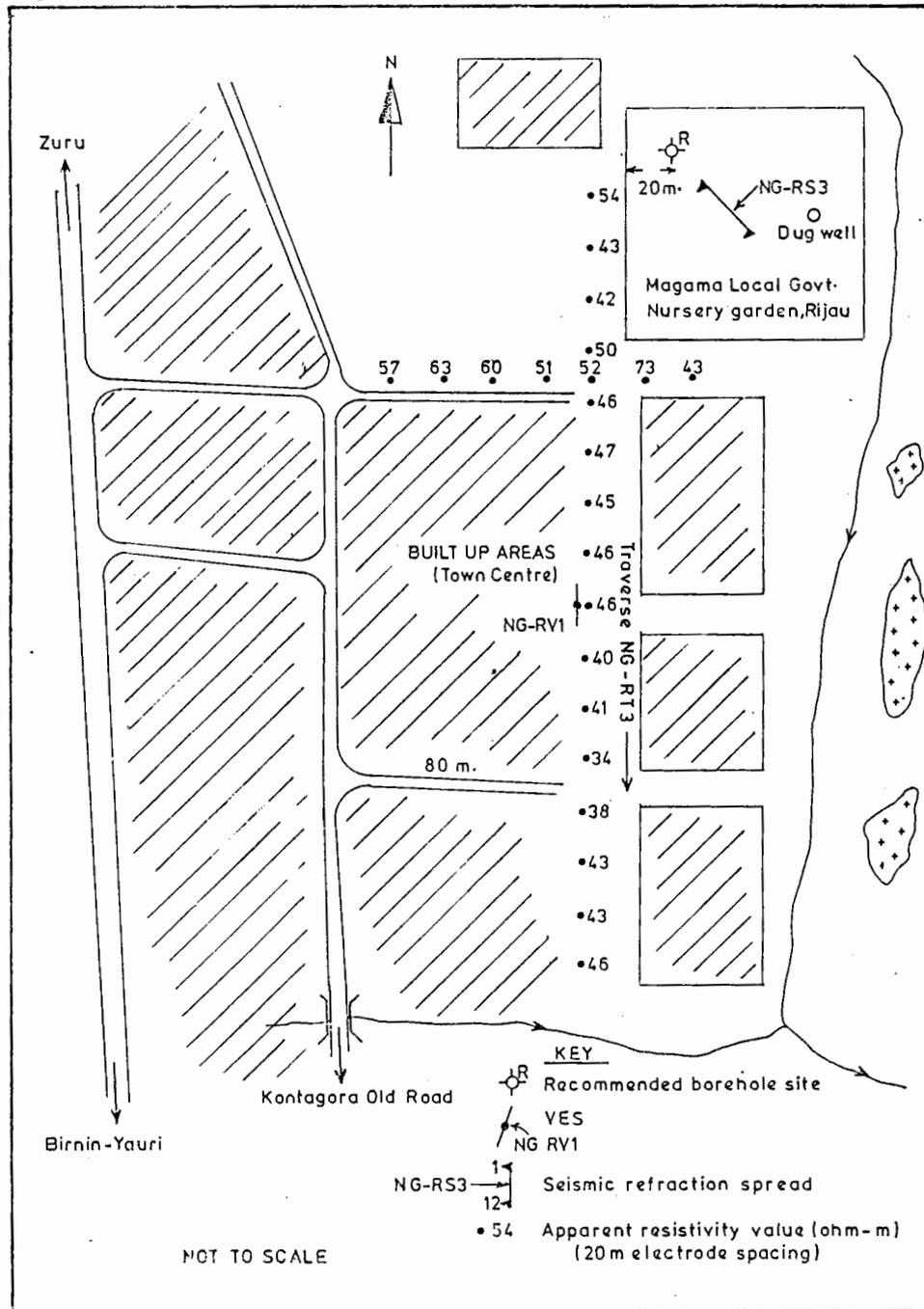


Figure 7-13 Rijau - GYTC Survey Area

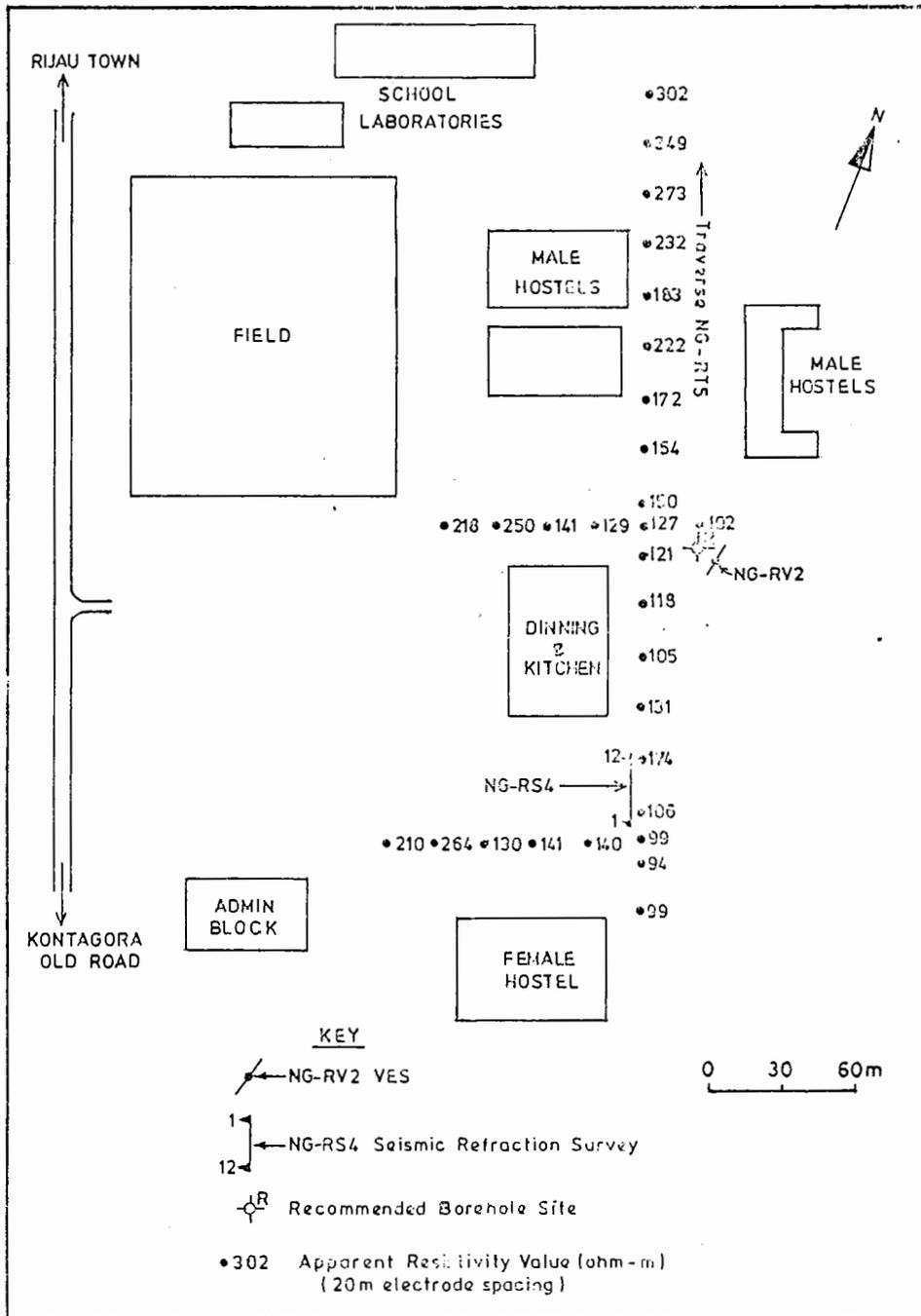


Figure 7-14 Rijau - Resistivity Profiles

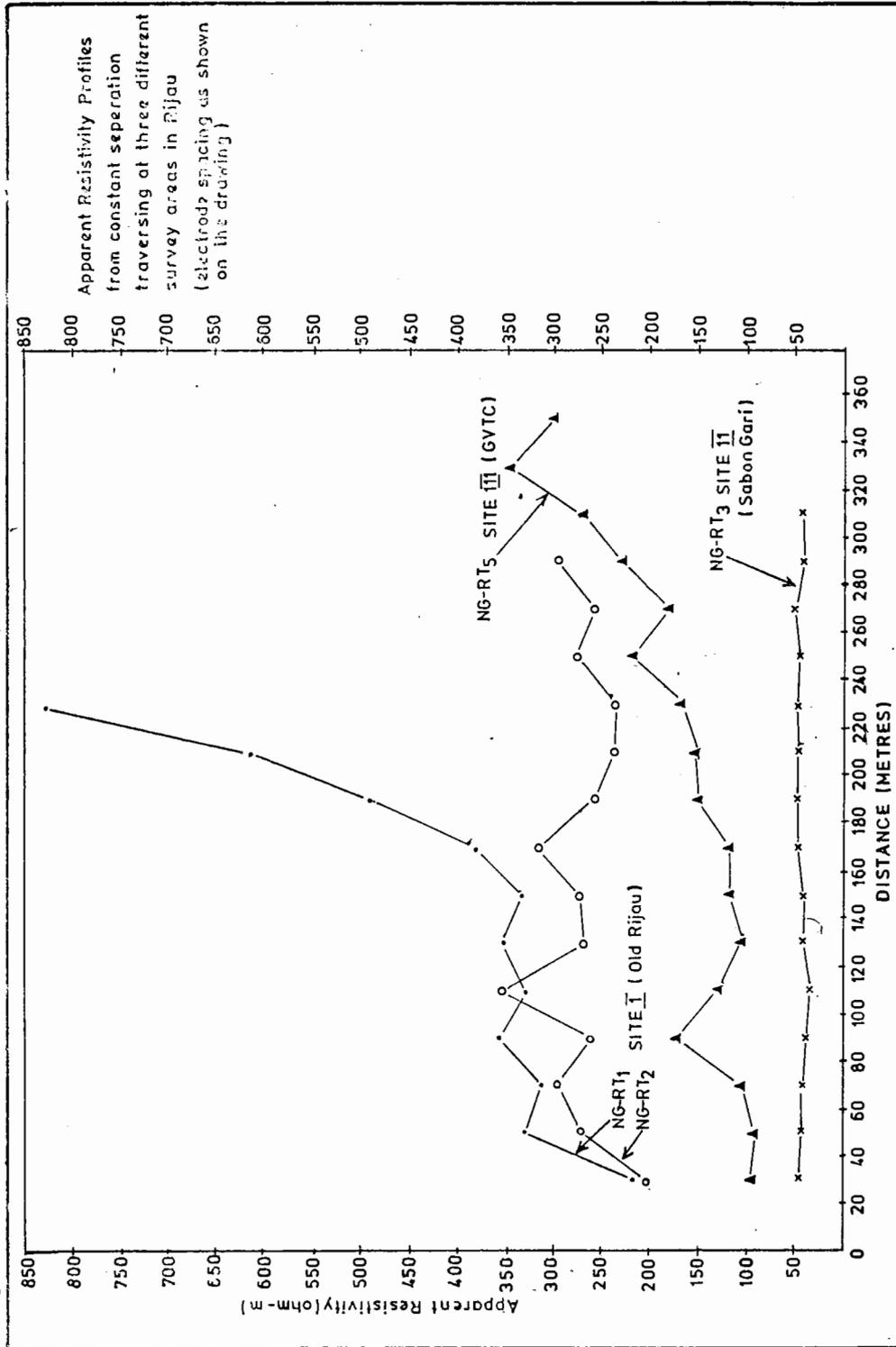


Figure 7.15 Nasko - Photogeological Map and Location of Geophysical Stations

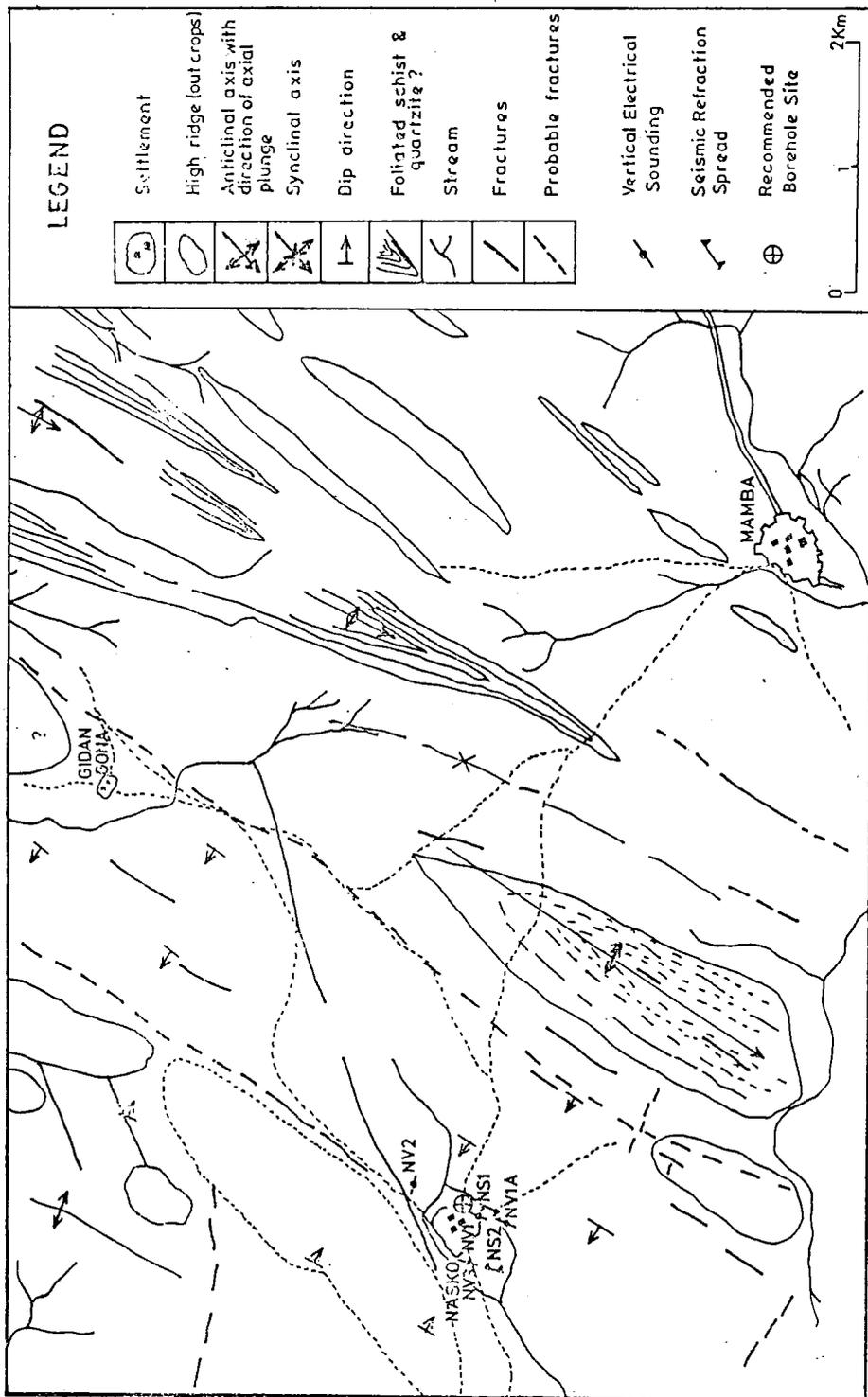


Figure 7-16 Nasko - Traverse Line

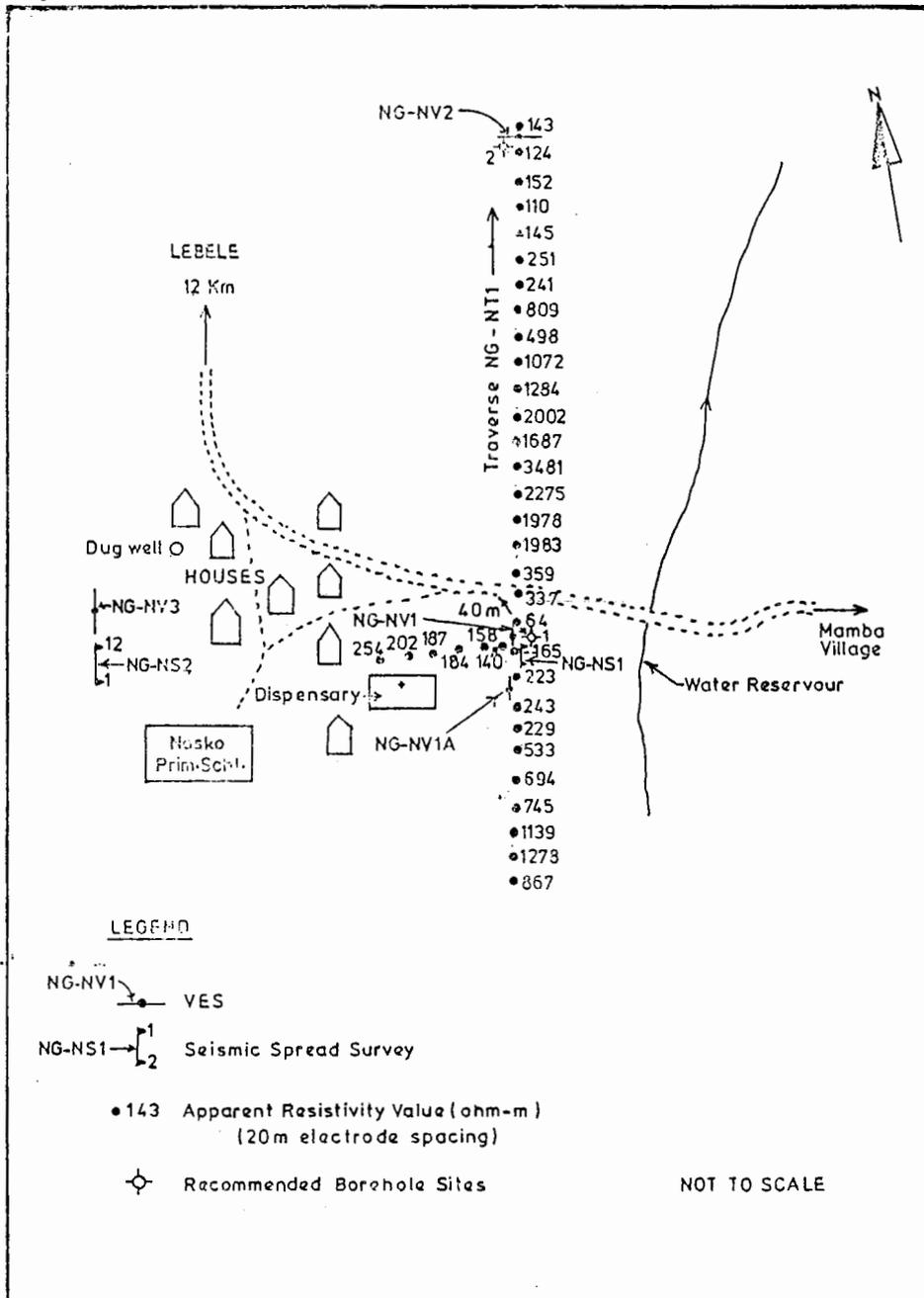


Figure 7.17 Nasko - Resistivity Profile

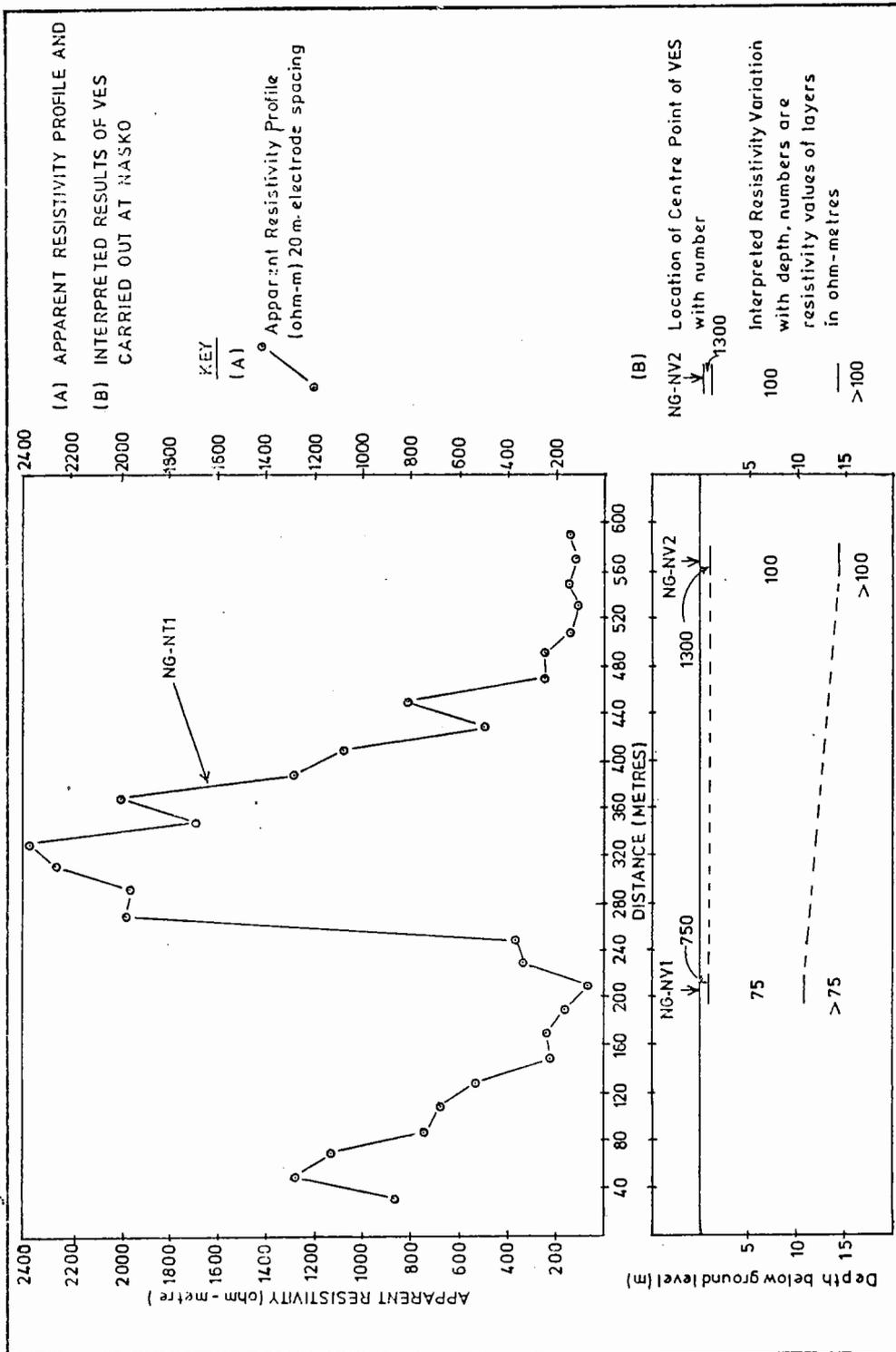


Figure 7.18 Pandogari - Location of Geophysical Stations

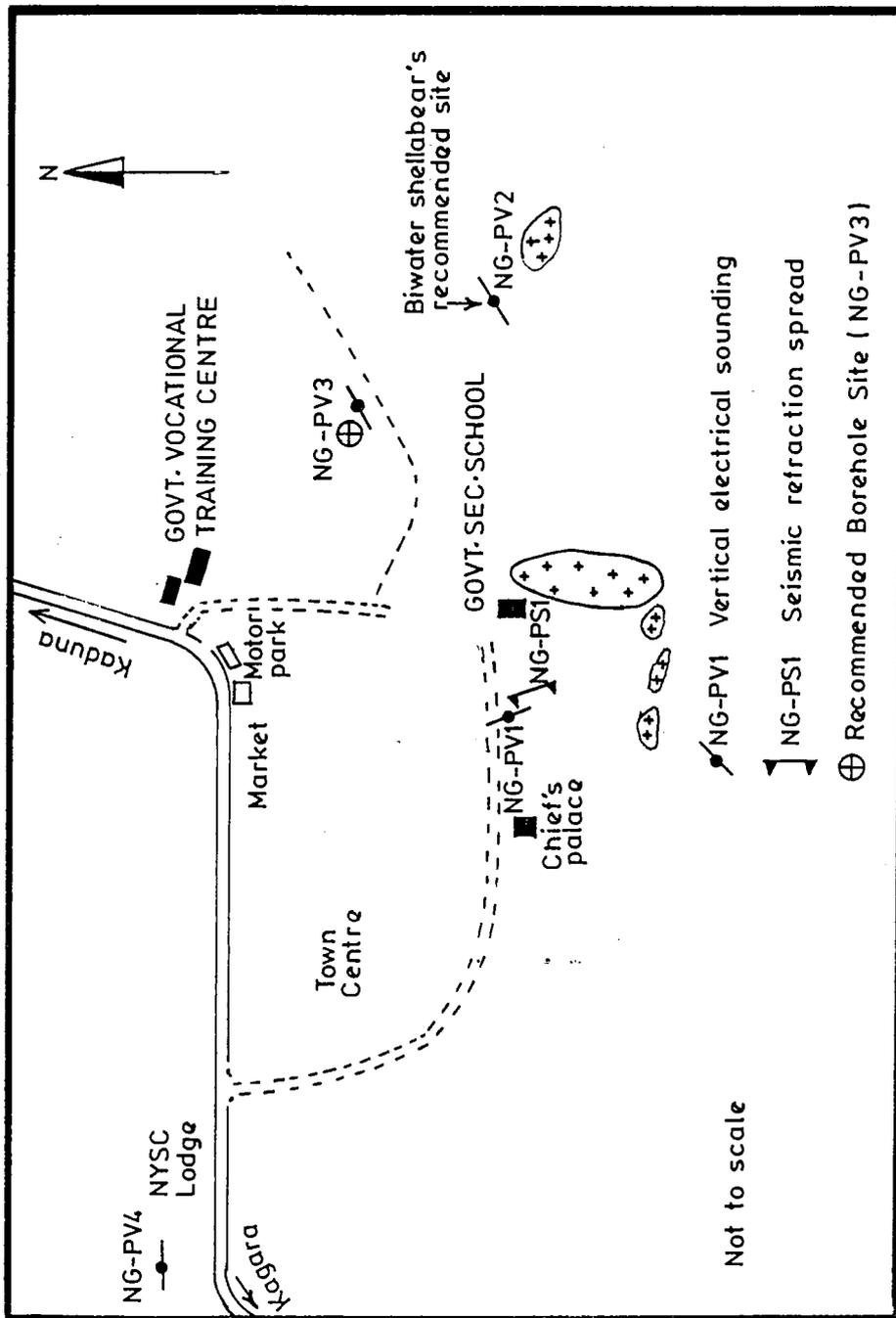


Figure 7.19 Pandogari-Survey Area I

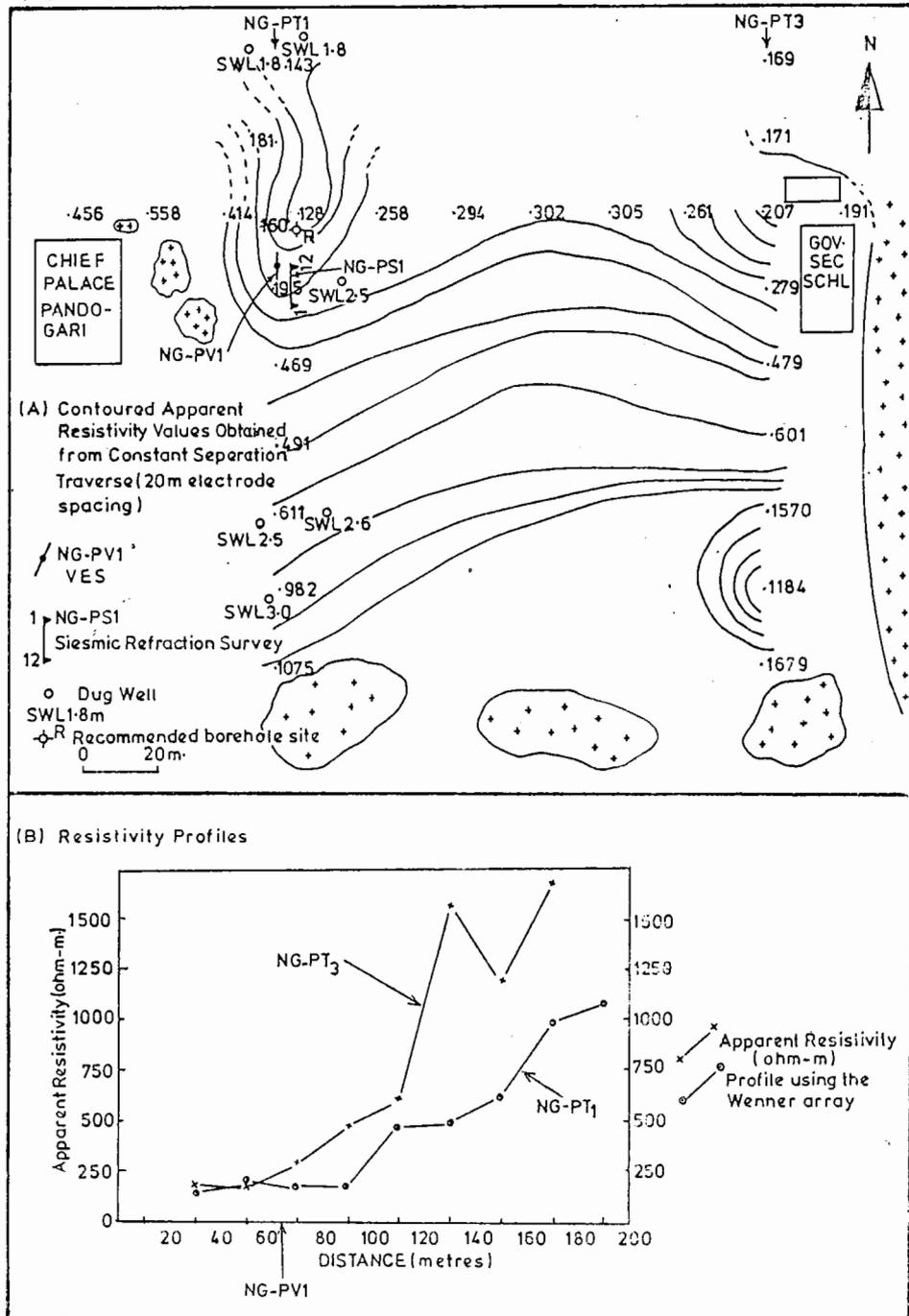
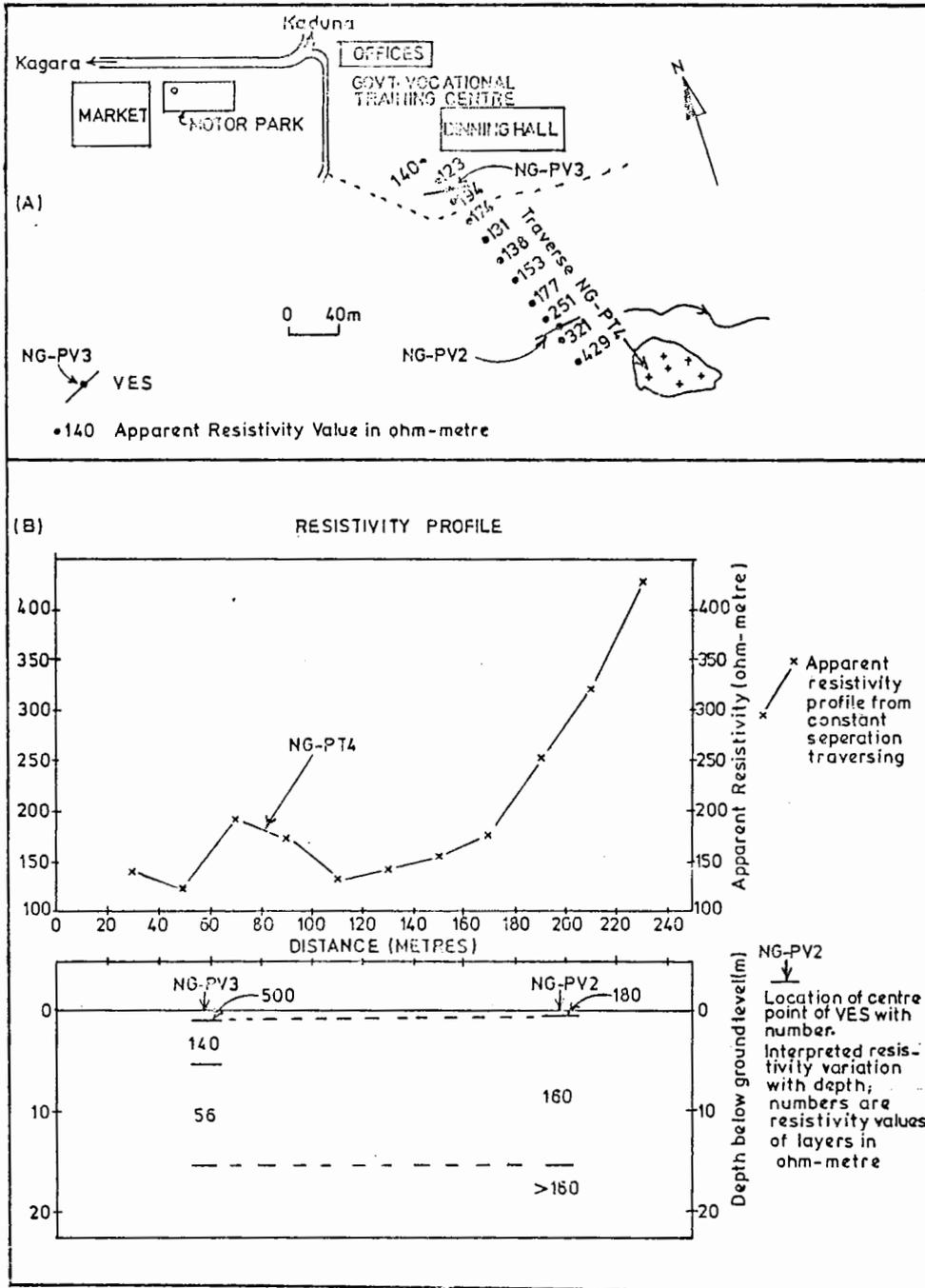


Figure 7-20 Pandogari - Survey Area 11



7.3.6 Kutigi

The only work so far carried out at Kutigi has been the drilling of the first of the three planned boreholes (GWR-7/1). Because of problems to the mud swivel on the rig drilling had to stop at 115m (the planned depth was about 270m). The borehole was completed as a piezometer with 4 inch PVC casing and screen.

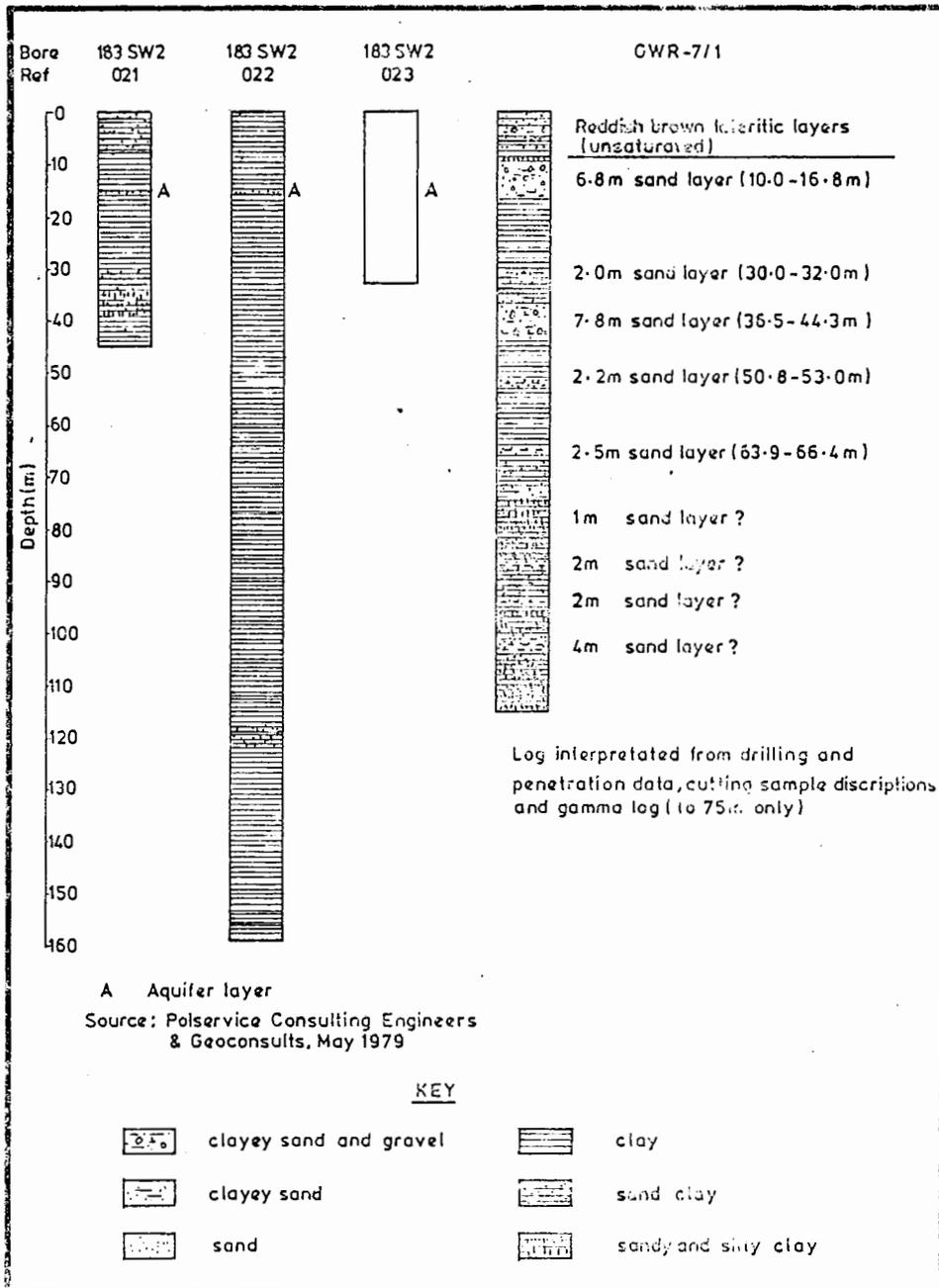
Kutigi lies in the zone of Shekwolo and Stenzel's aquifer type I (Figure 7.1), which is thought to offer the best groundwater prospects in the Nupe Sandstones Formation in the Middle Niger Basin.

The general conclusion from 13 vertical electrical soundings undertaken by Shekwolo and Stenzel at Bida, Doko and Kutigi was that aquifer layers are likely to be thin, confined between irregular lenses of clay and silt and occur mainly between 20 and 80m. At Kutigi itself, VES 12 (new post office) indicated aquifer layers at 30-44m and 48-64m, and VES 13 (Science College) indicated aquifer layers at 53-64m or 53-110m.

The drilling of GWR-7/1 largely confirmed these predications. Figure 7.21 shows that most of the formation consists of clays and silts, with significant sand layers of 7 to 9m thickness only occurring between 10 and 44m; from the water table at 9m and the gamma logging depth of 75m sand layers only account for about 32% of the formation.

Further investigations at Kutigi will have to await the repair of the mud swivel - a test well and a second piezometer are planned; one of these will be initially drilled to the depth originally planned for GWR-7/1 (270m) to determine whether the Basement and the accompanying basal Nupe sands and gravels can be encountered.

Figure 7-21 Kutigi - Borehole Logs



CHAPTER 8

FUTURE WORK PROGRAMME

8.1 Remainder of Project

8.1.1 Drilling

For the remainder of the project (April to June 1986) it is planned to complete all outstanding committed work in the ECA and Niger State. This work is as follows, and it will probably be carried out in the order indicated:

- (a) two piezometers between GWR-1/2 and GWR-1/3 in the ECA, and pumping tests;
- (b) test borehole at the Mokwa farm of Niger Mechanised Farms Ltd for the National Grains Production Company Limited;
- (c) test well and second piezometer at Kutigi, and pumping tests.

The work at Mokwa (b) will start once seals have been received for the reconditioned mud swivel. After Kutigi it is understood that drilling may be required at Shara and Ilorin in Kwara State.

Before the Consultant's departure all the equipment will be checked over, and an inventory made of the spare parts in the GWRD stores for handing over to the Institute's stores officer.

8.1.2 Geophysics

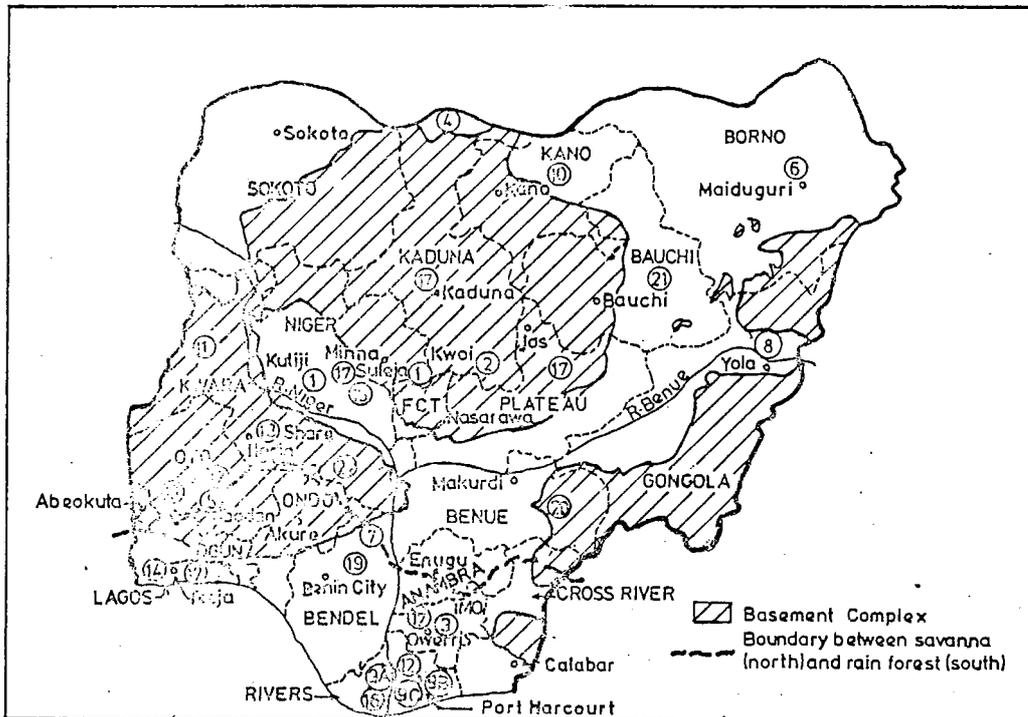
Further geophysical investigations will be carried out in the ECA at possible future drilling sites, and work will be undertaken at Kutigi and other locations on the Nupe Sandstones in the Middle Niger Basin.

8.2 Research Proposals

A questionnaire to gather proposals for possible research projects was sent to all the State Water Boards, River Basin and Rural Development Authorities, and FDWR zonal offices in February 1985. The response was very encouraging - 24 proposals were received (the figure includes the request from the Niger State Water Board which was received before the questionnaires were despatched). The locations of the proposed projects are shown on Figure 8.1.

These proposals should be used to formulate a long-term field programme for the GWRD. In order to enable the staff to gain some experience of working in the rain forests of the south of the country, it is suggested that priority be given to the following proposals:

Figure 8-1 Proposals for Groundwater Research Projects



Proposal Number	Authority	State	Project size (km ²)	Geology (1)	Scope/objectives
1	Niger State Water Board	Niger		B & S	B-borehole siting, S-well design
2	Kaduna State Water Board	Kaduna	225	B	Borehole siting
3	Imo State Water Board	Imo		S	To delineate gw. occurrence
4	Min. of Agriculture & Co-operatives	Kaduna	1000	A	Development of fadama aquifer
5	Oyo State Water Corporation	Oyo	490	B	Borehole siting & design
6	FDWR/BENUE/CBRDA /LCR/	Borno	50,625	S	Recharge of aquifer by boreholes
7	Benue River Basin & Rural Dev. Auth.	Bendel	-	S	Influence of topography on gw. occur.
8	Upper Benue River Basin & RDA.	Gongola	10	S	Reasons for falling yields & wl.
9A	Delta Basin & Rural Devel. Auth.	Rivers	2	S	Relationship high Fe. content gw./creeks
9B	Rivers State Utilities Board	"	0.02	S	Saltwater intrusion/location fresh gw.
9C	Federal Dept. of Water Resources	"		S	Determination fresh/salt gw. interface
10	Kano Hydro. River Basin & RDA.	Kano	2,500	S	Feasibility gw. irrigation
11	Kwara State Water Corporation	Kwara		B	Borehole siting and design
12	University of Port Harcourt	Rivers		S	Inventory of groundwater data
13	Min. of Agriculture & Natural Res.	Oyo		B	Gw. exploration for agric settlements
14	Min. of Agriculture & Co-operatives	Lagos	0.2	S	Groundwater irrigation development
15	Upper Niger River Basin & RDA	Niger	1	S	Reasons for low yield of Nupe Ss.
16	Rivers State Utilities Board	Rivers		S	Salinity, high Fe. content
17	Federal Department of Fisheries	Various		B & S	Groundwater explorat. for fisheries
18	Niger River Basin Devel. Auth.	Kwara			Aquifer properties, bh design & op.
19	Bendel State Water Board	Bendel	5	B & S	Gw. resource eval. using api.
20	Benue State Water Board	Benue	4,400	B	Borehole siting (geophys), drilling
21	Gongola-Jama'ara River Basin RDA	Bauchi	28,750	S	Aquifer evaluation
22	FDWR Ilorin Office	Kwara	1,310	B	GW potential for domestic / irrigal.

(1) B - Basement, S - Sedimentary Formations, A - Alluvium (fadama)

- (a) proposal nr.5 - identification of aquifers and optimum design of boreholes in the Basement Complex in Ibadan Municipal Local Government Area, Oyo State;
- (b) proposal nr.16 - investigations into the high iron content of borehole water, and the intrusion into coastal sedimentary aquifers of saline water, for the River State Utilities Board.



CHAPTER 9

FUTURE PROCUREMENT REQUIREMENTS

9.1 Introduction

The project was supplied with a comprehensive set of drilling and geophysical equipment, and two years worth of spares. However, virtually no items of hydrogeological equipment (EC meters, water chemistry kits, etc.) were included in the supply contract specifications because of assurances that they would be available locally for purchase by the FDWR/NWRI. Unfortunately, it was found that most items were not stocked locally and arrangements had to be made to borrow the equipment from FDWR Zonal Offices. There is a need to replace this equipment.

Also, during the course of the project it was felt that some extra items of drilling, geophysical and field support equipment were needed to enhance the capabilities of the items already provided, and to overcome some of the logistical problems experienced. Moreover, spare parts and some consumables not available locally will need to be replenished.

Finally, a provision should be made for the purchase of office equipment and other capital items originally included in the local currency budget prepared in 1984.

It is hoped that suitable funding arrangements can be made for this procurement.

9.2 Imported Equipment and Spares

It is assumed that all the spare parts that originally came with the equipment will need to be replenished, together with the supply of other needed spares. Full lists are given in Appendix C.

The extra equipment that is thought to be required is shown on Table 9.1, which also includes the estimated cost for the spares. The total cost (based on 1986 prices), including freight and insurance to Kaduna, is estimated to amount to some Pounds Sterling 116,288.

A microcomputer system is needed to replace the Consultant's machine for geophysical interpretation and word processing (report production). Although a relatively cheap machine would suffice for this purpose (such as the BBC B or Atari S20 ST) it would be wise to use the opportunity to procure a well proven business system which is fully IBM compatible. Such a machine, for example the Olivetti M24, with spreadsheet and database software would expand the capabilities of the department considerably. The cost in the table is for such a system.

A small portable generator (1.0 or 1.5 KVA) would be very useful for recharging batteries for the geophysical equipment in the field,

Table 9.1 Imported Equipment Requirements

Item	Description	Qty	Estimated Cost FOB UK Port (Pounds Sterling)
A. Drilling Equipment			
1	3m core barrel, sub and a set of catchers, suitable for collecting 3" diameter cores.	1	500
2	Chain suitable for 234C(233 1/2R) tong	2	400
3	Chain suitable for 233C(235cm) tong	2	400
4	Chain suitable for 236C(235cb) tong	2	400
5	High pressure mud gauges, various ratings up to 6,000 psi	3	300
6	Tricone bit, medium hard formation 12 1/4"	2	2,800
7	Tricone " " " " 9 5/8"	2	1,900
8	Tricone " " " " 7 7/8"	2	1,500
9	Tricone " " " " 5 7/8"	2	500
10	Tricone " " " " 4 3/4"	4	700
11	Drag bit blade set, 7 7/8"	2	340
12	DHH button bit, MACH 60, 7 7/8"	2	1,800
13	" " " " " 5 7/8"	6	2,900
	Sub Total		14,440
B. Geophysical Equipment			
14	Microcomputer system, consisting of computer, disc drive, monitor, printer, supply of consumables and relevant software	1	4,700
15	Uninterrupted power supply unit, 500w	1	1,000
16	Portable generator, 1.0 or 1.5 KVA	1	500
17	Electro-magnetic (EM) survey equipment	1	11,500
18	SAS 2000 booster unit for Terrameter	1	400
19	Short range (walkie talkie) radios	4	400
	Sub Total		18,500

Item Description	Qty	Estimated Cost FOB UK Port (Pounds Sterling)
C. Hydrogeological Equipment		
20 Compass/clinometer	3	100
21 Carbon-fibre reinforced tape measure, 50m/100m	3	60
22 Sample bottle, heavy duty plastic	200	100
23 Geological hammer, 0.5 kg	3	90
24 Hach DR EL/5 portable laboratory, HH/41800-00 (without conductivity, with pH meter)	2	4,300
25 Battery recharger and rechargeable batteries (D and AA size)	2	100
26 Geologist lens, x 10 or x 15 magnification	3	20
27 EC meter, type MC1 or similar	2	440
28 Desk stereoscope	1	300
29 Pocket stereoscope	3	60
Sub Total		5,570
D. Field Support Equipment		
30 2 berth caravan, c/w airconditioning, cooking stove, washing facilities, mounted on trailer suitable for towing by Land Rover	1	6,000
31 4 berth caravan, c/w airconditioning, cooking stove, washing facilities, mounted on trailer suitable for towing by truck	2	13,000
Sub Total		19,000
E. Office Equipment		
32 Binding machine, A3 capacity, with supply of plastic covers and rings.	1	200
33 Letraset, Letratone or similar	-	200
Sub Total		400

Item Description	Qty Estimated Cost FOB UK Port (Pound Sterling)
F. Spare Parts	
34 Drilling equipment and vehicles	- 44,000
35 Geophysical and hydrogeological equipment	- 1,000
Sub Total	45,000
Total FOB	102,910
Add 13% for insurance and freight to Kaduna	13,378
Grand Total CIF	116,288

where a mains electricity supply is unavailable or unreliable. The geophysical field team will not necessarily be working close to the drilling operations, and so will not always be able to make use of the generator supplied with the drilling equipment.

For Basement Complex areas lightweight electro-magnetic (EM) equipment (such as the Geonics EM34) can be used to undertake reconnaissance surveys (traversing) much more quickly and economically than with resistivity equipment. Vertical electrical soundings can be carried out at the most favourable points along the traverse line to select drilling sites and estimate the extent of the weathered zone and the condition of the rock. EM equipment was used to good effect on the KNARDA 1000 borehole programme where MRT achieved a 87% borehole success rate on the Basement Complex.

The potential usefulness of the ABEM Terrameter SAS 300 resistivity equipment already provided could be increased by the addition of an SAS 2000 booster to enhance the power input. This would improve the accuracy of readings, particularly in areas with a high resistivity surface layer, and when large electrode spacings are used; it could thus increase the maximum depth of investigation.

Geophysical field work could be made more efficient by using short range ('walkie talkie') radios. Relatively cheap Citizens Band radios would be adequate, assuming that licences could be obtained. Rechargeable battery packs (or individual Ni-Cad batteries) and a charger would be necessary to avoid the high local cost of replacing batteries.

Good field accommodation is essential for the well-being and productivity of field staff. Caravans, customised for tropical conditions and mounted on trailers suitable for towing by the existing project vehicles are the most practical option to fulfill this requirement. It is suggested that a 2-berth and a 4-berth caravan are supplied for the supervisory and senior drilling staff, and a 4-berth caravan for the geophysical team. A light (3 or 5 tonne) truck would be needed to tow the latter caravan and to support the geophysical team since the capacity of the existing vehicle (Land Rover station wagon) would be exceeded - such a truck could be procured locally.

9.3 Local Procurement

Table 9.2 lists the equipment, vehicles and major consumables for local procurement. The total cost (based on March 1986 prices and including a 10% contingency) is estimated to amount to some N 162,360.

When the local currency budget was drawn up in 1984 a provision was made for the purchase of two vehicles (Land Rovers or Peugeot 504 estates). Unfortunately, because of lack of funds these vehicles were not procured and instead the Institute provided the project with its Toyota Land Cruiser station wagon. However, there is still

Table 9.2 Local Procurement

Item Description	Qty	Estimated Cost (N)
A. Transport		
1 Light truck (3-5 tonne), Fiat Iveco 45NC or similar	1	29,000
2 Spare parts for Toyota Land Cruiser (windscreen, a/c unit, towing hitch, running spares, etc)	-	3,000
3 Tyres for Peugeot, Land Rovers and Land Cruiser	20	6,000
Sub Total		38,000
B. Office Equipment		
4 1 1/2 HP airconditioner	7	16,600
5 Desk, double pedestal lockable drawers	5	4,000
6 Desk, single pedestal	10	6,600
7 Drawing table	2	7,100
8 Long table (2 x 1.5m)	1	2,400
9 Map chest, 4 drawers minimum	1	500
10 Swivel chair	5	3,700
11 Upright chair	14	1,300
12 Moveable partition, 2 x 1.5m	5	2,800
13 Wall noticeboard, 2 x 1.5m	5	400
14 Bookcase, 5 shelves, floor standing	3	2,000
15 Bookcase, 3 shelves, lockable, wall-mounted	2	1,000
16 Desk lamp, 60w	10	1,500
17 Steel stationary cupboard, lockable	1	600
18 Voltage stabiliser, 400w	3	300
19 Drawing pen set, 0.1 - 1.2mm	2	200
20 Guillotine, A3 size	1	100
Sub Total		51,100

Item Description	Qty	Estimated Cost (N)
C. Camping Equipment		
21 Mess tent, 12 man	1	3,000
22 Mess table and benches, folding	2	2,000
23 Drinking water container, heavy duty plastic	8	100
24 Water filter	3	400
25 Gas stove, 2 burners, with bottles	3	600
26 Basins, buckets, kettles, cooking pans, etc	-	600
27 Camp bed	15	2,100
28 Mosquito net for camp bed	22	2,200
29 Blankets, pillows, etc	22	2,200
30 Water tank, 4.5 m3, steel	1	600
Sub Total		13,800
D. Protective Clothing		
31 Coveralls	12	1,400
32 Hard hats	12	800
33 Pairs of boots	22	3,400
34 Pairs of work gloves	15	200
35 Pairs of eye goggles	4	100
Sub Total		5,900
E. Workshop Equipment		
36 Electric compressor	1	2,900
37 Set commercial (split rim) levers and complete tyre change puncture repair kit	1	3,100
38 Vehicle inspection lamp	2	100
39 Bottle jack, 2 & 5 tonne	2	300
40 Heavy duty axle stand	4	700
41 Commercial wheel brace, metric	1	200
42 Set heavy duty tyre levers	1	100
Sub Total		7,400

Item Description	Qty	Estimated Cost (N)
F. Drilling Consumable and Borehole Components		
43 Bentonite, 50kg sack, ex-Port Harcourt	50	1,400
44 Foaming agent, 55 gal drum, ex-Port Harcourt	5	4,700
45 Custom mud, 5 gal. pail, ex-P/Harcourt	10	2,100
46 Steel casing 6"	100m	6,800
47 Steel casing 8"	50m	5,100
48 PVC casing 4"	100m	1,600
49 PVC casing 6"	100m	3,400
50 PVC screen 4" 0.5-1.0mm slot	50m	1,200
51 PVC screen 6" 0.5-1.0mm slot	100m	5,100
Sub Total		31,400
Total		147,600
Add 10% contingency		14,760
Grand total		162,360

a need for the second vehicle which, rather than a Land Rover or Peugeot 504 estate, should be a 3 or 5 tonne truck to support the geophysical team.

Drilling consumables and steel casing should be procured in Port Harcourt where the main oil field supply companies are located. PVC casing and screen are manufactured in Kano and Kaduna. The quantities indicated in the table are to make up for the consumption during the project.

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APPENDIX A
PROJECT EQUIPMENT

LOT 1 - DRILLING RIG AND ACCESSORIES

Supplier - Halifax Tool Company Limited

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
1.1	Halco V866 Varitork hydraulic drilling rig, fitted with water/foam pump and 300 litre water tank (tender ref.1.4), powered by Deutz F6L912 diesel engine, mounted on Magirus Deutz 320 M 33 AK 6x6 truck	1	18/6/84	2 inner tubes damaged - replaced by Halco. Gearbox air seal corroded - replacement bearing collars, seals, air swivel extracting tools and assorted washers, O rings delivered 12/1/85
1.1.10	Hand tools for rig	2 sets	25/6/84	
	- chain tong 12"	2		
	- " " 6"	2		
	- medium chain tong	2		
	- rigid pipe wrench 24"	2		
	- " " " 48"	1		
	- wire brush	2		
	- 4 lb club hammer	2		
	- 25 lb sledge hammer	2		
	- grease gun	2		
	- oil jug 2 pints	2		
	- oil jug 1 pint	2		
	- steel tool box containing comprehensive set of hand tools	1		
1.1.14	Casing jacks, clamps and slips		25/6/84	
	- 40 tonne x 0.3m lift heavy duty hydraulic lifting jacks, independent pumping unit	2		

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
	- intertube non-return valve, 90 mm	1		
	- 2 3/8" IF-pin down	1		
	- steel clamp for 14" steel casing	1		
	- steel clamp for 10" steel casing	1		
	- steel clamp for 8" steel casing	1		
	- complete set of slip bowl and slips for steel DHH tools	1		
1.2	Conrad Stork mud pump, type CD7580, powered by Deutz F6L912 diesel engine, c/w discharge and suction hoses, mud hopper, mixing gun, mud weight scale and Marsh cones, mounted on double-axle trailer	1	18/6/84	10m brake air-line and 10m electrical cable for trailer damaged - replaced by Halco (delivered 12/1/85)
1.3	Atlas Copco XRH 350 Dd' compressor, powered by Deutz air-cooled V12 diesel engine, mounted on double-axle trailer, c/w all hoses and unions, and 84m of 3" eductor pipe and 3/4" air pipe	1	18/6/84	Rear light/ brake light assembly damaged - replaced by Halco (delivered 12/1/85). Small slash on tyre - tyre replacement waived
1.5	Drill pipe and collars			
	- drill pipe, 102 mm diam. x 6.1m long (4" x 20'), 104.6 kg weight per length, 2 3/8" API IF tool joints, c/w elevator and hoist plugs	43	23/7/84	262.3m total length
	- male and female pipe joint set	10	"	
	- drill pipe, 102 mm diam. x 4.0m long (4" x 13'), 73 kg weight per length,	3	"	12.0m total length. To be used as starter

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
	2 3/8" API IF tool joints			tubes
	- steel end caps for drill pipe	45 pairs	23/7/84	
	- 4 3/4" x 10' drill collars (+ steel protectors)	6	25/6/84	33.5m total length
	- 6 5/8" x 10' drill collars (+ steel protectors)	5	"	
	- elevator and hoist plugs for collars	1 lot	"	
1.6	Bits		25/6/84	
	- 14 3/4" tricone, soft	1		
	- 12 1/4" " "	2		
	- 9 5/8" " "	1		
	- 7 7/8" " "	1		
	- 5 7/8" " "	2		
	- 4 3/4" " "	2		
	- 14 3/4" " , m. hd	1		
	- 12 1/4" " "	2		
	- 9 5/8" " "	2		
	- 7 7/8" " "	2		
	- 5 7/8" " "	2		
	- 4 3/4" " "	2		
	- 3 1/2" API Reg. pin connectors	2		
	- Hughes SH 800 drag bit bodies	2		
	- ream. stabil., 15"	1		
	- " " 12 1/4"	2		
	- " " 9 7/8"	1		
	- " " 7 7/8"	2		
	- " " 5 7/8"	2		
	- drag blade set 15"	1		
	- " " " 12 1/4"	2		
	- " " " 9 7/8"	1		
	- " " " 7 7/8"	2		
	- " " " 5 7/8"	2		
	- bit overhaul equipment			
	-- mild steel electrodes	20 kg		
	-- hard facing electrodes	20 kg		
	-- Aracoy hard facing kit 1/8" tungsten carbide granules	20 kg		

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
1.7	Down-the-hole hammers and bits		25/6/84	
	- Halco Mach 60 valveless DHH, c/w shock absorber unit, drill pipe sub and hammer stripping kit	2		
	- DHH button bit 5 7/8"	6		
	- " " " 7 7/8"	3		
	- " " " 9 5/8"	2		
	- Halco custom-built grinding kit	1		
	- diamond-impregnated grinding cup	10		
1.8	Adaptors	1 lot	25/6/84	To join drill pipe to hammers, drill pipe to collars, drill pipe to drill-head drive, drill collars to drill-head drive, bits to drill pipe and bits to collars
1.9	Fishing tools and bailers		25/6/84	
	- tap type fishing tool for insertion in 4" od drill pipe	1		
	- tap type fishing tool for 4" casing	1		
	- tap type fishing tool for 6" casing	1		
	- overshot fishing tool for 4" od drill pipe	1		
	- 4" flat valve bailer	1		
	- 6" " " "	1		

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
1.10	Drilling chemicals		25/6/84	
	- 200 litre drums general purpose foam for DHH and rotary use (Drill Aid product)	20		1 drum punctured and contents lost during transit
	- 50 kg sacks commercial bentonite	200		
	- 25 kg sacks CMC Hi-Vis	15		
	- 25 kg sacks drilling fluid thinner (Q-Broxin, non tannin based)	40		
	- 10 kg plastic tub Drill Aid Custom Mud	80		

LOT 2 - MAJOR PLANT

Supplier - Hydreq Ltd

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
2.1	Support vehicle - Magirus Deutz model 160.19 4 x 4 flat-bed truck, powered by Deutz F6L413F diesel engine, fitted with HIAB model 650A cargo crane between cab and truck body	1	18/6/84	Batteries not new - however, replacement waived in lieu of reimbursement
2.2	Water tanker - Magirus Deutz model 160.19 4 x 4 truck, powered by Deutz model F6L413F diesel engine, fitted with Whale water tank and self-priming centrifugal pump (65.5 m3/h rating) c/w 15m 76 mm suction hose and strainer	1	18/6/84	Suction hose and pipework couplings mismatched - replacement fittings arrived 3/5/85
2.3	Water trailer, single axle, 3 m3 capacity	1	18/6/84	
2.4	Fuel trailer, double axle, 6000 litre capacity, fitted with a metered semi-rotary hand pump for dispensing	1	18/6/84	
2.5	Estate car - Peugeot 504 family estate powered by 2.5 litre diesel engine	1	13/8/84	Tool kit and clock missing - however, replacement waived in lieu reimbursement
2.6	Land Rover 109	2	18/6/84	
2.6A	- station wagon, powered by 2.25 l diesel engine	1		

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
2.6B	- hard top, (panel truck) powered by 2.25 l diesel engine	1	18/6/84	Both door locks broken - however, replacement waived in lieu reimbursement

LOT 3 - MINOR PLANT

Supplier - Hydreq Ltd

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
3.1	Generator - Atalanta type Victor 90 having an output of 7 kW powered by Lister type HR2 diesel engine	1	18/6/84	1 piston and cylinder head damaged - replacement parts arrived 3/5/85
3.1A	Tent lighting set	10	"	
3.1B	Raylor Highlight 30 floodlight towers, trailer mounted	2	"	
3.1C	Electric cable	150m	"	300m in contract document (150m stolen) - however, replacement waived in lieu re- imbursement
3.1D	Junction box	1	"	
3.2	Test pumps	2	22/4/85	
3.2A	- Mono model C32P631CE, design operating duty 10 m ³ /h at 80m total mano- metric head, powered by Lister LT1 diesel engine, c/w 50m 2 1/2" column pipe and drive shafts	1		
3.2B	- Mono model BH250B, design operating duty 50 m ³ /h at 80m total mano- metric head, powered by Lister TS3 diesel engine, c/w 50m 4" column pipe and drive shafts	1		Seized up - could not be rotated. Replacement deliv- ered 24/2/86
	- trailer, double axle	1	22/4/85	
	- 2 1/2" discharge valve	1	3/2/86	
	- 4" " "	1	5/2/86	
	- Ott KL50 electric water level measuring tape	2	"	

Tender Ref.Nr.	Item description	Quantity Delivered	Delivery Date	Remarks
3.3	Cutting and welding gear		18/6/84	
	- Armourweld welding set type DA112M, portable, powered by Lister ST1 diesel engine	1		
	- oxy/acetylene saffire c/w gauges, spanners and valve operating key	2		
	- empty gas cylinder	2		
3.4	Workshop tools		18/6/84	
	- bench type hand drill Facom 833A	1		
	- Bosch type industrial single speed grinder	1		
	- set of assorted pullers (U103)			
	- assorted brass drifts			
	- nut crackers (splitters)			
	- stud extractor (Rosenburg)			
	- set of files, 12", 10", c/w handles			
	- hacksaw, c/w blades			
	- battery charger			
	- hand-operated trolley jack 4 ton			
	- hand-operated trolley jack 6 ton			
	- heavy duty foot operated air pump			
	- electric soldering iron			
	- assorted hammers (claw, ball pein, sledge)			
	- small hand-operated forge			
	- electric side wheel grinder			
	- bench vice, 6"			
	- 1 tonne block and chain, 3m lift			
	- Snap-on tool kit			

LOT 4 - WELL CASING AND SCREEN

Supplier - Hydreq Ltd

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
4.2	Conductor casing 14" 1.5m	12	18-19/6/84	
4.3	" " 16" 1.5m	4	"	
4.5A	Steel casing 4" 6.0m	25	"	
4.5B	" " " 3.0m	15	"	
4.5C	" " " 1.5m	4	"	
4.6A	Steel casing 6" 6.0m	102	"	
4.6B	" " " 3.0m	60	"	
4.6C	" " " 1.5m	15	"	
4.7A	Steel casing 8" 6.0m	43	"	7 less than in contract document; their replacement waived in lieu reimbursement
4.7B	" " " 3.0m	30	"	
4.7C	" " " 1.5m	8	"	
4.8A	Steel casing 10" 6.0m	19	"	1 less than in contract document; its replacement waived in lieu reimbursement
4.8B	" " " 3.0m	8	"	
4.8C	" " " 1.5m	4	"	
4.9	Conductor casing 6 5/8" 3.0m length	10	"	
4.11A	PVC casing 4" 5.7m	43	22/6/84	
4.11B	" " " 3.0m	30	"	
4.11C	" " " 1.5m	10	"	
4.12A	PVC casing 6" 5.7m	33	"	
4.12B	" " " 3.0m	27	"	
4.12C	" " " 1.5m	20	"	
4.13A	PVC screen 1.0 mm slot 4" 5.7m	33	"	
4.13B	PVC screen 1.0 mm slot 4" 3.0m	27	"	

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
4.13C	PVC screen 1.0 mm slot 4" 1.5m	22	22/6/84	
4.14A	PVC screen 0.5 mm slot 4" 5.7m	10	"	
4.14B	PVC screen 0.5 mm slot 4" 3.0m	10	"	
4.14C	PVC screen 0.5 mm slot 4" 1.5m	9	"	
4.15A	PVC screen 1.0 mm slot 6" 5.7m	32	"	
4.15B	PVC screen 1.0 mm slot 6" 3.0m	22	"	
4.15C	PVC screen 1.0 mm slot 6" 1.5m	21	"	
4.16A	PVC screen 0.5 mm slot 6" 5.7m	2	"	
4.16B	PVC screen 0.5 mm slot 6" 3.0m	23	"	
4.16C	PVC screen 0.5 mm slot 6" 1.5m	5	"	
4.17A	PVC screen 1.0 mm slot 8" 5.7m	17	"	
4.17B	PVC screen 1.0 mm slot 8" 3.0m	13	"	
4.17C	PVC screen 1.0 mm slot 8" 1.5m	10	"	
4.18A	PVC screen 0.5 mm slot 8" 5.7m	4	"	
4.18B	PVC screen 0.5 mm slot 8" 3.0m	6	"	
4.18C	PVC screen 0.5 mm slot 8" 1.5m	6	"	
4.19A	PVC screen 1.0 mm slot 10" 5.7m	5	"	
4.19B	PVC screen 1.0 mm slot 10" 3.0m	5	"	
4.20A	PVC screen 0.75 mm slot 10" 5.7m	5	"	
4.20B	PVC screen 0.75 mm slot 10" 3.0m	5	"	
4.20C	PVC screen 0.75 mm slot 10" 1.5m	20	"	

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
4.21	Stainless steel screen 1.0 mm slot 4" 2.9m	14	18-19/6/84	
4.22	Stainless steel screen 1.0 mm slot 6" 2.9m	14	"	
4.23	Stainless steel screen 0.5 mm slot 6" 2.9m	7	"	
4.24A	Steel/plastic adaptor 4"	5	29/6/85	
4.24B	" " " 6"	10	"	
4.24C	" " " 8"	5	"	
4.24D	" " " 10"	5	"	
4.25	Centralisers (1 for 10m of each size) for plastic casing and screen	200	22/6/84	
4.26	Centralisers (1 for 10m of each size) for stain- less steel screen	10	"	
4.32	Mild steel reducer 8-10"	3	29/6/85	
4.33	" " " 8- 6"	5	"	
4.34	" " " 6- 4"	5	"	
4.35	Plastic reducer 10-8"	1	22/6/84	
4.36	" " 8-6"	1	"	
4.37	" " 6-4"	5	"	
4.38	Mild to stainless steel reducer 8-6"	5	29/6/85	
4.39	Mild to stainless steel reducer 6-4"	5	"	
4.40	Mild steel to plastic reducer 10-8"	1	"	
4.41	Steel casing (buttress- ended), 6 5/8" 6.0m	15	18-19/6/84	
4.42	Casing head to suit 6 5/8" od steel casing	1	29/6/85	
4.43	Casing drive shoe to suit 6 5/8" od steel casing	2	"	

LOT 5 - CAMPING EQUIPMENT

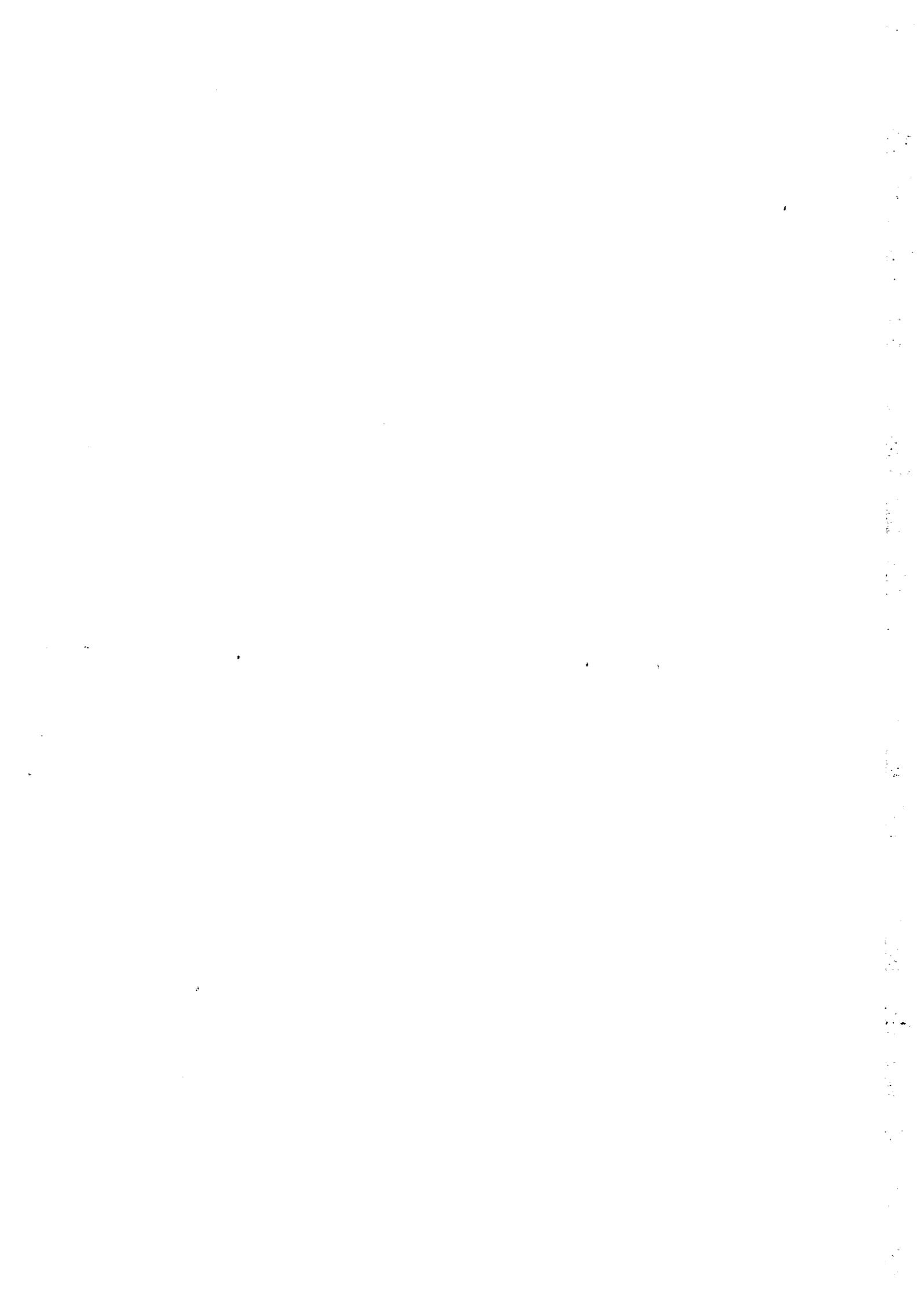
Supplier - Hydeq Ltd

Tender Ref.Nr.	Item Description	Quantity Delivered	Delivery Date	Remarks
5.1	Safari XXV heavy duty tent, c/w flysheet and extension	10	18/6/84	
5.2	Safari military model camp bed	7	"	10 in contract document
5.3	Camp chair	10	"	
5.4	Camp table	10	"	
5.5	Velor kerosene stove, 2 burners	4	"	
5.6	Steel jerrican, 5 gal, for fuel or oil	10	"	
5.7	Tilley Stormlight, kerosene	4	"	

GEOPHYSICAL EQUIPMENT

Nr.	Item Description	Quantity Delivered	Delivery Date	Supplier
1	McSeis-1500 seismic data acquisition system (enhancement unit and display/recording unit), 12 channel digital, 7.5 spacing electrode c/w 16 geophones, hammer switch with 3m cable and extension cable for hammer switch	1	13/8/84	Oyo Corp, Japan
2	SIE Geosource Portable Borehole Logger, model T450, c/w gamma ray, 15" caliper and SP-PR logging tools, winch unit model T106 (cable length 450m), T4 battery pack and charger, and T201 two pen recording system	1	"	Kalamos Co. Ltd., UK
3	ABEM Terrameter SAS 300 resistivity unit, c/w cable and electrodes	1	"	Craelius Co. Ltd., UK
4	BGS (Barker Geophysical Soundings)-256 offset sounding system	1	"	Geophysical Scientific Equipment Ltd., UK

APPENDIX B
DATA COLLECTION AND PRESENTATION FORMS



SAMPLE DESCRIPTION REFERENCE SHEET

 Boulders (blb) Cobbles (cab)	 Bouldery (blby)	 Gravel (gvl)	 Gravelly (gvly)
 Conglomerate (cong)	 Breccia (brc)	 Sand (sd)	 Sandy (sdy)
 Sandstone (ss)	 Arkosic (ak)	 Silt (slt)	 Silty (silty)
 Siltstone (slst)	 Clay (cl)	 Clayey (cly)	 Claystone (clst)
 Shale (sh)	 Shells	 Shelly	 Limestone (ls)
 Chalk (chk)	 Dolomite (dol)	 Marl (ml)	 Chert (ch)
 Halite (hal)	 Gypsum (gyp)	 Anhydrite (anhy)	 Basement Complex (undifferentiated)
 Igneous rock (undifferentiated)	 Granite (gnt)	 Diorite (drt)	 Schist (sch)
 Gneiss (gns)	 Migmatite (mgt)	 Quartzite (qtzt)	 FRDK Funny rock, don't know

coarse	cse	calcareous	calc	angular	ang
fine	fn	feldspathic	feldsp	rounded	rndd
medium	med	ferruginous	ferrug	sub-angular	sub-ang
		micaceous	mic	sub-rounded	sub-rndd

black	blk	washed cuttings	wc
blue	bl	unwashed cuttings	uwc
brown	brn		
cream	crm		
dark	dk		
green	gn		
grey	gy		
greyish	gysh		
light	lt		
off-white	off-wh		
orange	orng		
purple	ppl		
varicolored	varicol		
varigated	varig		
white	wh		
yellow	yl		

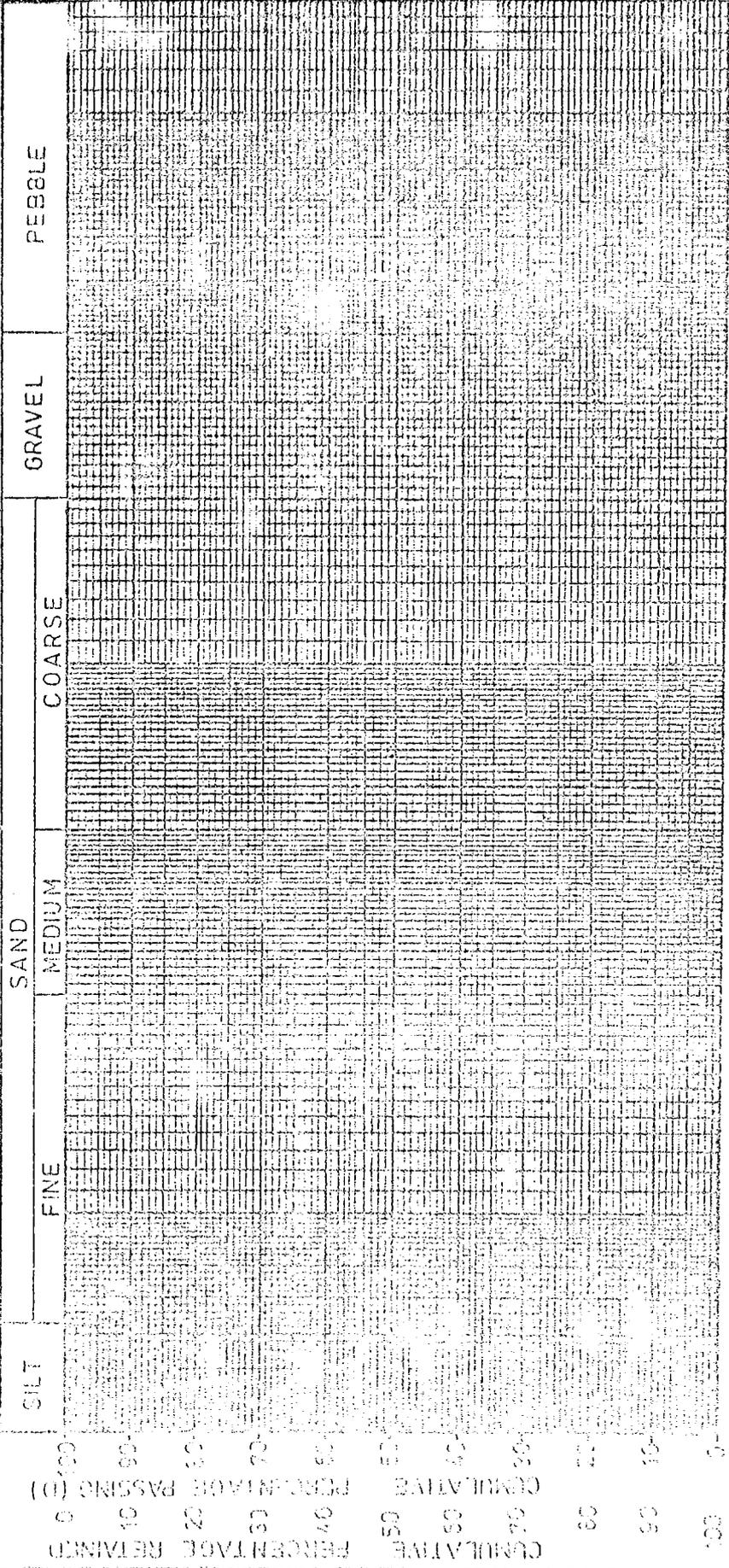
PARTICLE SIZE ANALYSIS

GROUNDWATER RESEARCH DEPARTMENT
 NATIONAL WATER RESOURCES INSTITUTE KADUNA

BOREHOLE NR :
 SAMPLE DEPTH(M) :
 ANALYSIS DATE :
 SIGNATURE :

D₁₀ =
 D₅₀ = $\frac{D_{50}}{D_{10}}$ =
 D₆₀ =

Sieve size (mm)	Cum. % retained	Sieve size (mm)	Cum. wt. retained	Cum. % retained
10-2		0.425		
6.7		0.300		
4.75		0.212		
3.35		0.150		
2.55		0.075		
1.18		Bottom pan		
0.600		Orig. wt.		



GWR/HG-10

GEOPHYSICAL LOGGING DATA

1. BOREHOLE DATA

Number Location

Drilled depth (driller).....m Drilled diameter (driller)..... in

Casing diameter, type, depth (driller).....

Drilling fluid type level (gl)..... m

2. ELECTRIC LOG

Run nr.	Date	Time start	Time finish	Datum	Log depth(m)	SP range	Resistivity range	Chart speed	Fluid EC(μ S/cm)

3. GAMMA LOG

Run nr.	Date	Time start	Time finish	Datum	Log depth(m)	TC	CPS range	Chart speed	Winch speed

4. CALIPER LOG

Run nr.	Date	Time start	Time finish	Datum	Log depth(m)	Chart speed

5. NOTES

PERFORMED BY:

PUMPING TEST DATA-FORM 1

Type of test :

Observations in Borehole Nr :

Type of Pump :

Pump setting :

Reference point description :

Height of pt. above gl. :

SWL ref. pt. :

time :

date :

Date	Clock time	t (min.)	WL (m)	s (m)	Discharge meas. data	Q (l/s)	Notes
		0					
		1					
		2					
		3					
		4					
		5					
		6					
		7					
		8					
		9					
		10					
		15					
		20					
		25					
		30					
		40					
		50					
		60					
		80					
		100					

PUMPING TEST DATA-FORM 2

Type of test : Constant Discharge

Observations in Borehole Nr :

SWL.ref. pt. :

time :

date :

Date	Clock time	t (min)	WL (m)	s (m)	Discharge meas. data	Q (L/s)	Notes
		120					
		140					
		160					
		180					
		200					
		220					
		240					
		270					
		300					
		330					
		360					
		390					
		420					
		450					
		480					
		540					
		600					
		660					
		720					
		780					
		840					
		900					

PUMPING TEST DATA-FORM 3

Type of test : Constant Discharge

Observations in Borehole Nr :

SWL.ref. pt.:

time :

date :

Date	Clock time	t (min)	WL (m)	s (m)	Discharge meas. data	Q (l/s)	Notes
		960					
		1020					
		1080					
		1200					
		1320					
		1440					
		1560					
		1680					
		1800					
		1920					
		2040					
		2160					
		2280					
		2400					
		2520					
		2640					
		2760					
		2880					
		3120					
		3360					
		3600					
		3840					

PUMPING TEST DATA - FORM 4

Type of test : Recovery

Observations in Borehole Nr :

Discharge : SWL ref. pt. : time : date :

Date	Clock time	t (min)	t' (min)	t _{1/2} '	WL (m)	s' (m)	Notes
			1				
			2				
			3				
			4				
			5				
			6				
			7				
			8				
			9				
			10				
			15				
			20				
			25				
			30				
			40				
			50				
			60				
			80				
			100				
			120				
			140				
			160				

PUMPING TEST DATA-FORM 5

Type of test : Recovery

Observations in Borehole Nr :

Discharge :

SWL ref pt.:

time :

date :

Date	Clock time	t (min)	t' (min)	t/t'	WL (m)	s' (m)	Notes
			180				
			200				
			220				
			240				
			270				
			300				
			330				
			360				
			390				
			420				
			450				
			480				
			540				
			600				
			660				
			720				
			780				
			840				
			900				
			960				
			1020				
			1080				

CHEMICAL ANALYSIS OF WATER SAMPLE

Location Borehole nr.
 Sample nr. Test section(m).....
 Date sample collected field analysis lab. analysis
 Field analysis by lab. analysis by.....

Total hardness mg/l CaCO₃
 Calcium hardness " " (×0.02 = meq/l)
 Magnesium hardness " " (×0.02 = meq/l)

Calcium (calcium hardness × 0.40) mg/l × 0.04990 meq/l
 Magnesium (magnesium hardness × 0.243) " × 0.08224 "
 Sodium " × 0.04350 "
 Potassium " × 0.02558 "
 Total cations "

Phenolphthalein alkalinity mg/l CaCO₃
 Total alkalinity " "
 Carbonate alkalinity " " (×0.02 = meq/l)
 Bicarbonate alkalinity " "

Carbonate (carbonate alkalinity × 0.60) mg/l × 0.03333 meq/l
 Bicarbonate (bicarbonate alkalinity × 0.61) " × 0.01639 "
 Sulphate " × 0.02082 "
 Chloride " × 0.02820 "
 Total anions "

Total cations and anions meq/l
 Error(difference/total) × 100 %

Total dissolved solids mg/l
 Electrolytic conductivity μmhos/cm. (temp. compensated)
 Water temperature (sampling point) °C
 pH

Silica mg/l
 Total iron "
 Nitrate nitrogen (N) "
 Nitrate (nitrate nitrogen × 4.4) "
 Fluoride

Notes / other analyses

COMPLETION REPORT-BOREHOLE NR.

1. GENERAL/SUMMARY

Research Project	:		
State	:	National Data Bank Nr.	:
Local Govt. Area	:	River Basin	:
Location	:		
Map Sheet Nr.	:	Sector	:
Longitude	:	Latitude	:
Rig	:	Rig on site	:
Depth drilled	:	Drilling method	:
Screen installed	:		
Reference Point	:	Open hole	:
Elevation Ref. Pt.	:	Source elev. data	:
SWL (date)	:	EC (date)	:

2. OBJECTIVES

3. PROGRAMME OF OPERATIONS

BOREHOLE NR: _____

Nr.

Operation(s)

Date

5. SAMPLING / AIRLIFT TESTS DURING DRILLING

BOREHOLE NR:

6. WELL DESIGN

7. WELL DEVELOPMENT

8 , PUMPING TESTS

9 . WATER QUALITY

BOREHOLE NR: _____

10 . CONCLUSIONS AND RECOMENDATIONS

COMPOSITE BORE LOG BOREHOLE NR:

GROUNDWATER RESEARCH DEPARTMENT
NATIONAL WATER RESOURCES INSTITUTE
PMB.2199, MANDO ROAD, KADUNA.

LOG COMPILED BY:

NATURAL GAMMA

SELF POTENTIAL - POINT RESISTIVITY

PROJECT : _____	LATITUDE : _____
LOCATION : _____	ELEV. GL. : _____
LONGITUDE : _____	
DRILLING PERIOD: _____	

SITE PLAN

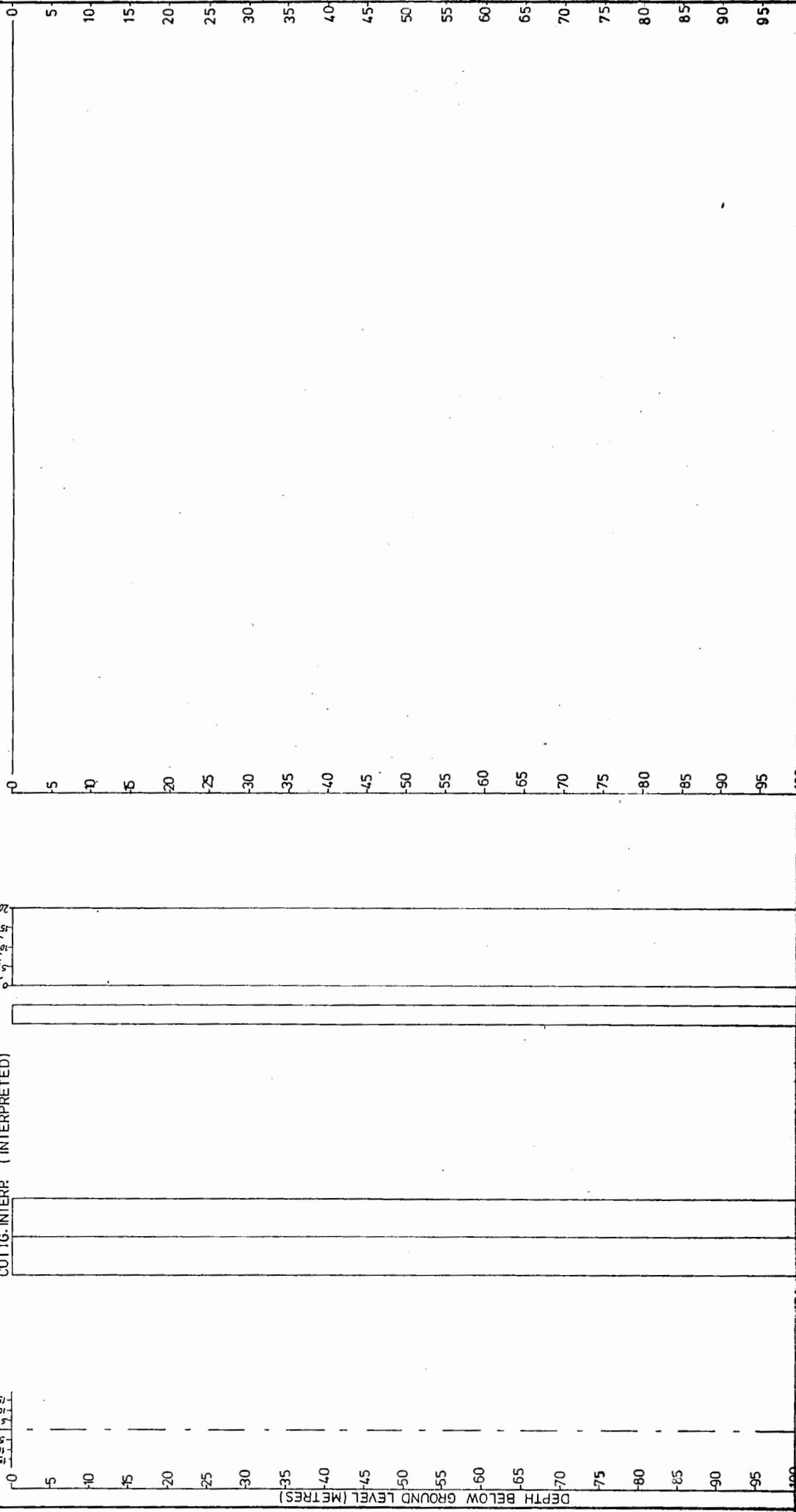
LOCATION SKETCH

WELL-HEAD CONFIGURATION

FMT PENETRATION DRILLING DATA

GRAPHIC LOG LITHOLOGY
CUTTG. INTERR. (INTERPRETED)

COMPLETED DESIGN



HYG**INFORMATION SHEET FOR WELL / BOREHOLE**

GWR / HG - 08

GROUNDWATER RESEARCH DEPARTMENT NATIONAL WATER RESOURCES INSTITUTE		1 National data bank nr:
Location \uparrow N		2 Local name / nr:
Site plan / well head details \uparrow N		3 Village / town:
		4 State:
		5 River basin:
		6 Map sheet nr: Sector:
		7 Longitude:
		8 Latitude:
		9 Owner:
		10 Purpose:
		11 Current condition:
		12 Ref. point:
		13 Ref. point elevation:
		14 Datum:
Construction details		15 Drilled by:
17 Drilling method:		16 Construction period:
19 Drilled diam. in from to m		18 Total depth m
20 diam. in from to m		23 Casing diam. in from to m
21 diam. in from to m		24 diam. in from to m
22 diam. in from to m		25 diam. in from to m
27 Screen type:		26 Casing type:
29 Screen diam. in from to m		28 Development period: hrs. method:
30 diam. in from to m		32 Formation grading: D ₅₀ mm
31 diam. in from to m		32 slot size: mm D ₆₀ mm D ₁₀ mm UC
34 Geophysical logs:		33 Gravel pack grading: mm
36 Data source:		35 Performed by:
Formation/Lithology		37 Aquifer formation:
38 from to m		47 Commissioning pumping test
39 from to m		47 Performed by:
40 from to m		48 Date:
41 from to m		49 Duration hrs.
42 from to m		50 Discharge: m ³ /h
43 from to m		51 SWL m below R.P.
44 from to m		52 DWL m below R.P.
45 from to m		53 Specific capacity: m ³ /h/m
46 Data source:		54 Transmissivity: m ² /day
Hydrochemistry Field		55 Screen length: m
57 Temp °C		56 Data source:
58 E.C. micromhos/cm		59 pH
60 HCO ₃ mg/l		61 CO ₃ mg/l
62 CO ₂ mg/l		63 D.O. mg/l
64 H ₂ S mg/l		65 Fe mg/l.
66 Mn mg/l		67 COL Hazem
68 Turb FTU		69 Others:
70 Sample type		71 Remarks:
72 Date		73 E.C. micromhos/cm
74 TDS mg/l		75 pH
76 Si mg/l		77 S mg/l.
78 Ca mg/l		79 Mg mg/l
80 Na mg/l		81 K mg/l
82 Total:		83 CO ₃ mg/l
84 HCO ₃ mg/l		85 SO ₄ mg/l
86 Cl mg/l		87 NO ₃ mg/l
88 F mg/l		89 Total:
90 Data source:		91 Remarks:
92 Date:		93 Pump make:
94 Type:		95 Set at m. below R.P.
96 Rising main diam. in		97 Prime mover make:
98 Type:		99 Estimated discharge: m ³ /h
100 Method of measurement:		101 Average use per day: hrs
102 Service area:		103 Average use per year: months
104 Data source:		105 Remarks:
106 Date:		107 Data source:
108 S.W.L. m. below RP. Date:		109 SWL. m. below RP. Date:
110 SWL. m. below RP. Date:		111 Water level recorder make:
112 Condition:		113 Reading m. below RP. Date:
114 Remarks:		
115 Inventoried by:		116 Date visited:

VERTICAL ELECTRICAL SOUNDING (OFFSET WENNER ARRAY)
Field Sheet

No. _____

LOCATION <small>sketch on reverse</small>											
Orientation											
Switch position	Cycles	Range (ohms)	Current (mA)	Reading (ohms)		Switch position	Cycles	Range (ohms)	Current (mA)	Reading (ohms)	
1	A					6	A				
	C						C				
	D1						D1				
	D2						D2				
	B						B				
2	A					7	A				
	C						C				
	D1						D1				
	D2						D2				
	B						B				
3	A					8	A				
	C						C				
	D1						D1				
	D2						D2				
	B						B				
4	A					9	A				
	C						C				
	D1						D1				
	D2						D2				
	B						B				
5	A					10	A				
	C						C				
	D1						D1				
	D2						D2				
	B						B				
Tripotential check (B+C)/A = 1 ± 0.05		1	2	3	4	5	6	7	8	9	10
Geometric factor K											
K(D1+D2)/2											
COMMENTS											
Operator _____										/ /19	

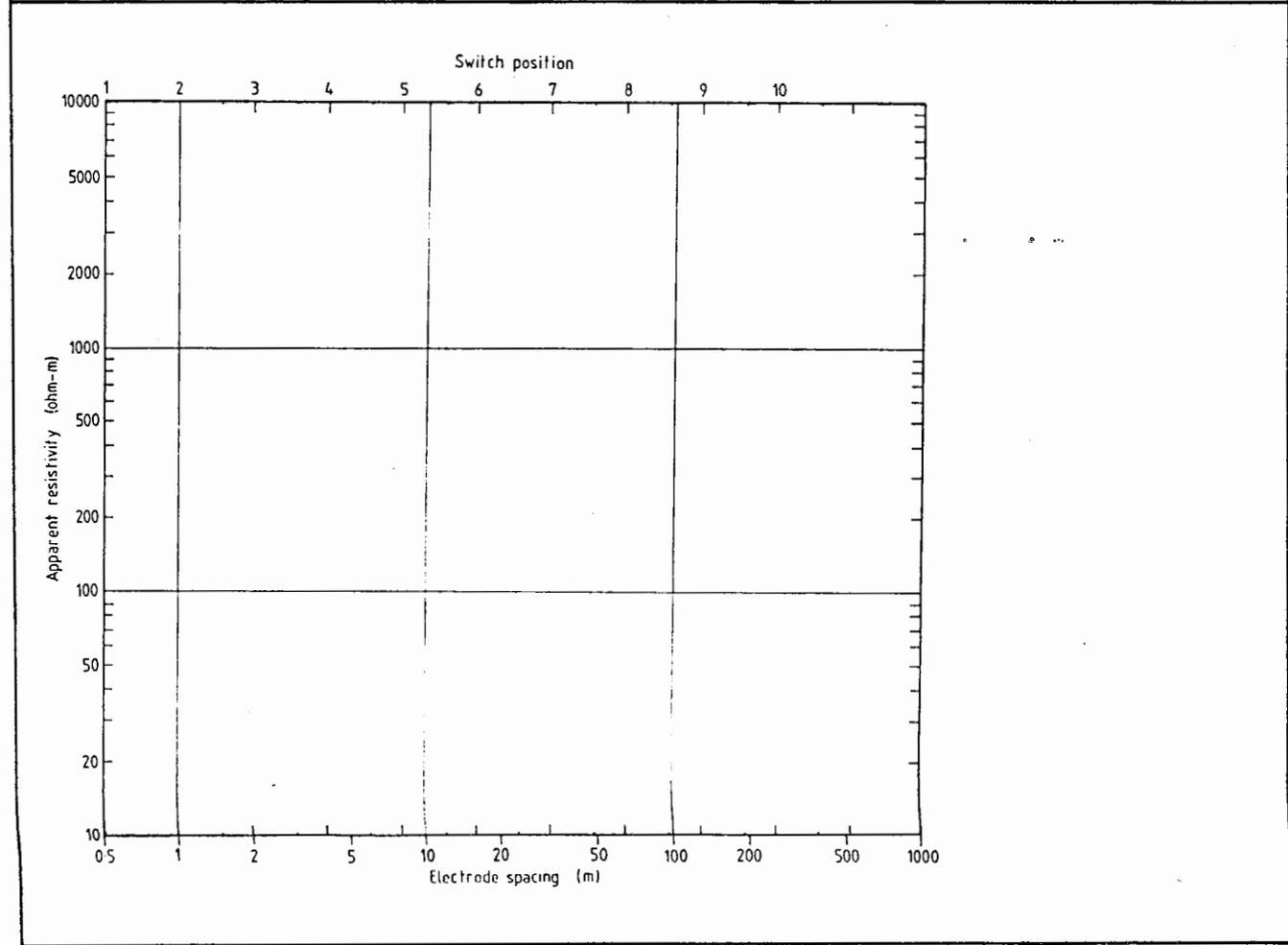
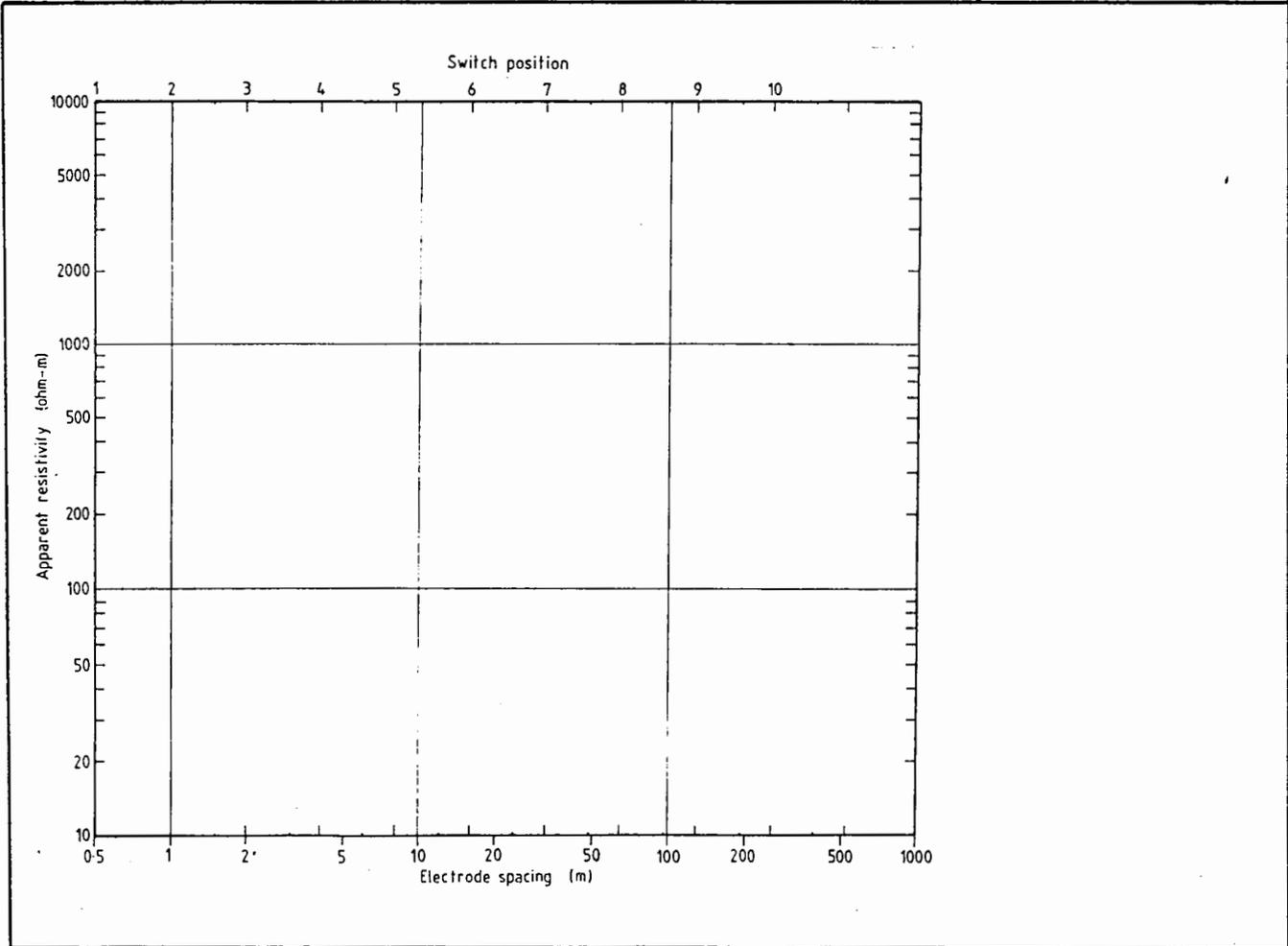
Groundwater Research Department

National Water Resources Institute

Kaduna

OFFSET WENNER ARRAY

Field Plot of Sounding Curves

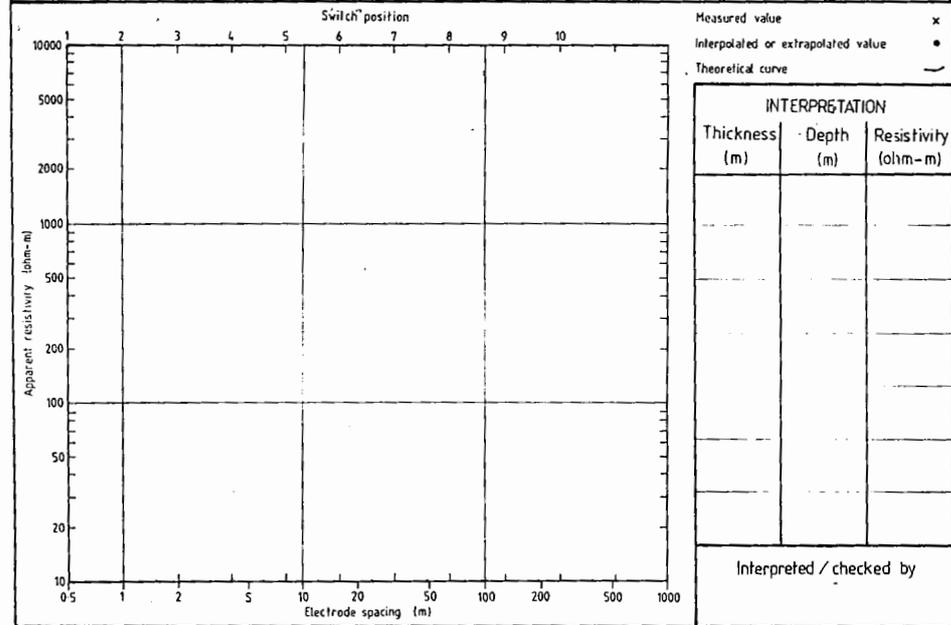


VERTICAL ELECTRICAL SOUNDING (OFFSET WENNER ARRAY)
Data Reduction & Interpretation

No. _____

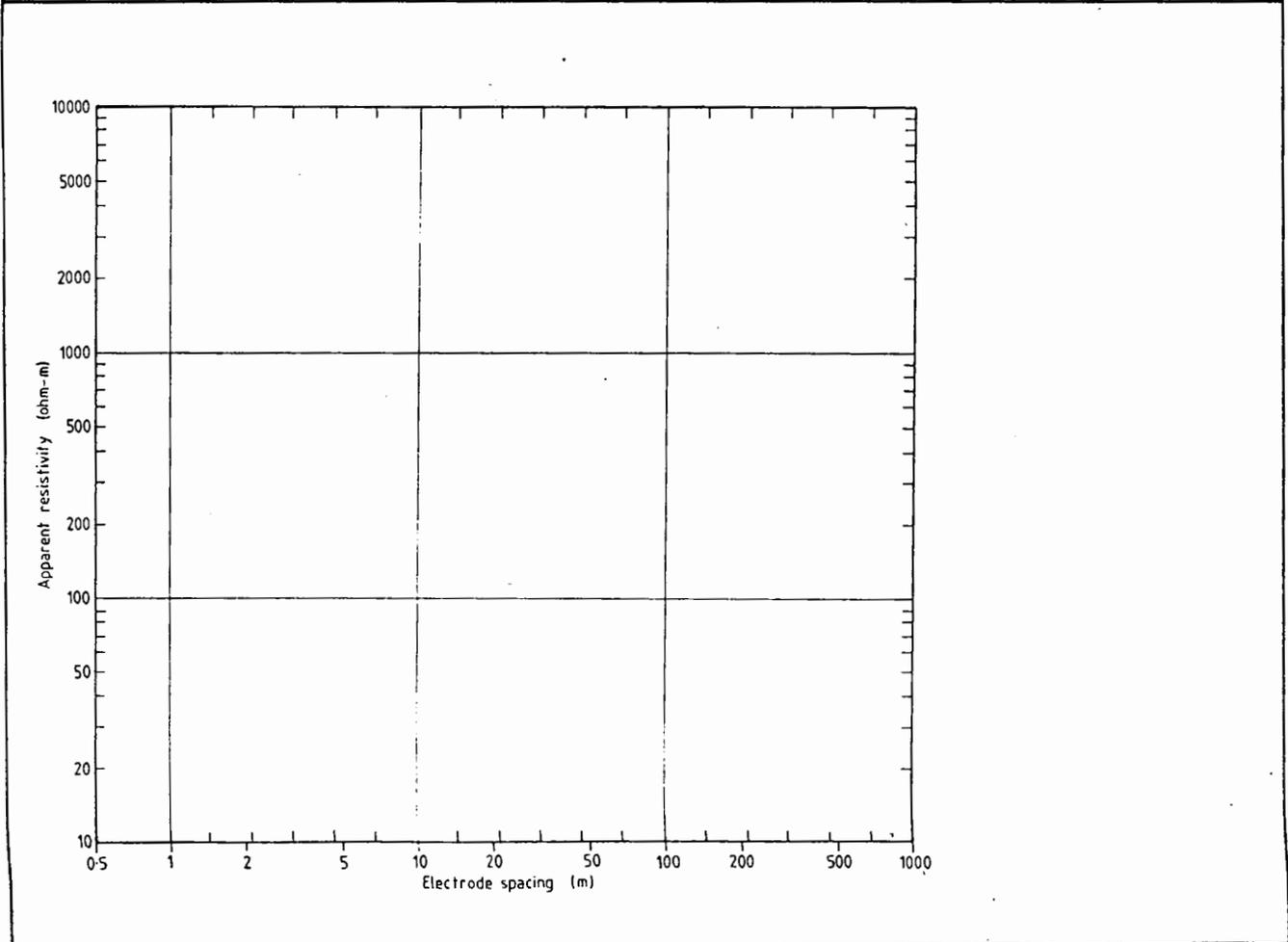
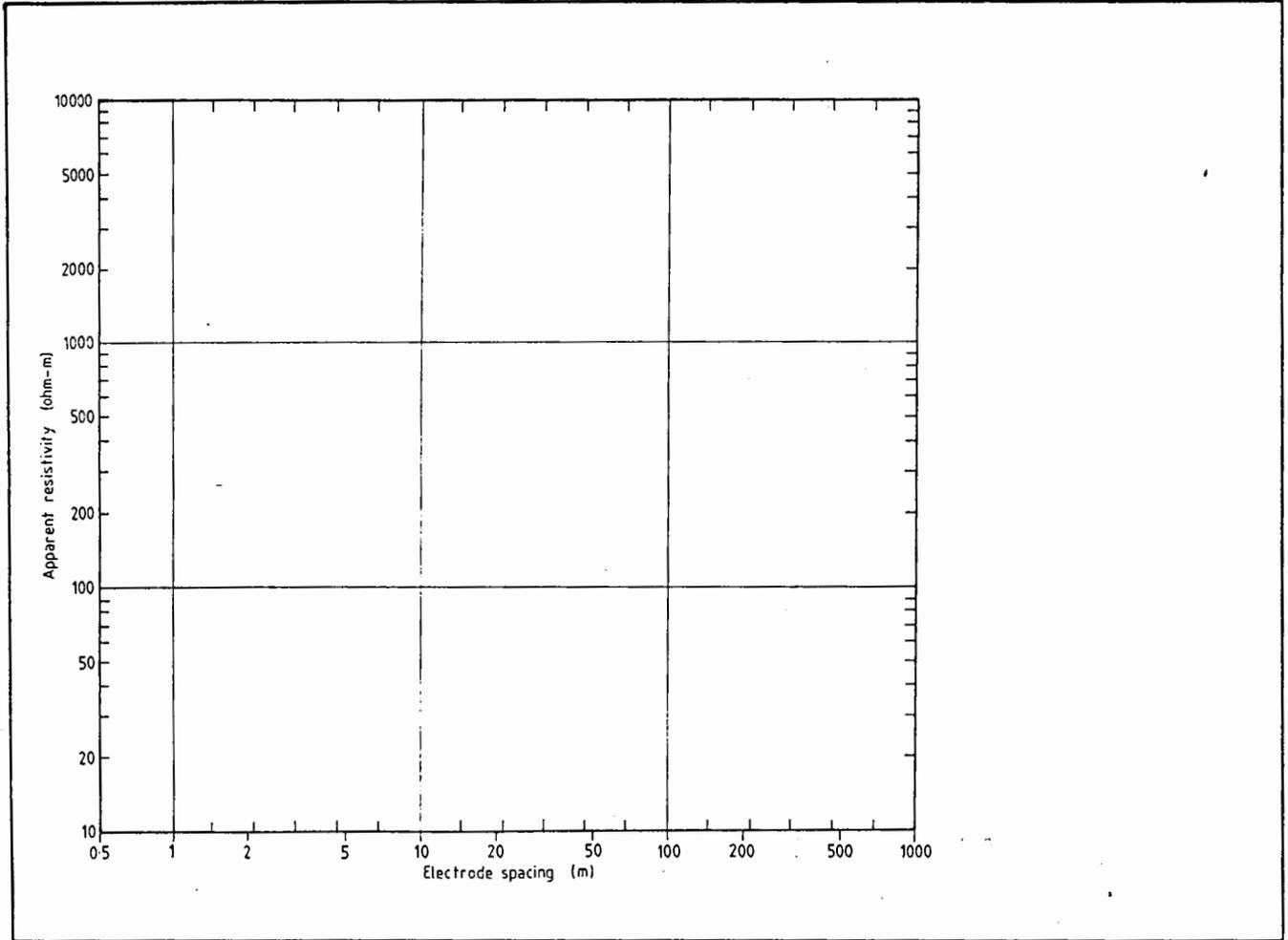
LOCATION _____

Switch position	Errors (%)			Electrode spacing (m)	Apparent resistivity (ohm-m)	Electrode spacing (m)	Apparent resistivity (ohm-m)
	observed	offset	lateral				
1				0.5			
2				1		1.5	
3				2		3	
4				4		6	
5				8		12	
6				16		24	
7				32		48	
8				64		96	
9				128		192	
10				256		384	
R. m. s. errors				512			



COMMENTS _____

SCHLUMBERGER ARRAY
Field Plot of Sounding Curves



SEISMIC REFRACTION SURVEY

FIELD SHEET

No. _____

Location: _____

SKETCH MAP

SHOT POINT 1 2

DISTANCE

Geophone	1	2	3	4	5	6	7	8	9	10	11	12
----------	---	---	---	---	---	---	---	---	---	----	----	----

Distance												
----------	--	--	--	--	--	--	--	--	--	--	--	--

ARRIVAL TIMES

Shot 1												
--------	--	--	--	--	--	--	--	--	--	--	--	--

Point 2												
---------	--	--	--	--	--	--	--	--	--	--	--	--

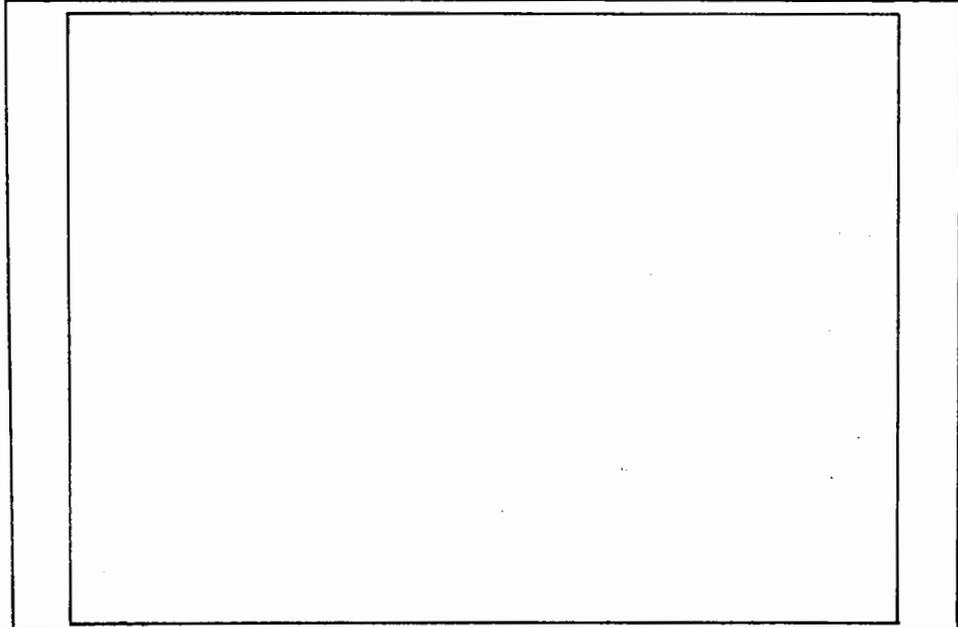
Comment : _____

SEISMIC REFRACTION SURVEY

Data Computation & Interpretation

No.

Location:



SHOT POINT	1	2
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Velocity & Int. Time	depth	depth	avg. depth(m)
V1			
Ti1			
V2			
Ti2			
V3			

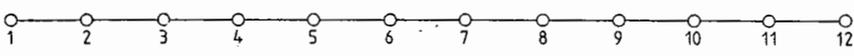
Comment :

SEISMIC REFRACTION SPREAD

No.
/ /19

LOCATION _____	
Sketch	

field sheet / fair copy

SPREAD


Orientation: _____ Geophone spacings _____ m. except as shown

SHOTPOINTS : Locations and ground conditions

FILTERS : Low pass in out Notch in out

COMMENTS _____

Operator _____

APPENDIX C

SPARE PART REQUIREMENTS

SPARE PART LISTS

List	Unit	Qty	Serial nr(s)	Remarks
A	Halco Varitork V866 drilling rig (except power pack)	1		
B	Halco Mach 60 hammer and schock absorber units	2		
C	IVECO Magrius Deutz trucks	3		
	- 320M33AK/F8L413F engine?		4900 140 433(chassis) 6595 810 (engine))Rig truck)
	- 160.196/F6L413F engine		4900 148 939(chassis) 6712 296 (engine))Flat-bed)truck
	- 160.196/F6L413F engine		4900 154 292(chassis) 6842 149 (engine))Water tanker)
D	Whale tank and pumping unit	1	PN.108934 (chassis nr.54292)	
E	HIAB 650 cargo crane	1	112056	manufact.nr.
F	Conrad CD 7580/75 mud pump (except power pack)	1	7580028	Order nr. 0631400
G	Deutz F6L912 diesel engines	2	6912143 6568711	Rig power pack Mud pump power pack
H	Atlas Copco XRH 350 Dd compressor	1	805252	Engine serial 6727508
I	Western trailer and fuel dispensing unit	2		
J	Peugeot 504 F40 diesel family estate	1	389 4028 (VIN)	
K	Land Rover III 109 2 1/4 litre diesel	2	175 171(chassis) 366 846 91A(engine) 175 121(chassis) 366 530 11A(engine))Station)wagon)Hardtop)
L	Atlanta Victor 90 generator set (except engine)	1	6930-1	

List Unit	Qty	Serial nr(s)	Remarks
M	2		
Monolift pump sets (except engines)			
- pump type C32 P631 CE			
- pump type BH 250 D		C10158	
- drive head type C32 DR 21		32/132134	
- drive head type C32 DS 21		32/132135	
N	1	832288/2	
Armourweld DA 112M welding set (except engine)			
P	4		
Lister diesel engines			
- HR2	1		Powers generator
- ST1	2	3211313ST1A12	Powers P631 pump
		3303432ST1C20	Powers welding generator
- TS3	1	3400464TS3A01	Powers BH250D pump
Q			
Geophysical and hydrogeological equipment			

In lists * indicates a newly specified part

LIST A

SPARES FOR HALCO VARITORK V866 DRILLING RIG

Serial Nr.

Item	Part nr.	Description	Qty
1. Mast Unit			
A 1	200442	Driveshaft	1
A 2	200419	M.T.A. Clamp	1
A 3	200444	Sliding Hub	1
A 4	200420	Fixed Hub	1
A 5	748076	Oil Seal	2
A 6	719063	Oil Seal	3
A 7	768088	O Rings	3
A 8	768089	O Rings	3
A 9	768096	O Rings	2
A 10	201411	Sealing Collar	2
A 11	719072	Air Seals	4
A 12	713012	V Belts Cat Pump	2
A 13	200409	Split Clamp	1
A 14	200422	End Cap	1
A 15	730015	Bolt 10 x 60	6
A 16	726398	Seal Kit (Drilling Manifold) for 726392	1
A 17	726372	Seal Kit (Drilling Manifold) for 726458	1
A 18	726309	Seal Kit (Drilling Manifold) for 726306	1
A 19	726415	Seal Kit (Drilling Manifold) for 726294	1
A 20	726313	Seal Kit (Drilling Manifold) for 726305	1
A 21	726333	Seal Kit (Drilling Manifold) for 726314	1
A 22	726318	Seal Kit (Drilling Manifold) for 726401/304/315	3
A 23	760011	Spring	1
A 24	760077	Spring	1
A 25	200401	Shims .002	3
A 26	200402	Shims .005	3
A 27	200403	Shims .010	3
A 28	200404	Shims .015	3
A 29	768085	O Ring	2
A 30	768033	O Ring	1
A 31	768030	O Ring	2
A 32	768016	O Ring	2
A 33	782138	Timer 24V	1
A 34	791288	Solenoid Air Valve 24V	1
A 35	791084	Pressure Regulator	1
A 36	781081	Pressure Gauge	1
A 37	726294	Servo Control Valve	1

Item	Part nr.	Description	Qty
A 38	768032	O ring	2
A 39	714556	Repair kit - piston assembly	1
A 40	714557	Repair kit - short cup	2
A 41	714558	Repair kit - discharge valve	1
A 42	714559	Seal kit	1
A 43	719066	Seal	1
A 44	760013	Spring	1
A 45	760020	Spring	1
A 46	714560	Seal kit - cat pump sleeves and seal kit	1
A 47	714233	Seal kit - pulse pump	1
A 48	726118	Lock valve complete	1
A 49	747020	O ring - lock valve	4
A 50	747016	O ring - lock valve	4
A 51	747017	O ring - lock valve	2
A 52	726419	Locking cart. ass.	2
A 53	726335	Seal kit	1
A 54	726426	1/2" check valve	1
A 55	781080	Hyd. Gauge 0-20 bar	1
A 56	781083	Hyd. Gauge 0-35 bar	1
A 57	781077	Water Ind. Bowl	2
A 58	791287	Seal kit for 791285	1
A 59	791028	Miniseal Valve	1
A 60	772038	1" couplings	4
A 61	772039	3/4" Coupling	4
A 62	772040	1/2" Coupling	4
A 63	772041	3/8" Coupling	2
A 64	772042	1/4" Coupling	2
A 65	773130	1" x 90o swivel swept bend	2
A 66	773129	1" x 45o " " "	2
A 67	773096	3/4" x 90o " " "	2
A 68	773098	3/4" x 45o " " "	2
A 69	773127	1/2" x 90o " " "	2
A 70	773095	3/8" x 90o " forged elbow	1
A 71	773100	1/4" x 90o " " "	1
A 72	096028	1" hydraulic hose SAE 100 R2AT	30m
A 73	096027	3/4" " " " " R2AT	20m
A 74	096026	1/2" " " " " R1T	20m
A 75	096025	3/8" " " " " R1T	20m
A 76	096024	1/4" " " " " R1T	20m
A 77	706242	Seal kit for deed ram	1
A 78	706243	Seal kit for mast elevating ram	1
A 79	706344	Seal kit for jack leg ram	1
A 80	706236	Seal kit for breakout ram	1
A 81	706312	Seal kit for swing out ram	1

2. Sledge Slide

A 82	201947	Bearing slide	2
A 83	201624	Shim spacer	8
A 84	201625	Spacer	4

Item	Part nr.	Description	Qty
A 85	201627	Slide Strip	4
A 86	096015	1/4" Nylon pipe	15m
A 87	096019	5/16" Nylon pipe	15m
A 88	799088	1/4" Tubing sleeve	10
A 89	799083	1/4" " nut	10
A 90	799090	5/16" " sleeve	10
A 91	799085	5/16" " nut	10
A 92	097017	Copperslip 4 kgs	1

3. Power Pack Hydraulics

A 93	716039	Strainer	2
A 94	716040	"	1
A 95	716018	Filter - Hand Pump	1
A 96	716051	Filter - Linde	10
A 97	716044	" - Pressure large	9
A 98	716043	" - small	3
A 99	761029	Tacho cable	2
A100	781039	Tacho	1
A101	761030	Speed Control cable	1
A102	717145	Air filter element (16 cell)	6
A103	781075	Hyd. Temp. gauge	1

4. Splitter Gearbox

A104	714120	Seal Kit for 714116	1
A105	714388	" " " 714115	1
A106	774131	Linde pump special hose	1
A107	774132	" " " "	1

5. Mud Swivel

A108*	75001	Mud swivel complete	2
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LIST B

SPARES FOR HALCO MACH 60 HAMMER AND SHOCK ABSORBER UNITS

Serial Nrs.

Item	Part Nr.	Description	Qty
B 1	601573	Bit Retaining ring assy.	2
B 2	601562	Make up spring	2
B 3	601563	Chuck Spacer	2
B 4	601554	Piston	2
B 5	601556	Chuck	2
B 6	601590	Make up Shim	8
B 7	601568	Body - foot valve pressing tool	1
B 8	601569	Pusher-foot valve pressing tool	1
B 9	601570	Foot Valve	6
B10	747038	O Ring (N.R.V.)	3
B11	768055	O Ring (fixed valve)	3
B12	760079	N.R. Valve spring	2
B13	707009	Rubber Spring	2
B14	747065	O Ring	1
B15	785003	Back Up Washers	2

LIST C

SPARES FOR IVECO MAGIRUS DEUTZ TRUCKS

Item	Part Nr.	Description	Qty
1.	Model 320 M33 AK (chassis nr. 4900 140 433; engine nr. 6595610)		
C 1	01173672	Temp Trans	1
C 2	01231567	Bearing	1
C 3	01242882	Motor	1
C 4	01260841	Filter	2
C 5	01287477	Fuel Lift Pump	1
C 6	01298826	Solenoid	1
C 7	01304985	O Ring	2
C 8	01306482	Brush	1
C 9	01307672	Shaft	1
C 10	01307672	Brush Set	1
C 11	02143294	Connector	2
C 12	02145079	Injector	4
C 13	02148228	Thermostat	2
C 14	02165049	Filter	6
C 15	02233216	Thermostat	1
C 16	02402876	Washer	16
C 17	02404843	Pipe	1
C 18	02406368	Oil Switch	1
C 19	02416643	Mag Valve	1
C 20	02417109	O Ring	1
C 21	02417871	Gasket	1
C 22	02417875	V Belt Set	2
C 23	02418366	Seal	3
C 24	02418444	Piston	1
C 25	01102551	Bulb	10
C 26	01103177	Fuse	10
C 27	01121329	Fuse	9
C 28	01121330	Fuse	9
C 29	01121332	Fuse	5
C 30	01121371	Bulb	5
C 31	01121428	Bulb	5
C 32	01122281	Ball Bearing	2
C 33	01123742	Hex Bolt	4
C 34	01127781	Bulb	5
C 35	01160243	Filter	40
C 36	01161249	O Rings	4
C 37	01163141	Relay	1
C 38	01163618	O Rings	1
C 39	01164294	O Ring	4
C 40	01164594	Oil Seal	1
C 41	01164648	Relay	4
C 42	01166035	O Ring	4
C 43	01166041	O Ring	1
C 44	01170540	O Ring	16
C 45	01171681	Alternator Assy.	1
C 46	01171955	Starter Motor	1
C 47	01173430	Filter	10

Item	Part nr.	Description	Qty
C 48	01173470	Contact Maker	1
C 49	02460863	Bracket	2
C 50	02475869	Wheel Stud	10
C 51	02475977	Oil Seal	2
C 52	02476077	Wheel Stud	10
C 53	02478435	Gasket	4
C 54	02512474	Shock Absorber	2
C 55	02513651	Gasket	16
C 56	02605062	Lamp	1
C 57	02633999	Flasher Lamp	2
C 58	02966261	Filter Element	4
C 59	02985032	Gear	1
C 60	03361218	Gasket	8
C 61	03361699	GKT	1
C 62	03423915	Spring	1
C 63	03435124	Switch	2
C 64	04144843	Seal	2
C 65	04144856	Seal	1
C 66	04454885	Retainer	1
C 67	04463196	Hose	1
C 68	04463198	Hose	1
C 69	04463201	Hose	1
C 70	04463201	Hose	2
C 71	04463202	Hose	2
C 72	04464486	Cylinder	2
C 73	04470743	Universal Joint	2
C 74	04501331	Hose	1
C 75	04675213	Regulator	2
C 76	04739151	Centre Plate	1
C 77	07980406	Kit	2
C 78	07980407	Kit	2
C 79	42001982	Seal	12
C 80	42002473	Brg	1
C 81	42009783	Pin	6
C 82	42013378	Relay	2
C 83	42014266	Lining	4
C 84	42014895	Rivet	200
C 85	42043436	Hand Pump	1
C 86	42024846	Switch	2
C 87	42026740	Switch	1
C 88	42030595	Cylinder	2
C 89	42033029	Adaptor	2
C 90	42033466	Leaf	1
C 91	42033467	Leaf	1
C 92	42037581	Seal	4
C 93	42037582	Seal	4
C 94	42037594	Seal Ring	4
C 95	42042638	Cylinder	2
C 96	42052729	Cylinder	1
C 97	42489502	Kit	1
C 98	42490587	Cover	4
C 99	42491638	Ball Joint	1

Item	Part nr.	Description	Qty
C100	42491950	Kit	2
C101	42159086	Pipe	1
C102	02911554	Eng.Gasket Set	1
C103	02911550	Head Gasket Set	2

2. Model 160.19 with Deutz F6L413F diesel engine
(chassis nr.4900 148 939; engine nr. 6712296)
(chassis nr.4900 154 292; engine nr. 6842149)

C104	02402812	Gasket	6
C105	01169577	O Ring	6
C106	01173430	Filter	12
C107	01287477	Fuel lift pump	1
C108	S/01287477	Surcharge	1
C109	03476293	Nut	1
C110	01160243	Filter	8
C111	02411201	Fuel line	1
C112	02417875	V belt set	2
C113	01163755	Alternator assy.	1
C114	S/01163755	Surcharge	1
C115	01168301	V belt	2
C116	02487687	Shock absorber	2
C117	02475977	Oil Seal	2
C118	02478435	Gasket	4
C119	42014266	Lining	8
C120	42014895	Rivet	120
C121	42037581	Seal	2
C122	42037582	Seal	2
C123	42061628	Rubber Ring	4
C124	42050056	Hose	2
C125	04463201	Hose	4
C126	04463202	Hose	4
C127	04463200	Hose	1
C128	02165044	Element	1
C129	02415950	Filter	1
C130	02477836	Clutch Disc	1
C131	S/02477936	Surcharge	1
C132	02479001	Master Cylinder	1
C133	24003473	Bearing	1
C134	04501331	Hose	2
C135	01266137	Hose	2
C136	01260841	Filter	1
C137	01290551	Seal	6
C138	01164648	Relay	1
C139	02480072	Relay	1
C140	01121371	Bulb	5
C141	01102551	Bulb	10
C142	01127781	Bulb	10
C143	01121428	Bulb	10
C144	01121412	Bulb	10
C145	01121328	Fuse	30
C146	01121330	Fuse	30

Item	Part nr.	Description	Qty
C147	42040784	Spring	2
C148	04470743	Universal joint	1
C149	42484668	Sealing Set	1
C150	42484614	Sealing Set	1
C151	42009785	Pin	4
C152	42037581	Seal	4
C153	42037582	Seal	4
C154	02476812	Bearing	4
C155	02476147	Bearing	4
C156	01268809	Bearing	4
C157	02417204	Ring Set	6
C158	04143187	Piston	2
C159	02411201	Fuel Line	1
C160	01171681	Alternator Assembly	1
C161	S/01171681	Surcharge	1
C162	42037581	Seal	6
C163	04459737	Plate	1
C164	04459140	Cylinder	1
C165	01121329	Fuse	30
C166	42040784	Spring	2
C167	42042293	Spring	2
C168	42484668	Sealing Set	1
C169	42484614	Sealing Set	1
C170	42037582	Seal	4
C171	02476147	Bearing	2

LIST D

SPARES FOR WHALE TANK AND PUMPING UNIT

Serial Nr. PN.108934 (chassis nr.54292)

Item	Part Nr.	Description	Qty
D 1	4410100	18" Manhole Seal	1
D 2	1413114	Sightglass Tube x 2m	1
D 3	1210141	3" Saunders Valve Ball	4
D 4	1210142	3" Saunders Valve Seals	8
D 5	1221112	6" Reiss Valve Packing Kit	1
D 6	1313106	3" Bauer Sealing Rings	8
D 7	1313118	6" Bauer Sealing Rings	8
D 8	-	Strainer Element 3"	2
D 9	1112104	PTO Shaft UJ Kit	4
D10	1112105	Shear Bolts	8
D11	1812138	Air Fitting Straight Connection	5
D12	1812130	Air Fitting Nuts	20
D13	1812131	Air Fitting Olives	40
D14	-	Air pipe 5/16" dia	15m

LIST E

SPARES FOR HIAB 650A CARGO CRANE

Serial Nr. 112056 (manufacture's nr.)

Item	Part Nr.	Description	Qty
E 1	50182	LP Hose	4m
E 2	49732	Gauge	1
E 3	50005	Adaptor	1
E 4	304 1832	Cushion	2
E 5	304 5838	Pin	2
E 6	304 9311	Pad	2
E 7	305 8123	Check Valve	2
E 8	308 0340	Sealing	4
E 9	308 0374	Link	4
E10	308 3802	Spindle	1
E11	308 5384	Swivel	2
E12	314 3252	Handle	2
E13	315 4921	Lock Washer	2
E14	315 5021	Lock Wire	4
E15	315 8802	Cover	2
E16	316 7011	Spindle	1
E17	316 7020	Spindle	1
E18	317 7051	Spindle	1
E19	317 1078	Spindle	1
E20	318 2801	Guide	1
E21	318 2959	Guide	2
E22	330 0307	Seal Kit outer boom	1
E23	330 0595	Seal Kit ext boom	1
E24	330 0625	Seal Kit outrigger leg	2
E25	330 0749	Seal Kit inner boom	1
E26	390 5268	Support	2
E27	390 9930	Link	2
E28	346 1424	Sleeve	4
E29	390 5853	Bolt	6
E30	990 3097	Pin	2
E31	990 4468	Ball	2
E32	990 6185	Greaser	2
E33	990 7921	Greaser	2
E34	991 5150	Pin	2
E35	991 6342	Hose	2
E36	991 7411	Seal	2
E37	992 1117	Hose	2
E38	992 1419	O ring	10
E39	993 3042	Hose	2
E40	993 3301	O ring	10
E41	993 3310	O ring	10
E42	993 3344	O ring	5
E43	993 3379	O ring	5
E44	993 7471	Bush	2
E45	993 7498	Bush	2
E46	994 9305	Clip	2
E47	995 2331	Hose	2
E48	996 1941	Element	2

LIST F

SPARES FOR CONRAD CD 7580/75 MUD PUMP

Serial Nr.7580028 (order nr.0631400)

Item	Part Nr.	Description	Qty
F 1	9.9905.264	Stuffing Boxes	12 sets
F 2	9.9905313	Piston Rods	6
F 3	9.9905324	Self Locking Nuts	6
F 3A		Washers 34mm	6
F 4	9.9920.654	Valve Cover Gaskets	8
F 5	9.9920.655	Cylinder head gaskets	2
F 6	9.9905.325	Fluid valve assemblies	8
F 7	9.9905.326	Valve Seats	8
F 8	9.9905.332	Valve inserts	8
F 9	9.9905.327	Valve springs	8
F10	9.9905.328	Liner sleeves	8
F11	9.9905.329	Tell tale rings	2
F12	9.9905.312	Pony rod with nut	1
F13		Packing (square braided)	2

LIST G

SPARES FOR DEUTZ F6L912 DIESEL ENGINES

Serial Nrs.6912143 and 6568711

Item	Part Nr.	Description	Qty
G 1	291-0048	Top set joint	12
G 2	337-1692	Rocker cover joints	36
G 3	121-6307	Rocker cover washer	36
G 4	337-2164	Injector seat washer	24
G 5	223-3085	Injector	8
G 6	414-6226	Inlet valves	2
G 7	241-2165	Exh.	2
G 8	336-2581	Sump joint	2
G 9	223-5533	Cooling tower and belt	12
G10	223-5181/0	Alternator V Belt	9
G11	117-3430	Lube oil filter	70
G12	116-0243	Fuel oil filter	60
G13	291-0184	Engine gaskets set complete	1
G14	213-0225	Fuel lift pump service kit	1
G15	223-4133	Front crankshaft oil seal	1
G16	223-4134	Rear crankshaft oil seal	1
G17	213-4511	Fuel lift pump	1
G18	116-2625	O ring F/lift pump	1
G19	126-0049	Fuel pump kit, small	3

LIST H

SPARES FOR ATLAS COPCO XRH 350 DD AIR COMPRESSOR

Serial Nr.805252

Item	Part Nr.	Description	Qty
1. Air End			
H 1	2910 0023 00	Service kit	1
H 2	2910 3002 00	" "	1
H 3	2910 3003 00	" "	1
H 4	2910 3004 00	" "	1
H 5	2910 3005 00	" "	1
H 6	2910 3006 00	" "	1
H 7	2910 3007 00	" "	1
H 8	2910 3008 00	" "	1
H 9	2910 4000 00	" "	1
H10	2910 6000 00	" "	1
H11	2910 7000 00	" "	1
H12	2910 4001 00	" "	1
H13	0333 3227 00	" "	3
H14	0333 3237 00	" "	4
H15	0653 1062 00	" "	2
H16	0661 1033 00	" "	1
H17	1619 2798 00	Element air filter	12
H18	1619 5545 99	Safty cartridge air	4
H19	2253 9891 00	Oil filters	27
H20	1619 5400 00	Valve	2
H21	2253 3039	Seal	1
H22	1404 1810 00	Membrane	1
H23	2252 6299 00	Gasket	2
H24	2252 8454	Spring	2
H25	2253 9671	Valve	2
H26	2253 1298	Valve seat	1
H27	663 7142	O Ring	4
H28	1089 0322 07	Circuit breaker	1
H29	1089 0341 02	Relay	3
H30	1089 9137 01	Switch	1
H31	1089 9138 01	Push button	1
H32	1091 0211 00	Bulb	2
H33	1619 5293 00	Diode	1
H34	1619 5504 00	Relay	1
H35	1619 5270 00	Pressure gauge dia. air press.	1
H36	1619 5257 00	Pressure guage oil press	1
H37	1619 5266 00	Level gauge fuel	1
H38	1619 5263 00	Tachometer	1
H39	1619 1700 00	Flex cable	1
H40	1619 5268 00	Pressure guage interstage	1
H41	1012 9356 00	Filter	1
H42	2253 7327 00	Capacitor	1
H43	1088 0003 04	Pin	1
H44	0346 1008 09	Clamp	1

Item	Part nr.	Description	Qty
H45	1087 0376 01	Temp switch	2
H46	1619 0456 00	Oil pressure switch	1
H47	1619 3708 00	Heat resistance	1
H48	1619 5288	Pressure sensor	1
H49	1619 1891	Start Relay	3

2. Deutz V12 Diesel Engine (Serial Nr.6727508)

H50	241 4793	Rear oil seal	1
H51	214 3549	Front oil seal	1
H52	214 4132	Push rod tube seal	24
H53	214 4877	Push rod tube gasket	24
H54	241 6589	Oil return pipe gasket	12
H55	214 5088	Oil return pipe basket	12
H56	214 4838	Rocker cover joint	48
H57	121 5500	Valve guide clip	48
H58	214 8385	Rocker seal	24
H59	117 0540	Inj. O ring	24
H60	2403867	Inj. washer (seat)	12
H61	214 5081	Inj. nozzle	12
H62	111 8647	Copper washer	30
H63	111 3430	Oil filter (engine)	30
H64	116 6146	Blower O ring	2
H65	116 8407	Fuel filter	12
H66	116 8398	Fuel filter	12
H67	128 7477	Fuel lift pump	1
H68	117 3470	Temp. transmitter	2
H69	414 1486	Inlet Manif. joint	12
H70	2146500	Exhaust manif. joint	12
H71	FL913/FL413	Workshop Manual	1
H72	240 7947	Blower O ring	2
H73	116 4594	Blower oil seal	1
H74	2911 536	Decoke set	12

LIST I

SPARES FOR WESTERN TRAILERS AND FUEL DISPENSING UNIT

Item	Part Nr.	Description	Qty
Trailer serial nrs.			
I1	-	Spare brake hub	1
I2	-	Diaphragm	2

LIST J

SPARES FOR PEUGEOT 504 F40 DIESEL FAMILY ESTATE VIN 389 4028

Item	Part Nr.	Description	Qty
J 1*		Lube oil filter cartridge	10
J 2*		Fuel filter cartridge	5
J 3*		Radiator pipe upper	1
J 4*		" " lower	1
J 5*		Drive belts	4
J 6*		Brake shoe set	8
J 7*		Brake cylinder seal set	2
J 8*		Brake hose	2
J 9*		Track rod	2
J10*		Ball joint	2
J11*		Exhaust pipe	1
J12*		Silencer	1
J13*		Injector	8
J14*		Injector washer	8
J15*		Shock absorber	8
J16*		Alternator	1
J17*		Starter motor	1
J18*		Air filter element	2
J19*		Preheater plug	4
J20*		Cylinder head gasket	2
J21*		Clutch plate	2

LIST K

SPARES FOR LAND ROVERS III 109 2 1/2 LITRE DIESEL

1. Station Wagon (chassis nr 175171; engine nr.366 846 91A)

2. Hardtop (chassis nr.175121; engine nr.366 530 11A)

Item	Part Nr.	Description	Qty
K 1	GFE130	Oil element	12
K 2	GFE5296	Filter element	12
K 3	564332	Injector	4
K 4	563165	Pipe	1
K 5	563166	Pipe	1
K 6	563167	Pipe	1
K 7	563168	Pipe	1
K 8	ERC4480	Spill rail A	1
K 9	599340	Stop control	1
K10	GEG1243	Gasket set	2
K11	GFB124	Fan belt	8
K12	GBS729	KB shoe axle	3
K13	GBS805	KB shoe axle	3
K14	GBS653	H. Brake shoe	1
K15	FMC311	Brake Mstr. C	1
K16	GWC303	F whl cyl LH	2
K71	FWC394	F whl cyl RH	2
K18	FWC305	Whl Cyl, LH	1
k19	gwc306	Whl cyl RH	1
K20	574871	Hose	4
K21	GRH585	Top rad hose	4
K22	GRH609	Rad hose bot	4
K23	564720	Hose	4
K24	564724	Hose	4
K25	GBH315	Brake hose	2
K26	GBH318	Rr Brk hose	1
K27	NRC132	Track rod TU	1
K28	NRC4609	Drag link TU	1
K29	GSJ152	Ball joint	3
K30	GSJ153	Ball joint	3
K31	GHS1003	Seal	2
K32	GHS206	Hub oil seal	4
K33	GHS1007	Seal	4
K34	GFG108	Axle flngesas (?)	4
K35	GEX1681	Front exh PI	1
K36	GEX1378	Pipe	1
K37	GEX3478	Silncr & tlpip	1
K38	GEX7325	Flexile mtg	3
K39	GEX7524	Exh pipe cla	4
L40	GEX7523	Mounting pla	6
K41	90517567	Clamp	2
K42	GEX7518	Clamp plate	3
K43	247726	Nozzle	2
K44	GEG452	Gasket vlv cvr.	4
K45	90606023	Overhaul kit	2

Item	Part nr.	Description	Qty
K46	266684	F W cyl kit	1
K47	275744	O haul kit	1
K48	NRC6474	Strg damper	2
K49	GSA392	Shk absorber	4
K50	GSA393	Shk absorber	4
L51	591364	Synchro cone	4
K52	FRC3201	1st spd gear	1
K53	RTC2685	Member asst.	1
K54	600603	Gasket kit	1
K55*	546799	Push rod	16
K56*	568335	Heater plug	8
K57*	RTC2415	Piston ring set std	8
K58*	RTC2415	0.02" O/S	8
K59*	RTC2415/20	0.04" O/S	8
K60*	RTC2776	Piston ring set std	8
K61*	RTC2776/20	0.02" O/S	8
K62*	RTC2776/40	0.04" O/S	8
K63*	RTC2775	Piston std	8
K64*	RTC2775/20	0.02" O/S	8
K65*	TRC2775/40	0.04" O/S	8
K66*	RTC1730	Bearing	8

LIST L

SPARES FOR ATALANTA VICTOR 90 GENERATOR SET

Serial Nr. 6930-1

Item	Part Nr.	Description	Qty
Newage Stanford Generator (Serial Nr.			
L1		Diodes forward	6
L2		Diodes reverse	6
L3		Surge suppressor	1
L4		Diode assy	1
L5		Bearing drive end	1
L6		Bearing non drive end	1
L7		Divert resistor	1
L8		Variable resistor	2

LIST M

SPARES FOR MONOLIFT PUMP SETS

Item	Part Nr.	Description	Qty
1.	Pump type C32 P631 CE (serial nr.)		
M 1	32B622210	Stator	1
M 2	32B2622531	Rotor	1
M 3	32SB2610	Bobbin Bearing Shaft	3
M 4	32B627705	Bobbin Bearing	2
M 5	32SB8710	Coupling for shaft	2
M 6	32P528700	Coupling for flexible shaft	1
M 7	32SC8720	Coupling for shaft	1
2.	Pump type BH 250 D (Serial Nr. C10158)		
M. 8	0032531901	Rotor/stator matched set	1
3.	Drive head type C32 DR 21 (serial nr. 32/132134)		
M 9	32DD1000	Packing Ring	3 sets
M10	32DM2005	Gasket (Housing Cover)	1
M11	32DR3200	Main Drive Shaft	1
M12	32DM3210	Drive Shaft	1
M13	32M7800	Spiral Bevel Gear	2 pr.
M14	W101081H	Wrench (for All4221F)	1
M15	W101051H	Wrench (for G114103F)	1
M16	32DM4720	Drive Shaft Gear Shim	2
M17	32DM4721	Drive Shaft Gear Shim	2
M18	32DM4722	Drive Shaft Gear Shim	2
M19	32DM4723	Drive Shaft Gear Shim	2
M20	32DM4724	Drive Shaft Gear Shim	1
M21	32DM4730	Upper Brg Hsg Gear shim (Yellow)	1
M22	32DM4731	Upper Brg Hsg Gear Shim (Green)	3
M23	32DM4732	Upper Brg Hsg Gear Shim (Grey)	4
M24	32DM4733	Upper Brg Hsg Gear Shim (Blue)	3
M25	S350363P	Rotary Shaft Lip Seal	1
M26	S350504P	Rotary Shaft Lip seal	1
M27	S350345P	Rotary Shaft Lip seal	2
M28	B160450B	Ball Bearing	1
M29	A170350B	Ball Bearing	1
M30	A170406B	Ball Bearing (Snap-Ring)	1
M31	C302400E	Ang/Contact Bearing	2
M32	C103350P	Circlip-ext with Lugs	1
M33	C103400P	Circlip with Lugs	3
M34	R104112F	Stl Rd.Hd/ Drive Screws	4
M34A		Tin of special Grease	1 (3kg)
M35	32DD3525	Shaft Sleeve	1
M36	32DD2810	Seal Ring	1
M37	32DM3500	Shaft Collar	1

Item	Part nr.	Description	Qty
4. Drive head type C32 DS 21 (serial nr.32/132135)			
M38	32CS21000	Packing Ring	3 sets
M39	32DS2005	Gasket (Housing Cover)	1
M40	32DS3201	Main Drive Shaft	1
M41	32DS3210	Drive Shaft	1
M42	32DS7800	Spiral Bevel Gear R.H.	1
M43	32DS7810	Spiral Bevel Gear I.H.	1
M44	W101101H	Wrench (for A115301F)	1
M45	W1010h1H	Wrench (for G117163F)	1
M46	32DS4720	Drive Shaft Gear Shim	2
M47	32DS4721	Drive Shaft Gear Shim	5
M48	32DS4722	Drive Shaft Gear Shim	2
M49	32DS4723	Drive Shaft Gear Shim	2
M50	32DS4724	Drive Shaft Gear Shim	1
M51	32DS4730	M/Drive Shaft Gear Shim	2
M52	32DS4731	M/Drive Shaft Gear Shim	2
M53	32DS4732	M/Drive Shaft Gear Shim	9
M54	32DS4733	M/Drive Shaft Gear Shim	2
M55	32DS4740	Bearing Cover Shim	2
M56	32DS4741	Bearing Cover Shim	2
M57	32DS4742	Bearing Cover Shim	2
M58	32DS4743	Bearing Cover Shim	1
M59	S350752P	Rotary Shaft Lip Seal	1
M60	S355621P	Rotary Shaft Lip Seal	1
M61	S355422P	Rotary Shaft Lip Seal	2
M62	A180450B	Ball Bearing	1
M63	C170700B	Ang/Contact Bearing	1
M64	C170650B	Ang/Contact Bearing	1
M65	C302600B	Ang/Contact Bearing	2
M66	W801140F	Locking Washer	1
M67	W801090F	Locking Washer	1
M68	W801060F	" "	1
M69	C103600P	Circlip-ext with Lugs	1
M69A		Tin of special Grease	1(3 kg)
M70	32DS2810	Seal Ring	1
M71	32DS3525	Shaft Sleeve	1
M72	32DS3500	Shaft Collar	1

LIST N

SPARES FOR ARMOURWELD DA 112 M WELDING SET

Serial Nr.832288/2

Item	Part Nr.	Description	Qty
Markon SCW21 welding generator			
N1		NDE bridge	2
N2		Bridge rectifier	2
N3	010 024	Carbon brushes	8
N4*	014 003	Bearing drive end	1
N5*	014 015	Bearing, non-drive end	1
N6*	011 001	Brush holder	2

LIST P

SPARES FOR LISTER DIESEL ENGINES

Item	Part Nr.	Description	Qty
1. Lister HR2 diesel engine (serial nr.			
P 1	-	Fuel Filter Element	4
P 2		Decarbonising joint set	2
P 3		Lub oil filter element	20
P 4		Big end bearing std.	2
P 5		Con rod nuts	4
P 6		Con rod bolts	4
P 7		Valve inlet	2
P 8		Exhaust valve	2
P 9		Injector nozzle	2
P10		Piston ring set std.	2
2. Lister ST1 diesel engines (serial nrs.3303432 ST1 C20 and 3211313 ST1 A12)			
P11	201-13117	Fuel filter element	10
P12	657-23501	Decarbonising joint set	3
P13	201-55370	Lubricating oil filter element	40
P14	201-80250	Valve inlet	1
P15	201-80241	Valve exhaust	1
P16	201-81393	Injector nozzle	1
P17	570-12910	Piston ring set std	1
P18	366-06227	Air cleaner element	6
P19	570-12980	Big end bearing std	1
P20	201-80300	Bolt con rod	2
P21	270-00004	Nut con end	2
P22	201-55350	Crankcase door joint	
3. Lister TS3 diesel engine (serial nr.3400464TS3A01)			
P23	203-32470	Fuel filter element	4
P24	201-55370	Lubricating oil filter	20
P25	657-29520	Decarbonising joint set	2
P26	570-12910	Piston ring set std	2
P27	210-30040	Inlet valve	3
P28	201-30051	Exhaust valve	3
P29	201-81393	Injector nozzle	3
P30	570-31370	Big end bearing std	3
P31	201-80300	Connecting rod bolt	6
P32	270-00004	Connecting rod nut	6
P33	203-30541	Sump joint	1
P34	366-06227	Medium duty dry type air cleaner element	8

LIST Q

SPARES FOR GEOPHYSICAL AND HYDROGEOLOGICAL EQUIPMENT

Item	Part Nr.	Description	Qty
SIE Geosource Portable Borehole Logger T450			
Q 1*	B54A	Chart metric 10cm for T20 recording system	12 roll
Q 2*	LA 125451	Disposable pen channel 1 (blue) for T201 system	12
Q 3*	LA 125452	Disposable pen channel 2 (red) for T201 system	12
Q 4*	B140	PCB E log module	2
Q 5*	B137	PCB control module	1
Q 6*		Silicone grease	2 kg
ABEM Terramater SAS 300			
Q 7*		Heat shrink sleeving suitable for range 2-6mm cable diameter	10m
Hach DR-EL/4 Laboratory 2508-05			
Q 8*		Glass combination calomel reference electrode for pH kit	2
Q 9*	14393-33	Titration cartridge 1.600 N H2SO4	4
Q10*	14399-01	" " EDTA 0.800 M	4
Q11*	282-37	Potassium hydroxide standard solution 8N	4
Q12*	942-99	Phenolphthalein indicator powder pillows	4 box
Q13*	14380-01	Titration cartridge 3.636 N NaOH	2
Q14*	836-69	Diphenyl carbazone reagent powder pillows	4 box
Q15*	921-01	Titration cartridge 2.256 N Hg(NO3)2	4 box
Q16*	424-37	Buffer solution hardness 1	4
Q17*	2054-97	Buffer powder pillows pH 4	2 box
Q18*	14107-97	" " " " 9	2 box
Q19*	12065-66	Sulfaver 4 sulphate reagent powder pillows	2
Q20*	393-33	Hydrogen sulphide test papers	2 vial
Q21*	17205-00	Delivery tube, straight, for digital titrator	4
Ott KL50 electric contact gauge			
Q22*	24.110.093.9.2	Tape with probe	2

Item	Part Nr.	Description	Qty
Graph Paper			
Q23 *		Arithmetic, cm/mm divisions, A4	5
Q24 *		" " " " A3	2
Q25 *		Log/log, 3 x 4 cycles, A4	2
Q26 *		Log/normal, 4 log cycles, A4	2
Q27 *		Trilinear, A4	1

